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April 2023

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Joint and Voiding Formation Mechanisms

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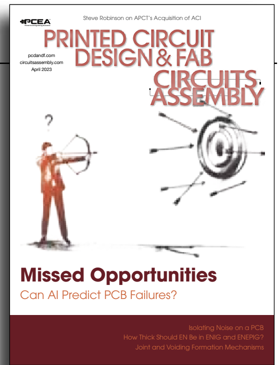

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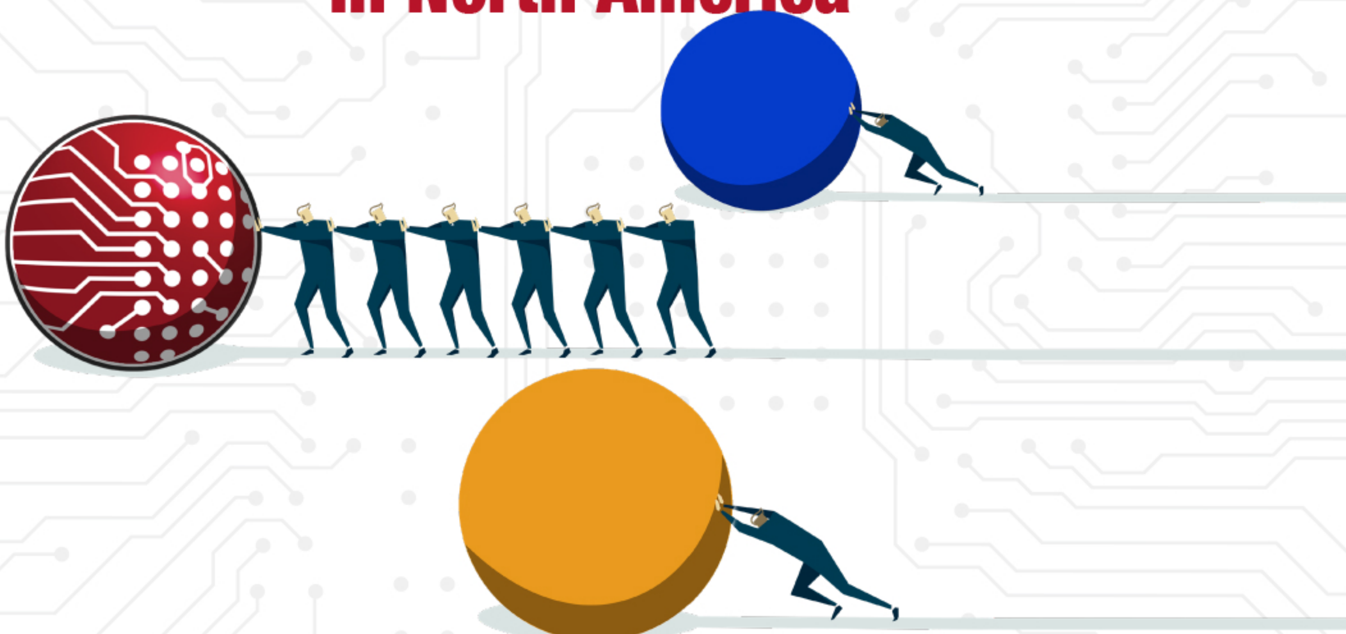

Hiring Lines

SPEAKING, AS WE were last month, about the current environment for electronics production, we noted the well-publicized layoffs at several blue-chip companies. Tech brands such as HP, Dell and Microsoft all announced pending workforce reductions through direct cuts and attrition ranging from 4,000 up to 12,000.

But insofar as the electronics design to manufacturing supply chain is concerned, jobs are plentiful and hiring proceeds apace. That's according to several tech recruiters and job search experts we spoke with last month.

In fact, companies in our space are ramping recruiting for positions at all levels, from techs to upper management. And some new trends are appearing, especially as firms look to gain a tighter hold on hard-won customers.

Search firm StepBeyond founder John Myers is perhaps the best-known recruiter in electronics. He called the recently concluded first quarter "probably the strongest Q1 I've seen in my 30 years in recruiting."

"Everyone has grown and has business," he says.

But that's not to say the hiring process is linear, where needed skills neatly fit with candidates of the precise experience sought. The low unemployment rates, lack of standardized training programs such as vocational schools, and newly sought-after job perks such as remote work have human resource specialists broadening their searches.

As Zach Swartz, founder and recruiter at ZZ Recruitment explains, "Players are looking for the right set of skills for electronics manufacturing, and also as we move into new times, culture is a big thing. Managers want teams that work well together. They want people to be creative and have a voice."

If anything, Myers and Swartz agree, Covid reinforced the employee-employer bond. Even during Covid, employers were trying to retain talent. "If you hadn't told me there was a pandemic, I wouldn't have known it," Myers said. "People were still hiring and trying to grow."

Curiously, while the pandemic may have accelerated some HR trends, the underlying shift was underway long before the virus hit. The fallback conversation at industry get-togethers was always, where are the young people? Yet according to the recruiters, we are a decade into a replacement wave, with some distinct differences from prior eras. However, they diverge – modestly – about the tendency for electronics companies to source human capital outside the industry.

Swartz says "some companies" are open to training workers from other industries but often the urgency for staffing up outstrips the timeline for transition.

Myers has a somewhat different take. "About 10 years ago, we increasingly saw more people being hired out of college with a few years of experience," he says. "Now I see hiring people with credentials and aptitude from other industries, not just with EMS experience." He points to better experienced staff that can afford to onboard workers who need additional training or time to learn new skills.

Both agree the market is strong across the country, which Myers credits in part to the arrival of a new generation of younger businesspeople who want to grow in the industry. Myers pointed to growth in regions that hadn't been active, like Pennsylvania. Swartz, whose firm is more oriented toward the Western US, said managers are looking to relocate to Nevada and Texas from California, often for tax reasons.

Only one group seems to be an outlier. Says Myers: "About 10 years ago, EMS companies started hiring business development managers. Now every department is hiring, except business development. Instead of business development, something is happening that I haven't seen in many years: they are hiring account management. They are looking for the farmers; people who can manage and grow the accounts that have been brought out."

What about all those layoffs at Meta, Microsoft and the like? Myers downplays the impact, calling manufacturing "almost not the same ecosystem" as the Fortune 50 tech firms.

"Those are really advertising companies, when you get down to it," he says.

Swartz agrees. "There's a definite distinction between [Big Tech and manufacturing]. If you are hiring for IT, and willing to offer remote, there are lots of people in the Silicon Valley with very strong skill sets available. Insofar as electronics manufacturing, however, layoffs have been minimal."

Asked for their prediction for the electronics job market for the rest of 2023, both recruiters chuckled. The past isn't always prologue, it seems.

Myers recalled the early 2000s when the head of a major EMS kept reassuring industry analysts that improvements were coming the next quarter, before finally giving up in the face of ongoing volatility, simply stating: "We have no visibility."

"Nothing is predictable anymore. This part of the year there will be a lot of movement, a lot of jobs. People can get the job they want, doing what they want. My concern is that in the later part of the year it will be really hard to find people as everyone moves around. As we grow, there's no more people. They will have to hire fresh graduates or people from other industries and train them – if you can find them."

Yet they remain hopeful. "With the CHIPS Act and everything with that bringing the realization to the government that it's the whole electronics ecosystem," Myers concludes, "I think we are seeing this resurgence in manufacturing and hopefully that will lead into increased education, and universities and trade schools training more people to stock these factories."

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P.S. For a firsthand take on the health of the industry, not to mention the best training for electronics design and manufacturing on the US East Coast, check out PCB East (pcbeast.com).

Over 60 hours of training and education, plus a one-day trade show on May 10 featuring more than 50 leading suppliers from across the design, fabrication and assembly industries.

Production Begins at SEL's New PCB Facility

PULLMAN, WA – Schweitzer Engineering Laboratories officially began fabricating printed circuit boards in its new facility in Moscow, ID in February.

The 162,000 sq. ft. facility, which the company began constructing in spring 2021, will house the operation to fabricate the printed circuit boards used in its products that protect, monitor, control and automate electric power systems around the world.

"SEL folks with many different backgrounds, educations, interests and experience teamed up to conceive, design, build and produce these essential components of our products–all on our own dime without any government handouts or subsidies," said president and chief technology officer Edmund O. Schweitzer, III. "We committed to each other to do it right, and now we are safely producing the highest-quality boards in the cleanest plant, using the least amount of resources that science and engineering afford us today. This is $100 million of employee owners' money well spent on creating our future right here at home. I'm proud of our entire team and grateful for the economic and political freedom we enjoy in America."

SEL has designed a highly automated and environmentally friendly process for manufacturing printed circuit boards that is focused on the health and safety of the community. The facility features zero-discharge water recycling and air filtration technology.

"We went into this not only thinking like a manufacturer but also like community members," said senior director of vertical integration Jessi Hall. "So much research, learning and testing has gone into designing our fabrication processes and selecting the best equipment and tools for the job. We are excited to see everything come together and to really start realizing the benefits of these investments."

The company will employ about 60 people in the facility in positions ranging from a variety of engineering roles, including chemical, mechanical, software and computer-aided manufacturing, to equipment operators and maintenance workers.


Inside SEL's new PCB fabrication plant.

The SEL property team served as the contractor for the construction project and partnered with multiple companies local to the Pacific Northwest. The team was able to complete the project within the expected timeline despite global supply chain challenges.

"I am so proud of SEL's partnership with dedicated subcontractors to find solutions when materials became scarce and timelines unwieldy," said vice president of property Jana Schultheis. "Our construction teams are second to none. It is a proud day to see this factory come online as a result of their ingenuity."

SEL plans to host a grand opening for the facility later in the year.

Sihui Fuji to Build New Plant in Thailand

GUANGDONG, CHINA – Sihui Fuji Electronics Technology announced that it will be building a 500 million yuan ($72 million) printed circuit board factory in Thailand.

The Chinese PCB supplier said the new factory will allow it to respond to the needs of its overseas customers and expand its international business, as its production capacity is currently concentrated in China.

The planned facility in Thailand's Amata Industrial Park in Rayong Province is slated to begin mass production in 2025. The company did not disclose the targeted design capacity of the plant.

NI Acquires SET

AUSTIN, TX – National Instruments announced the acquisition of SET, a German developer of aerospace and defense test systems and recent innovators in power semiconductor reliability tests. With the acquisition, the companies will aim to reduce time to market for critical, highly differentiated solutions and accelerate semiconductor-to-transportation supply-chain convergence with power electronic materials such as silicon carbide (SiC) and gallium nitrite (GaN), according to a release from NI.

NI first announced a strategic minority investment in SET in 2020 to help aerospace and defense companies solve soaring development costs and integration challenges. The collaboration enhanced a system-on-demand and model-based test approach delivered to shorten time-to-market schedules, reduce program risk, integrate labs, and optimize data and assets, which offered mutual customers more time spent ensuring the quality and safety of future products and less on building test systems. Those collaborative efforts will continue with a focus on sustainable commercial aviation, space launch vehicles, and urban air mobility applications.

Going forward, the acquisition will expand NI's opportunity in power semiconductor reliability systems for automotive, a high growth area of investment. SET has been innovating on new capabilities in the emerging automotive supply chain area of power semiconductors since before NI's initial partnership in 2020. SET's participation in cross-industry and academic forums on reliability test techniques has made significant contributions to the understanding of electric vehicle applications for power semiconductors.

"The automotive supply chain is going through a transformation where both OEMs and semiconductor players are rapidly innovating on new technologies. The ability to adequately specify and predict how these new technologies behave inside new electric vehicles is critical for performance and safety," said Ritu Favre, EVP and GM of NI Business Units. "SET is a clear innovator in this area as well as an established provider in avionics testing. NI is a global leader in automated test and measurement systems. By combining capabilities, NI and SET can offer more differentiated solutions to customers and grow together by leveraging NI's global scale."

"We leverage extensive expertise to develop groundbreaking solutions for power semiconductor testing," said Frank Heidemann, the founder of SET. "By offering new and dynamic test procedures, SET ensures the qualification of cutting-edge silicon-carbide (SiC) power semiconductors for the automotive industry with high precision and reliability. With our innovative approach, SET is leading the charge in solving the industry's most pressing qualification challenges."

NI funded the transaction through cash on hand. SET is headquartered in Wangen, Germany, with approximately 100 employees joining NI.

Kinwong Holds Groundbreaking for New Manufacturing Facility

XINFENG COUNTY, CHINA – Kinwong Electronics held a groundbreaking ceremony in March for its new PCB manufacturing facility in China's Jiangxi Province.

Liu Shaobai, chairman, Kinwong Electronics, said the ceremony marks the project's entry into the substantive construction stage, and said the factory should be finished by the end of the year.

The project will be constructed in two phases, with a total investment of about 3 billion yuan ($436 million). The facility will use advanced technology, intelligence and high-precision manufacturing equipment to create a high-level multilayer PCB R&D and production base with a high degree of automation, intelligence, production efficiency and cost advantages, Liu said.

Study: Environmental Impact of Flexible Electronics Can Be Reduced 90%

ESPOO, FINLAND – A recent study by the VTT Technical Research Centre of Finland found that environmental impact could be reduced by 86% when additive printing methods are used to create flexible electronic components.

"Traditionally, metal electronics parts are etched out of copper sheets in a process called PCB etching. The process removes unwanted copper from a printed circuit board, so only the required circuit remains while the rest of the sheet isn't used," says Liisa Hakola, senior scientist and senior project manager, VTT. "We found that flexible metal electronics parts can instead be printed onto bio-based substrates, like paper or bio-plastic. The process requires less energy and avoids the use of harmful chemicals while drastically reducing material waste and increasing the use of renewable materials. This change in the manufacturing process is the single largest factor in potentially reducing the climate impact of flexible electronics."

There are additional challenges that still need to be resolved, including the use of silver, which has a high environmental impact. The project found that silver can be replaced with more abundant and less valuable alternatives, such as copper or carbon-based materials, which can provide further reduction to the environmental footprint of flexible electronics. In addition, end-of-life management and longevity of product usability, i.e., better durability and decreased energy consumption, are also key factors in creating more sustainable electronics.

The flexible electronics market is expected to grow to $46 billion by 2026, and by 2030, global electronic waste will reach 74 billion kilograms, with only 20% collected or recycled properly. The electronics industry is currently facing major challenges with the availability of crucial materials combined with increasing pressure to cut its environmental footprint and move toward circularity.

In March 2022, the European Commission published its Sustainable Products Initiative, which aims to ensure that all products placed on the EU market become more sustainable. The initiative also includes electronics, and manufacturers are facing pressure to meet new sustainability requirements in the years to come.

"At VTT, our goal is to set a new standard for sustainability in the electronics industry and offer solutions that increase circularity at every stage of the electronics life cycle," said Maria Smolander, research team leader at VTT. "Implementing these new manufacturing methods on a mass scale is a challenge that the industry will inevitably need to tackle in the coming decade in order to keep up with increasingly strict regulations and demands from consumers."

MKS Invests in Package Substrate Research Site

YOKOHAMA, JAPAN – MKS Instruments in March unveiled a significant investment in its Yokohama Technical Center in Japan that will enable an integrated approach to creating solutions for complex package substrate manufacturing, satisfying current requirements as well as those needed for future roadmaps.

The recent investment in the YTC delivers the latest capabilities for producing next-generation package substrates. The YTC utilizes dedicated lasers, optics, and motion systems for high-precision, high-speed via formation in ABF build-up laminates, in combination with the latest process chemistry and equipment for desmear and electroless copper metallization. Using the latest Equalized Curtain Flow (ECF) plating tool, the YTC is able to support customers in their yield optimization and next generation process development for advanced packaging applications.

During a ceremony to celebrate the YTC expansion, Dr. John T.C. Lee, president and CEO of MKS Instruments, escorted visitors around the facility to showcase two new systems that have been installed, a ESI Geode A CO2 laser system and Atotech G-Plate plating tool, as well as demonstrating the Vitrocoat process for Plating on Glass (PoG).

"We are highly committed to driving and leading technology development within our industries," Dr. Lee said. "With these key installations, we are accelerating time to market through our combined capabilities, which allow us to view problems holistically and design solutions faster. This helps us to drive innovation for next generation electronic devices and offer customers and OEMs quicker development cycles for new products and materials enabling high-end SAP technology requiring <=5/5µm lines and spaces. Our unique portfolio of MKS combined services at our Yokohama technical center allows us to reduce the cycle time for a typical ABF sample from three months or more to less than one month."

DCP Capital Looking to Sell MFS Technology

HONG KONG – Chinese private equity firm DCP Capital aims to sell its stake in MFS Technology, which makes flexible printed circuit boards, for at least $550 million, Reuters reported.

The firm started marketing the sale in mid-March and will send out confidential information memoranda in April, sources said.

The sale is targeting primarily financial sponsors, but also strategic buyers, and initial bids are expected by late May.

DCP Capital bought a controlling stake in MFS in 2018 from Navis Capital Partners and Novo Tellus Capital Partners for an undisclosed amount. MFS manufactures circuit boards with applications focused on automotive, industrial, medical and data storage end-markets, and has manufacturing facilities in China and Malaysia.

Kulicke and Soffa Acquires Advanced Jet Automation

SINGAPORE – Kulicke and Soffa Industries in February announced the acquisition of Advanced Jet Automation, including the material business and assets formerly owned by its affiliate, Samurai Spirit Inc., a Taiwanese developer and manufacturer of high-precision micro-dispensing equipment and solutions.

The acquisition will broaden Kulicke and Soffa's existing semiconductor, electronic assembly and advanced display portfolio and increase opportunities in several growth areas including mini- and micro-LED, which support both backlighting and direct-emissive approaches, according to a release from the company.

K&S said the acquired dispense technology currently supports advanced backlighting production in a high-volume, high-accuracy environment and is complementary to its existing advanced display portfolio. Beyond advanced display, the dispense equipment market, which collectively includes both semiconductor and electronics assembly opportunities, is adjacent to several other K&S businesses serving the general semiconductor, automotive, LED, and memory end-markets.

AJA will operate as a business unit, leveraging K&S' global sales and distribution network, operational capabilities, and R&D competencies.

"This strategic acquisition accelerates our long-term roadmap and future growth potential supporting exciting new technology transitions. AJA's unique competencies and proprietary technology in high-precision dispense complement our market-leading advanced display, advanced packaging and electronics assembly solutions," said Chan Pin Chong, executive vice president and general manager, Kulicke and Soffa Products & Solutions.

"After working closely with the K&S team through a successful closure, I am confident our performance-based cultures, rich technology backgrounds and market-focused solutions are highly complementary. This alignment enables us to quickly scale our unique solutions, which address the evolving complexity and emerging opportunities within the large dispense market," said Raymond Chen, founder, AJA.

Foxconn Leases New Site in Zhengzhou

TAIPEI – Foxconn Technology Group has leased a 293-acre plot of land to build new smart warehouses in Zhengzhou, the same Chinese city where the company operates the world's largest iPhone plant.

The 197 million yuan ($28 million) lease in the Zhengzhou Comprehensive Bonded Zone comes after efforts by government officials to convince the Taiwanese assembler to keep its local operations.

The deal was announced days after Foxconn chairman and CEO Liu Young-way visited Zhengzhou, where he met Lou Yangsheng, the Chinese Communist Party's Secretary in central Henan province. Officials assured Liu that the government would provide comprehensive "services" to Foxconn's local operations and urged the firm to "take root" in Henan, according to a statement published by the municipal government of Zhengzhou, the provincial capital.

Foxconn's operation in Zhengzhou was severely disrupted late last year by the exodus of tens of thousands of employees and worker protests that turned violent amid a coronavirus outbreak, and the company has since secured a new manufacturing site in Vietnam and invested in its Indian subsidiary with plans to quadruple its workforce in India over the next few years.

Benchmark Hosts Grand Opening of New Precision Technologies Facility

MESA, AZ – Benchmark Electronics in March celebrated the grand opening of its new Precision Technologies facility here. The company plans to invest around $20 million into capabilities and technology at the new facility, in addition to hiring 100 people to support the facility as the company ramps up with customers.

The facility is designed to provide several key engineering and manufacturing solution services, most notably supporting the production of semiconductor capital equipment building blocks and solutions. It significantly expands the existing cleanroom capacity across its Precision Technologies group with additional opportunity for the vertical integration of key processes. Those processes include metal joining applications such as TIG welding and electron beam welding, precision cleaning and other chemical finishes.

"Benchmark is a key solution partner to the capital equipment market worldwide and this new facility will enable us to support our customers in the US and across the globe with next generation manufacturing and engineering solutions," said Jeff Benck, president and CEO, Benchmark. "The investments we're making to serve these customers will be critical to meeting the increasing demand for semiconductor capital equipment, especially with the growth in demand for semiconductors and new domestic fabs being built supported by the CHIPS Act incentives."

Benchmark celebrated the grand opening alongside Arizona Governor Katie Hobbs, Mesa Mayor John Giles, ACA President and CEO Sandra Watson, Benchmark customers, and Arizona dignitaries across the technology and economic development sectors.

"We are proud to celebrate the grand opening of Benchmark's new facility alongside the best and brightest technology leaders in Arizona," said Hobbs. "Since joining Arizona's thriving technology community, Benchmark has been an incredible partner, creating skilled jobs and advancing Arizona's innovation reputation. We look forward to seeing the great work done here at Benchmark Mesa to further enhance our growing semiconductor industry."

BMZ Group Acquires Visatronic

KARLSTEIN AM MAIN, GERMANY – BMZ Group, a specialist in lithium-ion batteries, announced the acquisition of Visatronic GmbH, a Mainhausen, Germany-based EMS supplier.

Visatronic had already been a supplier to BMZ Group for years, and the takeover of the company, which has seen steady growth since its foundation and recorded 2022 as the best year in its company history, offers synergies for both sides, BMZ Group said in a release.

Visatronic will retain its economic independence, and BMZ will integrate the supplier into the group to increase the security of supply. Visatronic will see a network expansion, particularly on the global stage, with regards to opportunities in purchasing, sales and expansion of production capacities. The management, which has been in the hands of the Gebauer brothers since 2000, will remain contractually secured for at least three more fiscal years. Beyond that, no fundamental changes are planned for existing customers and employees.

"We are very pleased about the inclusion of Visatronic into the BMZ Group," said Sven Bauer, CEO and founder of BMZ Group. "This strengthens another important Made in Germany factor in battery manufacturing. In times of uncertain supply chains, such alliances are indispensable for technology companies."

"We have known and appreciated the BMZ Group as a customer for many years and are taking the well-considered step of joining the group primarily with a view to expansion opportunities and future security for the company and its employees," said Michael Gebauer, managing director, Visatronic.

TTM to Sell Backplane Assembly Unit to Chinese Assembler

SANTA ANA, CA – TTM Technologies has signed a definitive agreement to sell its Shanghai backplane assembly plant for approximately $11.8 million, subject to customary post-closing adjustments, to DBG Holdings. TTM expected the transaction to close near the end of the first quarter.

BPA is a small assembly facility that generated $44.7 million in revenues and an immaterial amount of operating income in 2022, TTM said in announcing the sale.

TTM said the transaction is consistent with the printed circuit board fabricator's strategy to continue developing TTM as a diversified technology solutions leader and to reshape its core business portfolio for improved differentiation, financial stability and long-term profitability. This strategy entails investing in differentiated commercial and aerospace & defense ("A&D") capabilities.

Following the divestiture, TTM will exit the commercial backplane assembly business.

TTM called DBG a "particularly attractive buyer" due to its strategic commitment and understanding of the assembly business. It has existing customer relationships with Shanghai BPA customers, and also offers related products, services and expertise. The firm reported net profits of 76.1 million yuan ($10.9 million) on revenue of 301 million yuan in 2022.

"Shanghai BPA has been a longtime member of the TTM family, but we firmly believe this divestiture is in the best interests of our employees and customers," said Tom Edman, president and CEO, TTM. "TTM is selling Shanghai BPA to a buyer that is fully qualified and committed to achieve continued success for this business. In turn, this divestiture positions TTM to focus our full energy and resources on other lines of business where we are very well positioned to service our customers with differentiated product solutions to address the challenges and growth opportunities that exist across the aerospace & defense, automotive, medical, industrial & instrumentation, networking and data center computing end-markets.

"While we are announcing the divesture of the Shanghai BPA business today, we will continue to operate the business in the same manner as we do now through the date of close, which we anticipate to occur near the end of the first quarter. This includes fully supporting our Shanghai BPA employees and customers."

Zollner to Add 100 Jobs in Virginia

LEESBURG, VA – Zollner Elektronik will invest $18 million to expand in Virginia, including boosts to its electronics manufacturing operations in Danville as well as the company's U.S. headquarters in Leesburg, adding a total of 100 jobs between the two locations.

The expansions include $14 million to expand manufacturing operations in the Danville-Pittsylvania County Regional Industrial Facility Authority's Cyber Park to develop custom electronics products for clients using proprietary technology, which will add 80 jobs. In Leesburg, the company will invest $4 million and add 20 jobs.

The expansion comes after Zollner acquired Leesburg-based Electronic Instrumentation and Technology's (EIT) electronics manufacturing services (EMS) division last July.

"Zollner Elektronik's decision to increase its market reach with the expansion of its manufacturing capabilities in Danville and U.S. headquarters in Loudoun County demonstrates the strength of our business climate and workforce that benefits diverse industries and locations across Virginia," Virginia Gov. Glenn Youngkin said in a statement. "EIT has a long history of success in the commonwealth, and we look forward to building on that partnership with Zollner in the years to come."

EIT has locations in Leesburg, Danville and Salem, NH.

JEDEC Creates New Automotive Steering Subcommittee

ARLINGTON, VA – JEDEC announced the formation of the JC-42.9 Automotive Steering Subcommittee responsible for investigating memory technologies and recommending solutions pertaining to automotive applications.

Following approval by the standards group's board earlier in the month, the new subcommittee held its first meeting in Seattle, the week of Mar. 6.

Responsibilities of the JC-42.9 subcommittee include generating directional or recommended automotive-specific standards expected to be applicable across different devices or modules, such as temperature range & classifications, telemetry support mechanisms, related firmware, quality/reliability requirements, and test and certification process and procedures. The subcommittee may also research various memory technologies, such as DRAM, non-volatile or otherwise, at the device or module level for optimal memory solutions for the automotive applications. The subcommittee will liaise with other JEDEC committees and external partner organizations in fulfilling its objectives.

Industry participation is welcome, and interested companies are invited to contact the JEDEC office to join JEDEC and become involved with JC-42.9.

"The formation of JC-42.9 is an essential aspect of JEDEC's role in the landscape of standards development for automotive applications," said Mian Quddus, chairman of JEDEC's board. "One of JEDEC's core strengths is the breadth of our membership, and the diverse skillsets company representatives bring to technical committee activities, and we look forward to adding value to the industry by bringing this experience to bear on standards for automotive electronics."

PCD&F

Altair announced the rebrand of its entire data analytics and AI suite as Altair RapidMiner, uniting all data analytics technology into one platform.

Altest purchased 10 **Tagarno** digital microscopes for its PCB manufacturing facility in San Jose.

Altium officially opened its office in Korea.

American Standard Circuits purchased and installed a **CIMS** Galaxy 30μ AOI, a **Burkle** LAMV 125 thermal oil heated lamination press and two new lines from **Circuit Tech International**.

Ansys announced a $250,000 contribution toward funded curriculum proposals in 2023 as part of its ongoing mission to support the next generation of engineers and equip students with in-demand simulation skills to thrive in the industry.

Cadence Design Systems announced a $50 million purpose-driven investment in an impact investment program to address racial wealth inequities in affordable housing, homeownership and small business.

Hexagon's Manufacturing Intelligence division and **Altium** have entered a strategic partnership with a goal to help the design and manufacturing of electronics be more environmentally sustainable.

Icape Italia is expanding its plant to meet growing demand for printed circuit boards.

Nano Dimension installed an Admaflex130 3-D printer for **NASA Marshall Space Flight Center** and received a purchase order from a leading Western intelligence agency for a DragonFly IV 3-D printer. Nano Dimension also inaugurated its European headquarters in Munich.

Sihuifushi intends to invest in a new PCB production base in Thailand, with a planned investment amount of up to 20 million yuan.

Toppan was recognized for the second consecutive year as a Supplier Engagement Leader in the 2022 Supplier Engagement Rating conducted by **CDP,** an international nonprofit organization focused on environmental disclosure.

Trident is in the process of constructing a new factory in Thailand that will increase monthly production capacity by 4 million sq. ft.

Singapore is offering substantial subsidies to entice **TSMC** to build a domestic 12-inch fab.

Unimicron announced the investment of 1.26 billion baht ($366 million) into a new Thai subsidiary.

CA

Blue M announced the shipment of a burn-in oven to the electronics industry.

CalcuQuote named **MaRC Technologies** representative in Washington, Oregon, Idaho, and Texas.

Circuitwise has enlisted **E&P Corporate Advisory** to search for a private equity backer to help fund growth and manage succession.

Data I/O said **Noa Leading** will offer SentriX security provisioning services in Japan.

Datest announced a representative agreement with **PIT Equipment Services** for the East Coast US.

ESI purchased an **Ersa** Versaflow 3/45.

Hentec Industries/RPS Automation appointed **WepcoVintek** Southwestern US sales representative.

Jabil is cutting more than 200 jobs at manufacturing sites in California.

Kitron has received an order with a value of more than NOK180 million ($17.4 million) from Kongsberg Defence & Aerospace.

Kyocera AVX ordered its fourth **Hentec Industries/RPS Automation** Pulsar solderability testing system.

Libra Industries is expanding its footprint and sheet metal fabrication and powder coating capabilities in its manufacturing facility in Guaymas, Sonora State, Mexico.

Scienscope named **Seica** distributor in France.

Technology Group Co. installed a **Yamaha** YCP10 screen printer.

VVDN Technologies is expanding its EMS manufacturing footprint in India, with emphasis on vertical integration and design-led manufacturing. The company's planned $100 million investment over five years includes PCB fabrication capacity.

PCD&F

The High Density Packaging User Group announced the **Jack Fisher** Technical Excellence Award to honor the memory of the late technical guru, who passed away on Jan. 20, 2023.

Nelco Worldwide named **Jack Pattie** general manager.

Siemens Digital Industries Software named **John McMillan** senior content marketing strategist. After spending a year at Lifecycle Insights, he rejoins the company where he worked in marketing for 13 years. He also worked for Cadence and Cisco, among others.

CA

OSCAR LOPEZ

MARK EVANS

FX BEORCHIA

JUAN-ARANGO

MICHELLE OGIHARA

GINA PLOEG

ILONA NAVEZ

JOE HAJOST

AIM Solder promoted **Oscar Lopez** to national sales manager of Mexico and Latin America. Over his 23 years in electronics manufacturing industry, he spent nearly five leading AIM's sales efforts in Mexico.

Green Circuits hired **Mark Evans** as COO.

Inovaxe appointed **FX Beorchia** vice president sales for EMEA regions and named **Juan Arango** senior vice president of sales and marketing. Arango has more than 30 years' experience in electronics assembly with Universal Instruments, Panasonic and Koh Young.

Seika Machinery promoted **Michelle Ogihara** to vice president of sales. She joined Seika Machinery in 1998 and has held roles in sales and marketing.

StenTech promoted **Raza Khan** to Central Area sales manager. He has been managing StenTech's Chicago facility for the past 14 years.

STI Electronics named **Gina Ploeg** SMT assembly technician. She has 14 years of experience in electronics assembly and manufacturing.

Transition Automation hired **Ilona Navez** as Accounting Manager.

Variosystems appointed **Joe Hajost** head of Variosystems North America. He has over 30 years' experience in electronics and industrial services.

Zestron named **Joshua Archer** sales engineer.

Technical Knowledge Shared means SMT Manufacturers Better Prepared.

EUROPLACER IS ALWAYS EAGER to share its expertise. Amongst the unparalleled wealth of technical knowledge at Europlacer are key insights into component placement and factory-wide efficiency from the many subject matter and equipment experts in that process field. It allows manufacturers to get the very best productivity from their SMT assembly lines.

With a commitment to continually maximizing productivity for its customers, design experts at Europlacer keep a close focus on the throughput performance of the company's placement machines during development, while process experts take a wider view of productivity in terms of factory-wide production efficiencies, deploying intelligent assets like Stock Management solutions. In addition, along with members of the Europlacer applications support team these experts are keen to share knowledge on how to improve line-wide productivity, with Overall Equipment Effectiveness (OEE) as an evaluation tool at the center of performance assessments.

OEE refers to the critical measurement of the actual productivity of equipment. The outcome is a percentage measurement of the time during which the equipment delivers good product relative to the scheduled production time. A score of 100% indicates that the equipment is producing at full speed with no stoppages and no defects for the entirety of the Scheduled Production Time (SPT).

Identifying losses. To reach this percentage figure, the OEE evaluation has many facets. As well as SPT, which is a measurement of the total time allocated to producing a designated quantity of product within a specific timeframe, losses that impact that time must be considered. These are Availability Loss (AL), Performance Loss (PL), and Quality Loss (QL).

- AL is the aggregate total of time lost due to equipment setup, first article validation, major machine assists, substantial material shortage and unscheduled machine repairs.
- PL is the cumulative total of time lost due to brief stoppages for events such as routine material reloading, assisting another machine in the assembly line that is causing a bottleneck, and/or intentional equipment speed reductions due to lack of proper performance.
- QL is the collective time spent producing defective products.

AL, PL and QL inefficiencies exist in every work center, although the impact on productivity varies dramatically, depending on applications and equipment features. Curiously, these specifications do not appear in equipment brochures or data sheets; productivity is typically referenced only in raw machine tact time or IPC9850 placement speed (in Components Per Hour – CPH), but this is not representative of actual line-wide productivity.

While these variables in the OEE equation are not necessarily attributable to the equipment, some characteristics of equipment and software from specific vendors are designed to significantly reduce AL, PL and QL, and to substantially improve utilization.

In particular, the potential causes of AL can be broken down further into factors that are critical to profitability, especially in the CEM sector. Planned production activities with the potential to erode AL include:

- Kitting and Kitting Materials Availability
- Initial Equipment Program and Load Setup
- Virtual First Article Validation
- Functional First Article Validation
- Runtime Material Shortages
- Rolling Changeover to Next Product

EMS companies need to be able to predict these conditions for accurate job costing. OEMs working on a cost center basis can experience unanticipated overruns that will inflate actual product costs.

Solution strategies. These issues can be anticipated and addressed by the expertise of innovative equipment vendors through sophisticated features that reduce or eliminate the overall impact by implementing specific strategies. Evaluating each of the six AL aspects above demands detailed measurement and analysis based on the manufacturer's specific assembly line setup. These strategic solutions are covered by a Europlacer White Paper and will be addressed and presented in detail at the Europlacer US Open Days* in May 2023.

Monitor. Measure. Modify. Another dimension to assist both with OEE at the assembly line level and beyond to the wider factory environment is a set of tools that help to set up, validate and monitor the line, predict material supply shortages and provide real-time visibility that addresses Performance Loss (PL).

With today's workplace comprising fewer operators with broader responsibilities for tasks that maintain high productivity, tools that are portable convey an efficiency bonus. While production monitoring dashboards are not new, the advent of connected factory solutions that include portable wireless tablet control centers empower operators to stay informed in real time and allow management to oversee production processes from remote locations. This function itself eliminates any PL that might otherwise occur while waiting for approvals to resume production.

An operational efficiency analysis can be performed in any work center. However, the remedy to identified inefficiencies may prove challenging if attributable to a function of the design of the vendor's equipment. That's why published equipment specifications are essential and should be analyzed thoroughly. It is imperative to:

- Examine the design features and specific behavior of each piece of equipment in the line
- Secure a thorough understanding of the weakest link in the line
- Recognize the consequences of the vendor's engineering choices

The challenges identified by the OEE analysis are not typically revealed during a standard equipment demonstration, a presentation or even an application analysis. It's important that equipment vendors present and justify their approach to achieving Overall Equipment Effectiveness for an optimized work center.

** Learn more at the Europlacer US Open Days taking place at the company's US headquarters in Phoenix, AZ, on May 16 to 18, 2023. Mike Foster & John McMasters will present the OEE process in detail, covering aspects of Capacity and Utilization, potentials for AL, PL and QL losses and corresponding strategies to resolve those losses.*

Two-Day Talk on EMI Coming to Atlanta

Rick Hartley will present a special live two-day workshop on "Control of EMI, Noise and Signal Integrity in High-Speed Circuits and PCBs" in June in the Atlanta area. As Hartley notes, EMI is a leading concern for electronics designers and a major cause of failures. The seminar has been updated to contain a fair amount of new information that was not taught in years past.

Abstract. When time-varying energy travels in the transmission lines of a printed circuit board, state changing electric and magnetic fields are present. Not properly managed, these fields are the energy source of noise, EMI and signal integrity issues. "Noise" is "intentional energy" that we fail to control and contain. Uncontrolled energy can generate many forms of interference. Some circuits are noisy, others are not. With the right training, the reasons and solutions are easily understood. Compounding the issue are today's extremely fast ICs. A circuit with 100ps rise time IC outputs can generate very serious problems, whether clocked at 5MHz, 500MHz or 5GHz.

Knowing proper design of circuits and PCBs to contain E&H fields, as well as knowing how to mitigate the effects of high-speed devices, are the keys to successful design of low noise circuits. This two-day seminar is a crisp focus of the issues PCB designers/engineers must know to prevent EMI, signal integrity, crosstalk, ground bounce and grounding issues in high-speed digital and mixed signal designs.

Each attendee will receive a color PDF copy of the full slide deck. For details, click here.

Topics covered include:

Day 1

- Impact of frequency on PCB layout
- Frequency – analog vs. digital
- Where energy travels in circuits
- Noise, what is it, and why it occurs
- Impact of proper grounding on noise & EMI
- Transmission lines and energy return paths
- Critical importance of proper plane assignment
- Common misuse of planes
- Noise and signal attenuation factors
- Routing and reflections
- Propagation time and velocity
- Lumped vs. distributed length lines
- Transmission line impedance control
- Impact of nearby traces on impedance
- Extreme importance of reflection mode switching
- Routing and termination styles
- New thoughts on line termination
- Best line routing styles
- Impact of long Ts in transmission lines
- Proper DDR routing
- VCC and ground bounce
- Basics of jitter and inter-symbol interference
- Basics of skin effect and loss tangent

- Impact of trace corners and vias
- Crosstalk – what is it, exactly
- Backward and forward crosstalk
- Crosstalk critical length
- Eliminating forward crosstalk
- Realistic crosstalk levels in circuits
- Guard traces – good or bad?
- Differential pair basics
- Differential pairs in a PCB vs. a cable
- Differential impedance … what really matters
- Differential pairs – crosstalk
- Differential pairs – tight vs. loose coupling
- Differential pair length matching and skew issues
- Differential line termination – best approach

Day 2

- Basic types of EMI
- Antenna basics and PCB radiators
- Keys to controlling common mode energy
- Energy feeding the edge of a plane
- Solutions to EMI from plane edges
- Basic component placement issues
- Board routing to control EMI and noise

- EMI impact of layer changes when routing
- Mixed analog and digital PCB design
- Islands in power / ground planes
- Routing on ground planes
- Impact of connector pin assignments
- Goals for power distribution network (PDN)
- IC impact on PDN switching noise
- Importance of low PDN impedance
- Impact of via and plane inductance
- Impact on PDN of decoupling location
- Decoupling boards with routed power
- Decoupling conventional 4-layer boards
- Decoupling high-layer-count boards
- Impact on PDN of IC package inductance
- Analog IC power decoupling
- Ferrites in the power bus – good or bad?
- Extreme importance of PCB stackup
- PCB stackups that work for SI and EMI control
- Board stackups to avoid at all cost
- 4- and 6-layer board stackups that work
- High-layer-count boards that work
- I/O filtering and blocking
- Setup of single ended I/O structures

- Setup of differential I/O, including ethernet
- Setup of high frequency differential I/O
- EMI control in metal and plastic enclosures
- Slots and openings in enclosures.
- Proper shielding of cables, low and high frequency.
- Extreme importance of I/O connector placement
- Cabling methods to avoid, always!
- Cables inside the enclosure – good or bad?
- Potential problems when using chassis as a heatsink
- Switch mode power supply layout to control EMI
- Transformer isolated outputs of SMPS
- Layout of SMPS to minimize EMI
- SMPS critical circuit loops, including feedback
- Proper grounding of the SMPS switch node
- SMPS – secondary methods to control EMI
- SMPS inductor types and proper mounting

About the instructor. Rick Hartley, retired from L-3 Avionics, is the principal of RHartley Enterprises, through which he consults and teaches internationally. Hartley's focus is on correct design of circuits and PCBs to prevent and resolve EMI, noise and signal integrity problems. He has consulted with major corporations in the US and 14 other countries. His career has focused on telecommunications, computers and aircraft avionics, as well as medical, appliance and automotive circuits. Hartley has taught seminars at numerous conferences, including the IEEE EMC Symposium, PCB West, PCB East, AltiumLive, Freescale Technology Forum, IPC Apex/Expo and others. He is on the board of directors and the Education Committee of the Printed Circuit Engineering Association (PCEA), a past member of the editorial review board of *Printed Circuit Design* Magazine and has written numerous technical papers and articles on methods to control noise, EMI and signal integrity, as well as general printed circuit board design techniques.

PCEA **CURRENT EVENTS** **BRIEFS**

Chapter News

San Diego. We will have a booth at the Del Mar Electronics Show on Apr. 26-27. On April 26, Mike Konrad of Aqueous Technologies will speak on cleaning low-residue solder fluxes and Dave Lackey of American Standard Circuits will speak on flex circuits as part of a PCEA special seminar. Visit manufacturing.show for details.

Orange County. We had another successful Lunch 'n Learn event on Feb. 23 and are planning our next meeting in May.

Seattle. We are looking at getting the Seattle Chapter back up and running. If anyone is interested in assisting with the chapter activities please contact Tim Mullin at tim_mullin@comcast.net.

National News

Education Committee. The Palomar College Advanced Course is running well with interest from students. Next year's Starter Course is also looking like it will fill up quickly, which if it does may result in a second course being offered. An "Intro to Hardware Design" Content is underway and will be having its initial high-level review before the end of March.

Ethan Pierce

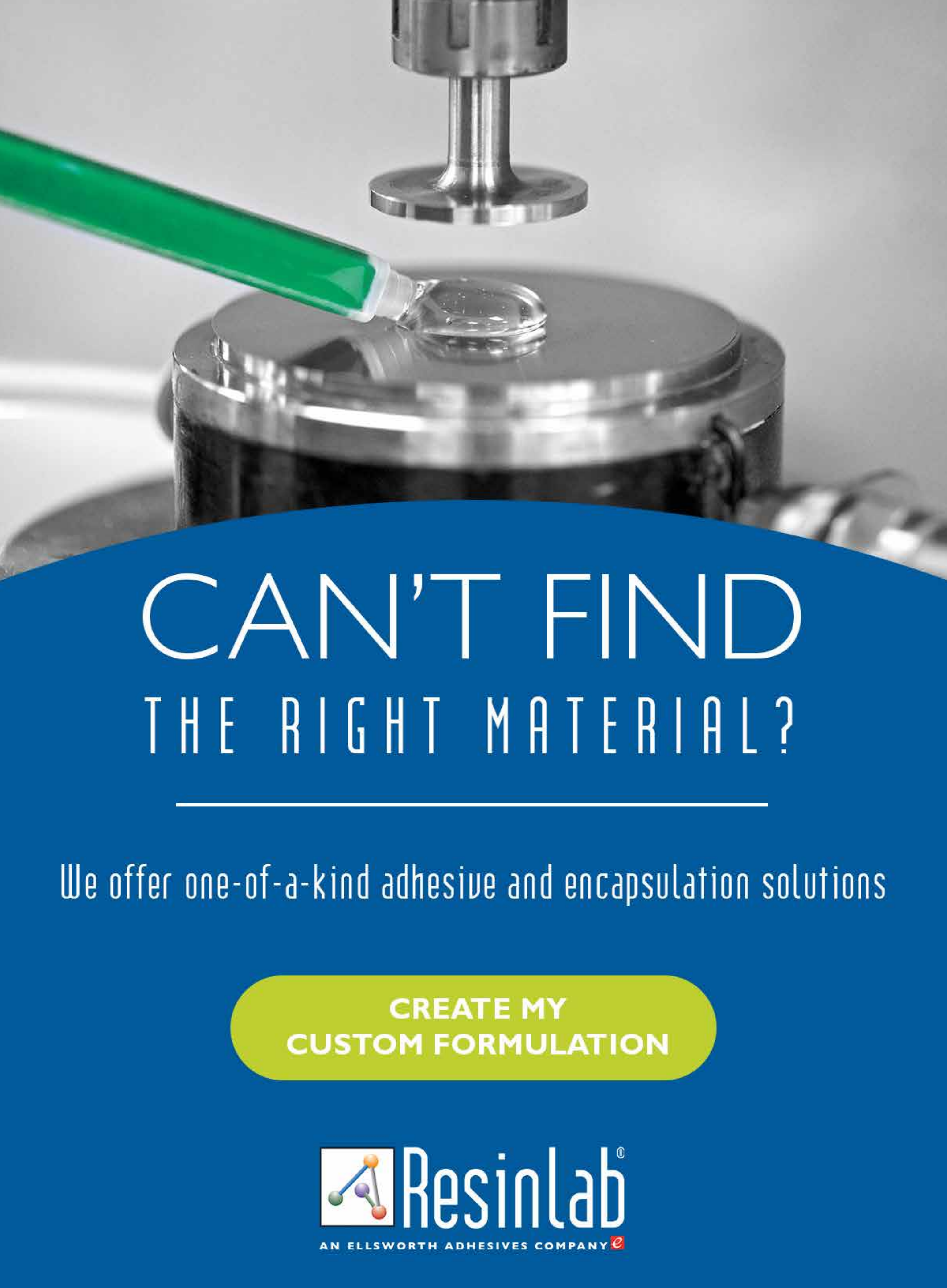
This month we will host a pair of free webinars for PCEA members. On Apr. 11, “Reverse Engineering PCBs: How to Recreate a Lost Design,” by Ethan Pierce, presents a skillset to technicians, designers, and engineers that leverages assembled PCBs without design data to be recovered and recreated. Using a set of software- and hardware-agnostic processes, this course analyzes a design of unknown origin and recreates that design with a set of commonly available tools. To register, click here.

Richard Weiland

And on Apr. 25, “Engineered Reliability: Safeguarding Electrical Components and Devices with Nanocoating Technology” by Richard Weiland, director of nanocoating applications for HZO Inc., focuses on real-world examples where significant product challenges were presented (such as humidity, temperature, or corrosion) and the investment of time and resources focused on device dependability and functional testing. To register, click here.

Conferences task group. We received 75 abstracts for the PCB West 2023 Technical Conference. Twenty-five of the abstracts were submitted by speakers who have never presented at PCB West. A draft schedule is under review by the task group and the final schedule will made available to the public the week of Apr. 10.

Eptech tour. PCEA will cosponsor a guided tour of the Eptech trade show in Toronto on May 9 (eptech.ca/location/toronto/). Ata Syed of PFC Flexible Circuits and Nick Koop of TTM Technologies plan to invite students from various institutes and give a tour of the show from an industry point of view. Contact pcea@pcea.net for details.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China to Remain Leading PCB Manufacturer, Study Says

TAIPEI – The global PCB industry will continue to grow in the near future, and China will hold its position as the center of manufacturing for the industry, according to a prediction from Prismark released by the Taiwan Printed Circuit Association in late February.

The firm forecasts annual growth of around 4.6% for PCB output in China until 2026, and the PCB output value will reach around $67.8 billion by 2027 based on growth in the communications market, computer market, automobile market, consumer electronics and other industries.

In 2021, due to factors such as a recovery in demand, upgrading of technical equipment, and a sharp rise in raw material prices, the output value of PCBs in mainland China grew to reach $51.2 billion, a year-on-year increase of 28.4%. For that year, the output percentage of products from China was 49% standard multilayer boards, 18% HDI boards, 14% rigid single-layer boards and 14% flex circuits. High-value IC substrates accounted for 4% of the country's output, and rigid-flex boards accounted for 1%.

The top three categories for China's 2021 output were communications, computers and commercial equipment, and automobiles, accounting for 32%, 27%, and 16% of the nation's output respectively. Looking at industry trends, computers and commercial equipment grew rapidly in 2021, mainly due to the increase in demand for commercial equipment with the construction of new infrastructure such as data centers; while the demand in the communications field declined, mainly due to a decrease in demand for mobile phones. Compared with the rest of the world, the PCB demand in mainland China's automotive sector was significantly higher than the global average.

PERIPHERALS TAKE CENTER STAGE

Trends in the US electronics equipment market (shipments only)

	% CHANGE			
	NOV.	DEC.[r]	JAN.[p]	YTD
Computers and electronics products	0.1	-0.2	0.4	6.2
Computers	0.40	1.2	7.9	7.5
Storage devices	-2.1	-1.8	4.7	15.0
Other peripheral equipment	3.1	-1.2	5.1	118.9
Nondefense communications equipment	-1.5	-1.9	-1.0	-5.7
Defense communications equipment	0.0	0.9	-0.5	7.7
A/V equipment	2.5	-5.2	11.0	-6.0
Components[1]	1.1	-1.4	0.9	5.6
Nondefense search and navigation equipment	0.8	-0.2	-0.1	3.2
Defense search and navigation equipment	0.3	1.3	-1.4	1.0
Electromedical, measurement and control	-1.3	-1.0	-0.3	2.8

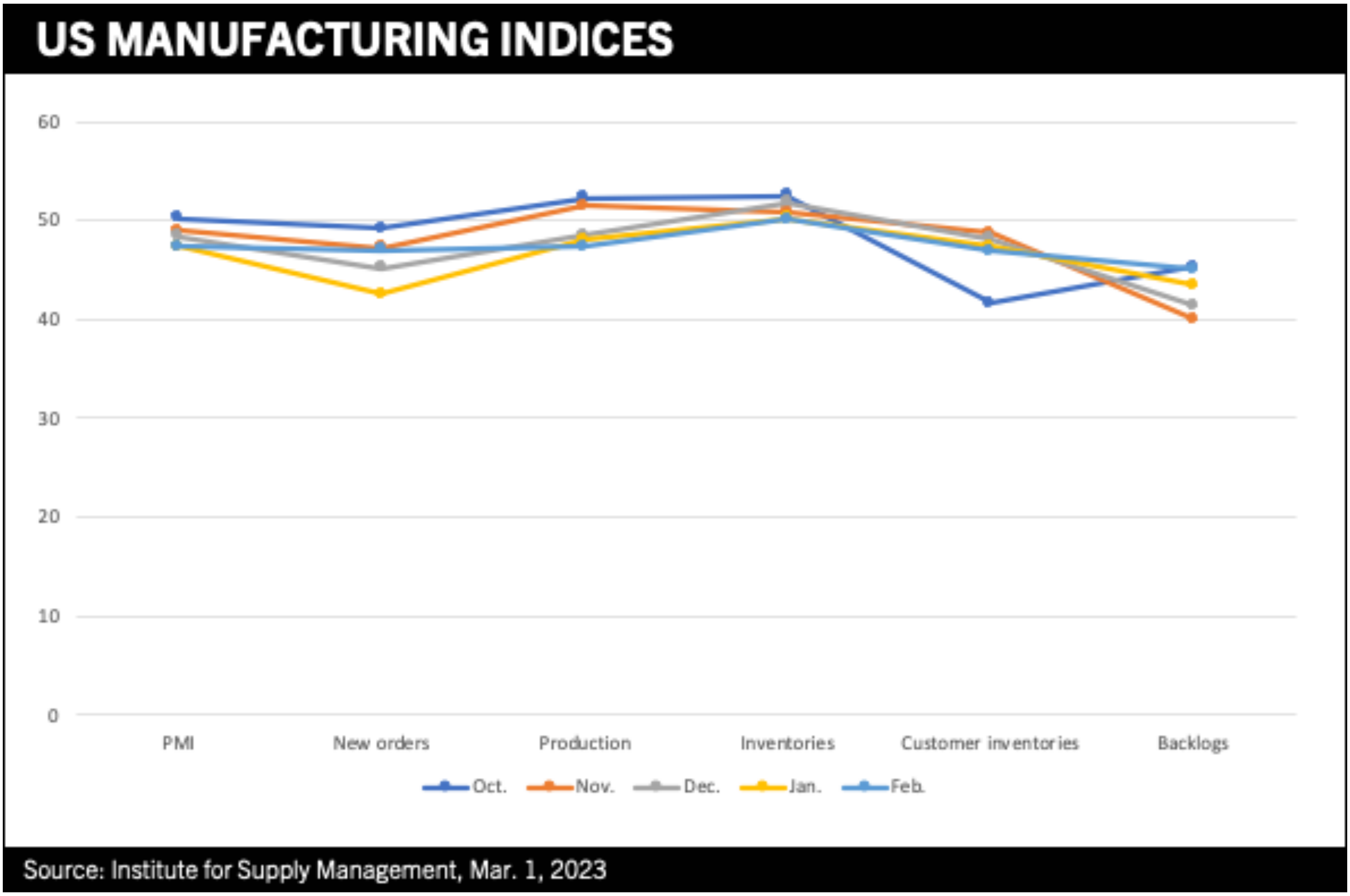
[r]Revised. [p]Preliminary. [1]Includes semiconductors. Seasonally adjusted.

Source: US Department of Commerce Census Bureau, Mar. 6, 2023

KEY COMPONENTS

	SEPT.	OCT.	NOV.	DEC.	JAN.
EMS book-to-bill[1,3]	1.3	1.3	1.38r	1.36p	1.35%p
Semiconductors[2,3]	3.0%	0.3%	2.9%	4.4%r	-18.5%p
PCB book-to-bill[1,3]	1.1	1.3	1.0	0.87r	0.94r
Component sales sentiment[4]	82.3	75.6	58.1	65.8	82.2

Sources: [1]IPC (N. America), [2]SIA, [3]3-month moving average, [4]ECIA, [p]preliminary, [r]revised



Hot Takes

Tech salaries grew 2.3% in 2022 compared with 2021, reflecting a steady upward trend since 2017. (Dice)

North American EMS shipments were up 5.1% over last year in February. Shipments decreased 4.9% sequentially. Bookings fell 5.4% year-over-year and dropped 16.4% percent from January. (IPC)

PC monitor shipments hit a record low in the fourth quarter, but a recovery is expected in 2024. (IDC)

The top 10 global OEMs decreased their **chip spending** by 7.6% and accounted for 37% of the total market in 2022. (Gartner)

North American PCB shipments in February were up up 5.6% compared to the same month last year, and up 16.4% compared to January. Bookings were up 1.5% from a year ago and 7.8%

sequentially. (IPC)

Global shipments of AR/VR headsets declined 20.9% year-over-year to 8.8 million units. (IDC)

Global DRAM revenue fell by 33% quarter-over-quarter to $12.28 billion – a decline larger than the third quarter's 28.8% drop and close to the sequential decline of 36% for the final quarter of 2008, when the global economy was in the midst of a major financial crisis. (TrendForce)

Despite a fourth quarter slowdown, the **PC workstation market** managed to achieve a shipment record of nearly 7.7 million units, growing 2.1% and surpassing the previous record of 7.5 million set in 2021. (IDC)

The **worldwide hardcopy peripherals** market saw overall shipments grow 11.6% year-over-year to nearly 25 million units in the fourth quarter. (IDC)

Future **demand for servers and data centers** will grow steadily, and suppliers of PCB multilayer boards, HDI, and ABF carrier boards will benefit. (Business Times)

Vietnam's electronics industry has seen good progress in recent years, accounting for about 18% of the total industrial production value and more than 30% of the total export revenue of the country. (Vietnam General Statistics Office)

Smartphone shipments will decline 1.1% in 2023 to 1.19 billion units, down from the 2.8% growth in the prior forecast as market continues to suffer from weak demand and ongoing macroeconomic challenges. (IDC)

Sweet Music: The PCB Reunion Tour

Getting the North American electronics band back together will take significant time and effort.

THANKS TO A series of events and geopolitical shifts – think global supply chain strains caused by a pandemic; import tariffs ricocheting throughout the electronics industry; weapon systems depleted from regional wars – there is an outcry to get the band back together: the band being North American electronics manufacturing.

The band was playing the hits in the late 1980s and early 1990s when North America was in a leadership position as gauged not just by technical development but the ability to produce that technology in volume. The music (read: technical development) is still being written profusely, but where are the bands to play (read: manufacture) the music? That is why the crowd is chanting to get the band back together. The chanting comes in the form of legislation such as the CHIPS Act, as well as from "strategic sourcing" executives searching for local North American suppliers like they had back when the band was alive, well and making the hits.

But how exactly do you get the band together when it has been decades since they last stepped on stage? When the PCB music shifted to places far away, many decided to embrace other genres of music, or even far more different art forms such as construction. When tastes, or demand, changes, some musicians choose a different gig and industry genre. Others retire to bask in memories of their glory days. Getting the band back together is not a simple task, and playing the hits as once before may be an even more difficult challenge.

Though popular in concept, it takes more than throwing money around to get the music cranking again. Bands, especially great ones, need talented musicians who can create and execute consistently and accurately. Going on tour means establishing the concert list, practicing over and over, and then nailing it night after night. It's tough to do on a good day, but when most of the talent has migrated elsewhere or retired, getting a band together requires extraordinary effort from a new generation of musicians.

Yet some new and very talented musicians have entered the scene. These people have created great music and, on a limited basis, have been able to produce and perform that music. But do we currently have enough to really get them kicking out the hits in the volume the crowd is demanding? And if not, then from where and how do you find the needed talent to perform in the genre of electronics? Back in the heyday of the '80s and '90s, places like Route 128 around Boston and Silicon Valley in California were hubs filled with available and wanting talent. Today, Route 128 focuses on biotech, while the Silicon Valley is more software than silicon. Seeking the next bandmate from the hotbeds of the past will not work. Times change, and so does where and how the next generation of talent will be found.

Regrettably, over the decades that have passed since the hits were coming, fewer people have wanted to be in a manufacturing band. Those that choose manufacturing often opt for a genre other than electronics – let alone printed circuit boards. So, a revival will require a series of initiatives – and investments – to fill all the positions that are going to be needed.

Time and money will need to be invested at the local community and technical college levels. Time to explain and demonstrate that there is long-term career potential in electronics that can be lucrative and secure for those who dedicate themselves to learning and relearning as technology develops, pivots and morphs, as it has with PCBs. Equally important is stressing that, as in any career, it's the little things such as showing up every day, on time and with a willing attitude to learn and contribute that create success. Money will be needed to furnish labs and classrooms with the manufacturing equipment that students will be operating upon graduation. Hands-on teaching works exceptionally well when developing manufacturing talent.

Those who most want the band together will also need to invest by putting some skin in the game of showing up at schools, colleges, universities and especially local workforce development programs to promote – sell – the opportunities available to those who enter our industry. This may involve opening facilities up for student tours, or when regulations prohibit that, creating a video that presents the feel of a day in the life of making the hits.

Getting the band back together, or even just starting one, is no easy task. With the crowd chanting now is the time, we need to convince a new generation that electronics – and specifically producing printed circuit boards – requires talent that yearns to be industry rock stars.

PETER BIGELOW is president and CEO of IMI, Inc. (imipcb.com); pbigelow@imipcb.com. His column appears monthly.

What's Your Process for Protecting ITAR or Sensitive Data?

Make sure export-controlled information is going where it's supposed to go.

IN MY DECEMBER column, "One Errant Click and IP Protection is Gone," I wrote of the importance of corporate IP protection. But the safe handling of ITAR or MIL data is even more vital to your company's well-being.

PCB buyers must know what information they're sending and where it's going.

"An export applies to more than just physical product placed in a box being shipped overseas," says Tom Reynolds, an export compliance consultant. "Most companies don't realize the act of electronically sending information out of the country is considered an export."

Most fabrication drawings don't indicate whether they are export-controlled. Many board buyers fail to confirm the status of their customers' files and often blindly send those out for quotes to both domestic and, unwisely, offshore PCB manufacturers.

That means a PCB buyer can inadvertently export information that is legally required to stay in the US.

Understanding how PCB files are controlled or protected is crucial to compliance, and companies can't hope to comply with the regulations if they don't understand the fundamentals.

It is crucial that EMS and OEM companies have a corporate compliance policy in place when it comes to managing export-controlled information, according to Reynolds.

"This is critical for several reasons, as companies need written proof they are making efforts to comply, especially when all documentation being received and sent is not clearly marked as it should be," he says.

Another area of concern Reynolds identifies is that many companies rely on only one employee to manage all things related to export compliance, meaning there is no backup when that employee is on vacation, gets sick, or leaves the company.

Firms sometimes have no idea how to recover from this compliance vulnerability in a timely manner, leaving them legally exposed for possible violations of export control regulations.

A documented program that several employees have been trained on is best practice for companies that buy circuit boards. Here's what firms should do on an annual basis to ensure they are keeping their compliance procedures up to date:

1. **Training.** Most companies don't know what they don't know, and this is especially true when it comes to export compliance. Put together an internal compliance team to learn about these regulations and how they apply to your business.
2. **Policy and process.** Develop a written plan for compliance and implement this program throughout your business. Make sure employees understand the importance of following it to protect themselves *and* the company.
3. **Audit and assess.** Perform internal audits to see if your program is being followed, and if it's not, find out why. It could be a training issue or a process gap. Find the root cause of the problem and fix it. Your company's entire program should be reviewed at least annually as regulations do change.

As important as it is to know what information is being sent, EMS and OEM companies also should be clear on who is receiving that information.

Has your PCB supplier let you know what they can or cannot legally receive? Do you have that in writing?

If the PCB manufacturer is purely a domestic facility, this is more than likely a nonissue. But you should still be sure you have the manufacturer's ITAR registration or some statement concerning controlled information on file.

If the domestic manufacturer also brokers PCBs from Asia, be sure you have a copy of its ITAR registration, and then find out how it segregates quotes that are permitted to be sent offshore from those that must stay domestic.

If your supplier is a pure broker, files accidentally being sent overseas is a real possibility. It is vital to have an agreement in writing with all involved parties that breaks down how sensitive files are to be sent and received, and to stipulate when they may not be sent at all.

Even with a concerted effort to safeguard controlled information, companies can find themselves with export violations. But, according to Reynolds, the US government gives "great weight" to those companies that come forward, voluntarily disclose mistakes, and – most important – make sincere efforts to improve.

"It recognizes that no company or individual is perfect," he says. "Problems will happen and the purpose of having a program in place is not to allow those problems to repeat."

PCB buyers need to ensure all data related to its printed circuit board purchases go only where they are supposed to. Retaining an export compliance consultant that can help your company minimize its exposure to export violations is a great insurance policy in this global economy.

Au: Tom Reynolds has more than 14 years' experience as an export compliance consultant. He can be reached at tomr@exportsolutionsinc.com.

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 DirectPCB and can be reached at greg@directpcb.com.

FOCUS **ON BUSINESS**

Post-Pandemic Program Management

Adapting Covid-era processes to a more rational demand level.

I FREQUENTLY SAY that program management is the most challenging job in the electronics manufacturing services (EMS) industry because program managers are expected to keep programs on schedule with little control over the variables that need to align for them to be successful in their jobs. Supply-demand imbalances in both the supply chain and with customers have made that job even harder. And, just like those late night informercials that tease "but wait, there's more," the chaos of the past two years is about to get worse.

The new challenge program managers are starting to see this year is a return to historical demand in many customer industries. Material availability is starting to improve in some areas, but not all part manufacturers are relaxing the draconian noncancellable, non-returnable (NCNR) policies put in place during the supply-demand imbalance. That basically means that even if customer demand is coming down, in some cases, orders scheduled for delivery several quarters from now can't be adjusted with some suppliers because extended NCNR terms put in place when chipmaking capacity was at a premium are still present.

This issue is bad for two reasons. First, it is slowing the natural capacity balancing that would occur if unneeded part orders were flushed out of the system. Second, it makes it harder to bring down existing inventories at EMS providers.

This issue is a symptom of a larger problem. We've been in a challenging environment for so long that policies developed to control the chaos have become a normal way of doing business. It's why people still wear masks in grocery stores. The market is beginning to shift to a more normal state, and it is important to look closely at which policies still make sense for risk mitigation in this transition period and which need to be adjusted. Program managers are in a unique position to help identify these policy changes because they see the demand shifts in their programs and understand what policies are negatively impacting cost or efficiency.

The Covid era has not been without benefits. Some changes make sense to keep. These include:

- Better tools for assessing inventory liability vs. demand
- Increased real-time tools for assessing material availability at suppliers and calculating price changes when converting from quote-to-buy
- Increased use of videoconferencing vs. travel for meetings
- Better computer security and infrastructure for remote work
- Efficiency improvements in production practices designed to add flexibility to chaotic scheduling
- Stronger relationships between program teams and their customers.

Supply-chain capacity continues to be strained in some commodities. Geopolitical turmoil continues to open the door to unplanned supply chain disruptions or spikes in demand. Thus, a complete return to the leaner, more efficient business models of the past isn't advisable. However, it is time to begin fine-tuning forecasts with customers whose demand is trending down to historical levels and developing plans for reducing higher-than-normal inventories in those situations.

Another area to assess is new product introduction (NPI) capacity. Historically, periods of severe allocation are always followed by high customer turnover as unhappy customers that delayed moves from suppliers decide it is safe to choose a new one. Typically, those decisions happen faster than usual because customer teams want to minimize material availability uncertainty. Given that new customer acquisition slowed during the pandemic and supply-demand imbalance period, NPI teams and associated program managers may be rusty at ramping new customer programs, particularly if there is a greater-than-normal number of new customers in a short period of time.

If there have been breakdowns in customer service over the past two years, customer satisfaction assessment should be another area of focus. Improved material availability translates to greater account vulnerability when customers are dissatisfied.

Just as the past two years have tested program management competency in addressing an unparalleled series of challenges, the next year or so will test the ability of program managers to leverage improved tools and relationships in restoring the business practices normal to the EMS industry.

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DESIGNER'S **NOTEBOOK**

Isolating Noise on a Printed Circuit Board

Proper planning can protect a board's victims from noisy aggressors.

GOOD FENCES MAKE good neighbors, or so they say. That said, some folks can get along just fine without a fence or wall to provide peace of mind. The signals that run around on a printed circuit board are similar in that regard. Aside from the presumably inert ground domain, all the energized copper contributes to the overall noise factor.

Just as there is an audible difference between a major city and a wide-open prairie, location matters. A high-density layout is more likely to run into locations where a so-called victim finds itself in proximity to an aggressor. So, what is an aggressor and why does it bother the victim? Defining the aggressors is easy. They're everywhere.

- **Switch mode power supplies:** SMPSs are devices that regulate power by metering it out in tiny doses, one right after another. The switch turns the power from full on to full off at a rate that averages out to the indicated voltage. A big inductor plus a small cap help even out the waveform. Nonetheless, the output pin of the power supply is likely connected to the LC filter with a wide trace, or better yet, a shape. Placement is critical in reducing the area of the V-Out net. After that, it's not so bad, but the SMPS should be located near its load to reduce routing length.
- **Crystals and other clocks:** This family of nets are also quite talkative as they are the ones that regulate all the other nets. Those other nets only switch on occasionally while the clocks never miss a beat. That continuous buzz requires a bit of room to dissipate. A rule-of-thumb is that the

air gap should aim for three times the line width, or more precisely, the dielectric thickness between the trace and reference plane.

- **Ahh, the memories:** Today's processors do a tremendous load of work. The memory bank can be staggeringly hard to solve unless it is in the form of package-on-package (POP) style. For the rest of us, length-matching can be diabolical, knowing that any amount of skew creates signal integrity issues. It only gets worse with the popular double data rate (DDR) dynamic random-access memory (DRAM) that can be counted on as a frat house of a neighbor.
- **Analog signals (RF):** Transmission lines can be both aggressors and victims. Isolation is more extreme to the point where each trace runs within a copper flood that creates a Faraday cage around the signal. Naturally, the receive chains are prone to picking up spurious signals, while the transmit side pumps out more sauce, so they would have better immunity. The traces are run on the outer layer to avoid the discontinuity presented by a via. The exception here is if the run is particularly long. In that case, we should review the placement to see if there is a way to make the RF circuit more compact.

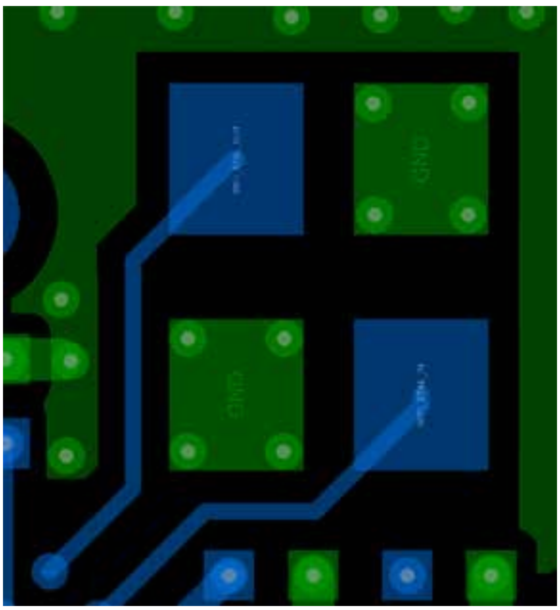

Figure 1. Crystals are one of the few items that would get an isolated ground zone. The reason I might do this is if there is a receptive signal in the vicinity.

Victims include the receive chains of the high-frequency circuit, especially the antenna but also any sort of device that gathers data from its surroundings. If the chip has the word sensor or detector in its title, then you can bet it needs a pristine setting on the PCB. Different components include gyroscopes, compasses, microphones, hall effects sensors, image sensors, photonic detectors, and so on. Just being on the list of aggressors does not mean that its feelings can't be hurt. Interference cuts in both directions.

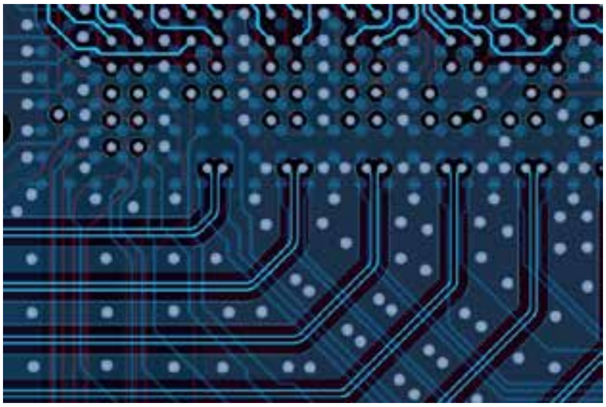

Figure 2. Differential pairs are ideal for their noise-cancelling effect. Shrouding them between ground planes increases their electrical isolation.

If a supplier wants a market for their product, it behooves them to provide layout guidance. If a sensor requires some additional space for the design to work, that space should be allocated to the chip at the component level. The large courtyard is much easier to implement before routing the board. These specific rules can be missed if the data are not embedded with the footprint. If not, then that leaves us to wonder if the components related to the sensor can be in the exclusion zone. When in doubt, ping the vendor, they are there to help.

A shield can contain EMI. Coexistence can require more than just the breathing room around the chip. Enter the RFI shield to cap the nest of aggression and victimhood that makes up the typical radio frequency solution. Once we cross into the GHz range, we're probably looking for a shielding solution. Off-the-shelf shielding systems are available, but they are going to be rectangles in a limited range of sizes. No problem to design one of those around the sensitive electronics for the breadboard stage of development.

Most likely, a custom shield will be required when it comes to production runs. Size always seems to matter in consumer electronics. Rectangles are still worth considering as the bespoke shapes are more costly to produce. A one-piece shield is the bargain solution, but once it is installed, forget about repair in the field. A two-piece shield consisting of a wall and a lid is the more reasonable plan.

The issue is that we give up a little headroom, as the wall structure will have a web across the shielded area that supports a circular area in the center. That circle is the pickup point for robotic placement. That “web” and the flange around the perimeter are areas we must watch for our taller components. The lid itself is made of a relatively flexible steel bent in a way that keeps it on with just friction between the wall and lid.

The most shielded things I’ve ever worked on were VR and AR headsets. They have a ton of computing and rendering going on. Wireless is there to stir the pot of electronics that generally do not get along with each other. When it is strapped to a person’s head, every gram matters. Smartphones are that way too. Still, there’s a collection of shields over most of the electronics.

Just allowing the potential to put a shield around the SMPS will push toward a rectangular layout that is easy to reuse. The gap around it for the shield wall may be all the isolation needed. If not, then you saved the day by having space cleared out for a shield footprint.

Figure 3. This Wi-Fi card has a multi-channel in/out (MIMO) radio system that requires shielded areas within the analog block.

The best defense against crosstalk is a well-considered layout from the connector locations onward. Printed circuit boards tend to have leakage around their edges. The less stuff out there, the better. The perimeter ground band forces the voltage planes inward just by being there, but it’s a good idea to keep the voltage planes clear of the edge. The preferred distance is a function of the dielectric thickness between copper layers. I've heard it called a "6X rule," which is the ratio of dielectric thickness to route keep-in for the power planes. That's giving up considerable area, but it may be possible with planning – and a generous board outline.

While we can't always get it, the rural approach where everything lives in its own little area is the easiest approach to both thermal and EMI challenges. As things get denser, be mindful of the nature of each device, and like a good city planner, keep the industrial sections away from the boutique fussy end of town.

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A Solution 100 Years in the Making

The IoT could finally permit RFID to reach its full potential.

A "SOLUTION WAITING for a problem" is a label often affixed to technologies and inventions. It's perhaps one of the harshest judgements the world could pass, after all the time and care and emotional energy that gets poured into its creation. Yet it's a risk any developer must accept. Often, we cannot know for sure that our pet project will take off in any way – much less that it will achieve the incredible success we have seen in some cases over recent years: Google, cellphones, ARPANet….

RFID has been a labor of love for many generations of engineers. It's probably impossible to credit a single inventor, although the Russian scientist Leon Theremin – who, in 1919, created the eponymous contactless musical instrument credited with inspiring modern synthesizers – is often cited. His passive listening device, later dubbed "The Thing," enabled Russian intelligence services to hear private conversations held in the US embassy in Moscow from 1945 until 1952. For those seven years, it remained embedded in a hand-carved ceremonial plaque – the Great American Seal – that had been presented as a gift to the ambassador and hung on his office wall. Russian teams would activate the device by aiming a radio transmitter at the plaque from outside the embassy building. Without its own radio transmitter or power source, The Thing foiled bug-sweeping techniques of the time. The game was up only when British radio journalists from the BBC alerted staff after finding they could hear American voices interfering with their broadcasts.

RFID continued to mature as a technology, and applications evolved throughout the remainder of the century. Only in the 1990s were standards established. Although now assessed as an $11 billion market, with healthy prospects for double-digit growth, RFID remains little understood to the world outside: tech-savvy consumers who "get" the technologies behind smart living – 5G, mobile payments, e-ticketing, facial recognition – often have little concept of RFID and its capabilities.

Despite its success in an arguably narrow field of application, so much more is possible. Is it a solution waiting for a problem? That could be about to change, thanks to the passive nature of RFID tags. Running off the excitement energy provided by the reader, the tag requires no built-in power source. And that answers issues that are incredibly important to us today. Tags can have an effectively indefinite lifetime, requiring no maintenance such as battery changing or recharging. This makes managing even an extremely large field of deployed devices relatively easy. They can be used anywhere, and – extremely important today – disposal is simple with no consequences for the environment due to the degrading of discharged batteries. It sounds like the perfect sensor technology for the IoT.

Many of today's RFID applications involve pointing a handheld reader to interrogate tags in a manufacturing or retail logistics setting. Flipping that model, so that the tags are roaming and give up their data as they pass static readers placed in specific locations, helps IoT application developers address the perennial question of how to power and maintain large numbers of remote sensors.

Numerous tracking applications can be implemented – and scaled – at a relatively low cost. These could include monitoring the locations of employees within a large site such as a mine or a farm, to protect their safety, simply by tagging industrial clothing. No need to invest in large numbers of expensive personal transponders, such as Bluetooth or LPWAN transceivers, to distribute, maintain, and accept the costs of loss and damage. Similarly, visitors to a large indoor or outdoor attraction can be cost-effectively tracked for safety and geofencing, as well as marketing purposes like measuring the relative popularity of the available experiences.

In addition, by leveraging angle-of-arrival techniques, it is possible to identify the positions of RFID tags – and hence people or objects – within a space. It becomes much more cost-effective to authenticate ourselves with smart systems. Room lighting and heating can activate and automatically adjust to our personally preferred settings. Of course, there are other ways to accomplish these capabilities. The concepts are well-explored by people like the scientist and advocate of implant parties, Kevin Warwick, aka Captain Cyborg.

It's the passive, power-free nature of RFID that's empowering and could make this happen. We can envisage a future in which it is normal for humans to have an implanted RFID tag. The absence of any battery chemicals simplifies biocompatibility, and the freedom from maintenance is also attractive. There is the flexibility to update personal data, such as new access permissions within a building or endorsements on a driving license. The Swedish company Biohax International has offered a similar vision, developing implantable NFC technology for personal identification to ease access to services like banking, payments, transport, and social benefits.

These applications raise valid concerns, giving the opportunity to track and identify individuals everywhere they go. Serious ethical questions are associated with permanent, obligatory tagging. Some control must be afforded to the wearer and access to any data must be securely restricted.

Even so, the opportunities are exciting for those who are actively engaged in bringing these ideas to life. Within the PCB industry, our substrate knowledge can contribute to the development of new and better ways of making tags. Some applications may require tougher materials. In others, there may be an argument for biodegradability. I recently read about microwave-proof food tags that can identify the dish so that the oven can self-adjust to cook the contents to perfection.

As with many of the technologies we develop, we can expect great benefits for our lives. On the other hand, there are challenges to the freedoms that we value so much and should seek to protect.

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Flexible Heater with Non-Heating Leads

Three methods for incorporating non-heating leads into a heater pattern.

A FLEXIBLE HEATER is needed where Constantan or Inconel is used for the heating area. Is there a way to incorporate a resistive layer into a standard flex circuit to have non-heating (copper) leads going to the heater pattern?

Answer: Yes, this is a common request and can certainly be done. Several methods are used to accomplish this, with limitations. A couple of these methods require selective plating of copper onto the resistive alloy element traces to lower the resistance, or using plated vias on other layers to make the non-heating connections. This works well on copper/nickel alloys like CuNi 715 or Constantan, but not so much so on Inconel 600 (these are the three most common resistive alloys used in flexible heater construction). The Inconel restriction is covered in more depth later in this column.

The first method requires three total layers in the stackup, with the internal layer the resistive (heating) layer. The outer layers are standard copper and include the traces feeding the heater along with any other circuitry you wish to include. Top and bottom copper layers are needed even if there are only the two heater leads and/or a couple of thermistor leads. In many cases, one of the outer layers will be only pads. Reason: To connect the heater element to a copper layer with a via, the entire panel must be electroless copper-plated to metalize the vias for electrolytic copper plating. If one of the outer layers is the resistive foil, that layer will now have a layer of copper plating that will significantly lower the overall resistivity of the element – making it non-heating. By burying the resistive element between copper layers, the element will receive copper plating in the via areas only.

The second method starts with a single layer of resistive foil, and then selective traces are copper-plated in areas you do not want heat generated **(FIGURE 1)**. The one stipulation is that this can be done only on applications where the heater is a copper/nickel alloy like CuNi 715 or Constantan (i.e., not Inconel). The reason is copper-nickel alloys are very easy to plate with copper, and the bond between CuNi and copper plating is very good. Inconel, on the other hand, is relatively easy to copper plate, but the bond between Inconel and plated copper is very poor. The result is similar to plating copper onto stainless steel. In many cases the plated copper will peel off the Inconel before it can be locked in place with a polyimide cover. One potential workaround is to drill several holes along non-heating traces, then plate pads on the back side around each of the drilled holes, which effectively creates rivets, in addition to copper plating the trace on the top side. This does not improve the bond between the copper plating and Inconel, but will in most cases keep the plating in place until cover lamination locks everything in place. For this to be effective, the plated through-hole "rivets" need to be relatively close together, which can cause mechanical issues if the heater must be bent in the non-heated lead area (which is pretty common).

Figure 1. A CuNi element trace copper-plated to be non-heating (right side of image).

Overall, it is better to just increase the trace width of non-heating Inconel leads as much as possible and bypass the copper plating. Doubling or tripling (or more) the width of the traces you do not want to heat can reduce the heat generated in those traces by 50% to 75% or more. If real estate is not available to significantly increase the trace width of the heater leads, I recommend looking at using a thinner CuNi alloy with smaller traces to get similar overall resistance to Inconel. Again, it is a simple matter to then copper-plate the heater leads to keep them cool.

The last method for creating a flexible heater with non-heating leads is to build a standard flexible heater and a standard copper flex, and then connect the two using eyelets, conductive adhesive, etc. This can be done on CuNi alloy and Inconel-based heaters, and is typically considered when the size or shape of the overall heater/lead assembly results in extremely poor processing panel density. Significant improvement in panel density of both the heater and flex is common if they are built as separate items. While there will be an increase in assembly costs over selective copper plating, in some cases the material savings will result in lower overall cost of the flexible heater assembly.

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Understanding Electroless Nickel Thickness in ENIG and ENEPIG

The actual phosphorus content in the deposit must be considered.

by ROBERT WEBER

While the current focus in the electronics industry is chips, components and microelectronics, the printed wiring board (PWB) also plays a vital role. Continued miniaturization and environmental considerations, such Restriction of Hazardous Substances Directives (RoHS), have led the industry to create and improve surface finishes to meet current and future generations of electronic assemblies. Two PWB finishes have become very common: ENIG and ENEPIG. The industry trade association, IPC, released IPC-4552 in 2002[1] to help standardize the global printed circuit board industry around a specification for ENIG. IPC-4556 was released in 2013[2] to establish industry standards around ENEPIG surface finishes.

The electroless nickel layer plays important roles in the functionality of printed boards. Electroless nickel provides a diffusion barrier between the copper basis metal and the surface finish layers of immersion gold (ENIG) or electroless palladium and gold (ENEPIG). It also provides a stable metallization for wire bonding, and acts as a wear resistant layer for switch pad applications that copper, or other copper basis surface finishes, cannot offer. The formation of nickel-tin (Ni_3Sn_4) intermetallic compounds (IMCs) have shown to offer similar long-term reliability when compared to copper-tin IMCs (Cu_6Sn_5 and Cu_3Sn) that have been the standard for reliability studies since the inception of the electronics industry.[3] Both IPC-4552B and IPC-4556 specify the electroless nickel thickness for rigid boards shall be 3 to 6µm (118.1 to 236.2µin).[4,5] IPC-4556 contains an additional requirement to apply a ±4 Sigma (four standard deviations) from the mean to account for measurement uncertainty. (Note:

IPC-4552 also provides electroless nickel thickness requirements for flexible circuits. For brevity, this article addresses only rigid boards. The concepts detailed can be applied to flex boards, however.)

The background for the thickness range requirements for electroless nickel arise from both practical and physical requirements. IPC-4552B indicates electroless nickel thicknesses below 3µm may be appropriate for high-frequency applications.[6] Electroless nickel thicknesses below 1.27µm (50µin), however, are not recommended due to increased potential for copper diffusion through the electroless nickel layer.[7] Practically, the time to deposit 1.27µm of electroless nickel is shorter than the time to deposit the required thicknesses of immersion gold, especially important on an automated plating line. Plating the minimum 1.27µm would require freshly deposited nickel PWBs to be placed into a "holding station" or rinse water tank for an extended period. This risks passivation of the nickel prior to the immersion gold (or palladium) deposit. Passivated nickel presents problems with subsequent plating layer(s) adhesion and solderability. To minimize hold times, and potential impact on the nickel, the minimum thickness has been established at 3µm. This was found to work well with automated plating lines as well as providing an excellent minimum thickness for wire bonding. The maximum thickness of 6µm (236.2µin) was incorporated to prevent high insertion forces and therefore possible damage for press-fit pins into PWB through-holes.[8]

X-ray fluorescence (XRF) instrumentation is the only accepted IPC-4552B metrology method[9] to measure thicknesses for plated layers. IPC-4556 does not restrict ENEPIG thickness measurements to XRF but Appendices 4 and 9 highlight and detail specific guidance and considerations for use of XRF to measure ENEPIG.[10] XRF instruments calculate thicknesses by determining the amount of mass of material present in a defined measurement area. The analysis, or measurement, area of a specific XRF measurement is colloquially known as the "spot size." The spot size is defined by type of XRF system used, either with mechanical collimators or polycapillary optics. IPC-4552B specifies use of either a 0.3mm or 0.6mm mechanical collimator, or a system equipped with polycapillary optics (measurements made with polycapillary optics shall be made with a scan over the surface).[11] IPC-4556 does not directly specify a spot size but does detail measurement spot size "shall not exceed 30% of the feature size being measured."[12]

Calculation of coating thickness, using XRF, while complicated, can be simplified to a core principle, measuring the amount of mass of material within in a known measurement surface area. The measurement surface area is defined by either the collimator size or polycapillary optic spot size. An

XRF instrument observes and quantifies an amount of mass of material(s), uses known or user input for the density of the material(s), and calculates a thickness value.

Thus, calculating the thickness of electroless nickel presents challenges. Electroless nickel is a self-sustaining, autocatalytic reduction process using hypophosphite chemistry.[13] As the nickel deposits on a substrate, by design, a quantity of phosphorus is incorporated within the nickel layer. The addition of phosphorus changes the density of the deposit. As described in the paragraph above, XRF measurements use mass in a defined surface area to derive a layer thickness. Changes in density, if not included in the measurement calculation, will present themselves as a change in layer thickness.

Accurate measurement of the electroless nickel layer thickness is possible if a user corrects for density changes caused by the inclusion of phosphorus in the nickel deposit in a specific sample. The thickness measurement will be calculated with the appropriate density (e.g., fixed percentage; 92% Ni, 8% P) of the specific sample. Some XRF instruments are capable of directly measuring the phosphorus content (calculating the alloy percentage in wt.%) in each sample and will automatically calculate a thickness with the correct density.

Experimental

Testing for the effects of phosphorus content on the thickness was conducted on a ENIG calibration standard, serial identifier AVPQ **(TABLE 1)**. The sample was measured using a calibrated XRF instrument with collimated optics and measured with the test conditions as detailed in **TABLE 2.**

Measurement Sample	Layer	Known Thickness, µm (µin)
	Au	0.045 (1.77)
	NiP	4.24 (167) @ 9.2 wt. % P

Table 1. Measurement Sample

Measurement Excitation Conditions	
Measurement Instrument	FischerScope® XDV®-SDD
X-ray source (anode)	Tungsten (W)
Excitation voltage	50kV
Primary Filter	Ni – 10µm
X-ray detector	50mm² SDD
Collimator size	0.6mm
Measurement time	60s
Test methodology	Repeatability conditions[14]

Table 2. Sample Test Conditions

The sample was measured five times under repeatability conditions[14] (same person, same location, short time frame, same instrument, etc.). The phosphorus content was initially set at 5% and the measurement calculation recipe was then manually adjusted **(FIGURE 1)** between each group of measurements, in increments of 1%, to a final value of 13 wt.% P. Mean values and standard deviations were calculated from the individual measurements **(TABLE 3)**. The calculated thickness was plotted vs. the wt.% P used in the measurement calculation **(FIGURE 2)**.

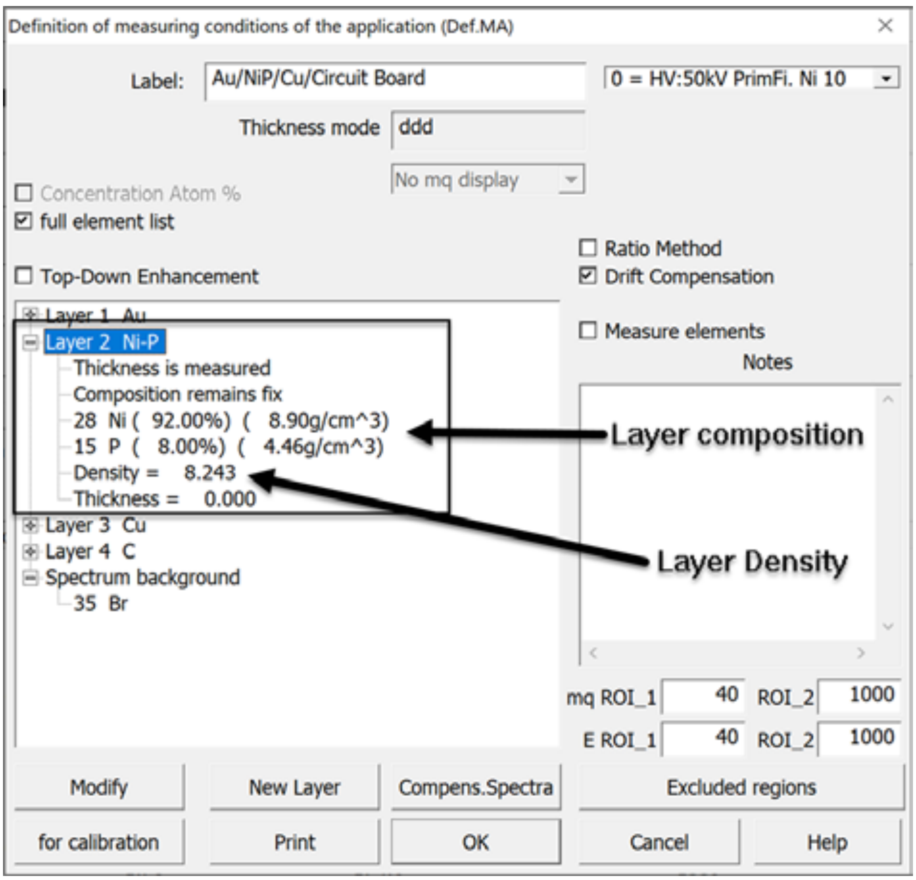


Figure 1. Setting the phosphorus % in the measurement recipe.

Sample ID	wt.% P	Au (µm)	Au 1σ	NiP (µm)	NiP 1σ
AVPQ	5	0.045	0.0003	3.86	0.0023
AVPQ	6	0.045	0.0003	3.95	0.002
AVPQ	7	0.045	0.0003	4.01	0.002
AVPQ	8	0.045	0.0003	4.14	0.003
AVPQ	9	0.045	0.0003	4.23	0.003
AVPQ	10	0.045	0.0003	4.34	0.003
AVPQ	11	0.045	0.0003	4.44	0.003
AVPQ	12	0.045	0.0003	4.55	0.003
AVPQ	13	0.045	0.0003	4.66	0.004

Table 3. Measurement Data, Sample AVPG, Changing wt.% P

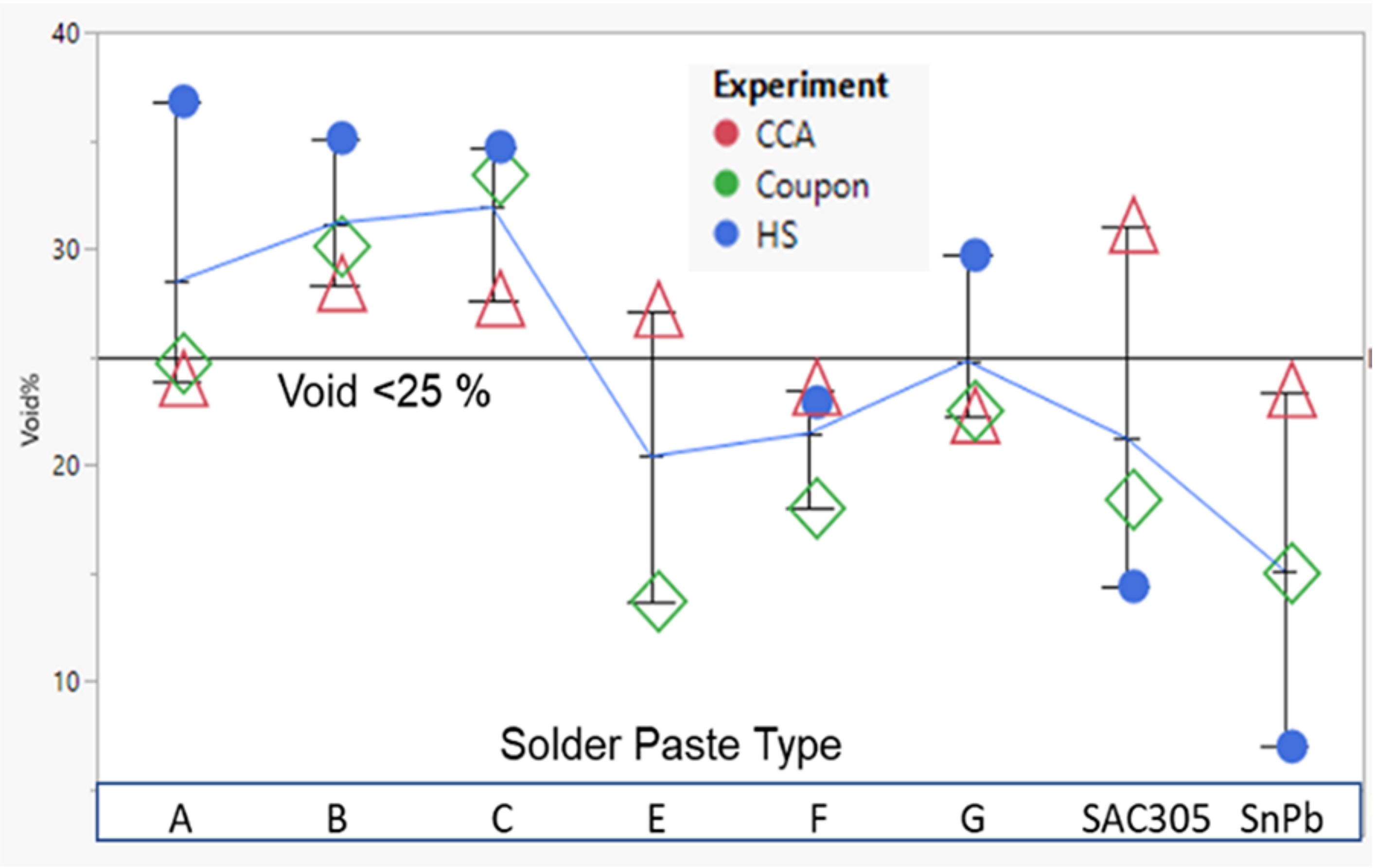
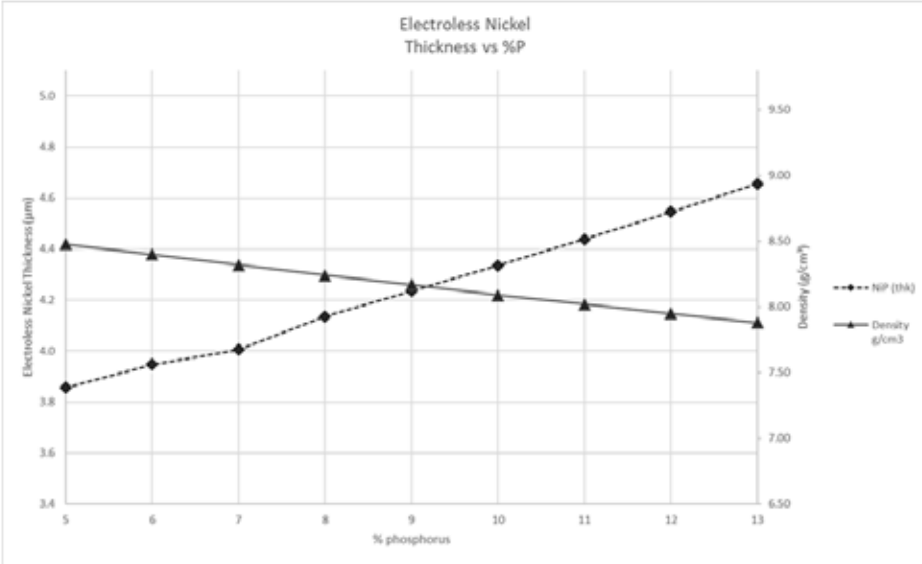


Figure 2. Electroless nickel layer thickness vs. wt.% P content.



3 REQUIREMENTS OF ENIG DEPOSIT

Table 3-1 Requirements of Electroless Nickel/Immersion Gold Plating

Tests	Test Method	Requirement Paragraph	Class 1	Class 2	Class 3
General					
Measurement Capability	XRF		Gage capability $C_g \geq 1.33^1$		
XRF Thickness Sample Size	XRF	3.5.3.2	C=0 with n (minimum) = $[2/C_g]^2$ as necessary		
Visual	Visual	3.3	Uniform plating and complete coverage of surfaces to be plated		
Electroless Nickel Thickness Rigid Printed Board	Appendix 3	3.5.1.1	3 to 6 µm [118.1 to 236.2 µin]		
Electroless Nickel Thickness Flex Printed Board[2]	Appendix 3	3.5.1.4	1.27 to 6 µm [50.0 to 236.2 µin]		
Immersion Gold Thickness **(Exception Required on Procurement documentation)**	Appendix 3	3.5.2.1	The minimum immersion gold deposit thickness **shall** be $\bar{X} - 3s \geq 0.04$ µm [≥ 1.58 µin] The maximum immersion gold deposit thickness **shall** be $\bar{X} + 3s \leq 0.1$ µm [≤ 3.94 µin] as measured on a pad size of 1.5 mm x 1.5 mm [0.060 in x 0.060 in] or equivalent area, ± 10% Where: $\bar{X}$ = the mean gold thickness s = the standard deviation of a sample		

Figure 3. IPC-4552B thickness specification for ENIG.[15]

Additional testing was performed on a second sample to evaluate how different percentages of phosphorus affected electroless nickel thickness measurements near the lower limit of the IPC specifications. Testing was performed using a certified electroless nickel sample at 3.05µm (120.1µin) containing 8% phosphorus over a solid copper base. The phosphorus content for the thickness calculation was manually varied, in the measurement settings (Figure 1), from 5 to 10 wt.% P. These data are displayed in **TABLE 4.**

wt/.% P (for calculation)	Mean Thickness[1] (µm)	1 σ	4 σ[2]
5%	2.87	0.005	0.021
6%	2.93	0.005	0.022
7%	2.99	0.006	0.023
8%	3.05	0.006	0.023
9%	3.11	0.006	0.024
10%	3.17	0.006	0.024

[1]Average of five 30s measurements, 0.6mm collimator. [2]IPC-4556 guard band.

Table 4. Electroless Nickel Thickness on Copper with Varying wt.% P

Discussion

The effects of phosphorus content on electroless nickel are apparent from the data shown in Tables 3 and 4 and graphically represented in Figure 2. The data clearly show the effects changing phosphorus content has on the layer thickness of an electroless nickel deposit. This explains why the actual phosphorus content in the deposit must be considered by both PWB manufacturers and end-users when evaluating electroless nickel thickness vs. the IPC specifications. This becomes most relevant when parts are subject to either acceptance or rejection based on the nickel layer thickness.

The risk of rejecting good parts, or conversely accepting failing parts, is real if we accept or reject solely on the thickness of the electroless nickel layer. Recall from Figure 2 and Table 3, the dimensional thickness of the electroless nickel layer is affected by phosphorus content in the layer. From **TABLE 4** we see how an understanding of these effects is critical when the sample is at, or near, the specification's tolerance (Figures 3 and 4). Referring to Table 4, the sample, as measured at 8% phosphorus, will pass both IPC-4552B and IPC-4556 minimum electroless nickel thickness, but will fail if the sample is measured at 7% phosphorus.

3 REQUIREMENTS

Table 3-1 Requirements of Electroless Nickel Electroless Palladium Immersion Gold (ENEPIG) Plating

Inspection	Class/Test Frequency (A.Q.L.)				Requirements	
Tests	Test Method	1	2	3/3A	Paragraph	Remarks
General:						
Visual	Visual	4.0	2.5	1.0	3.1	Uniform color and complete coverage of surface to be coated.
Electroless Nickel Thickness	Appendices 4 and 9	6.5	4.0	2.5	3.2.1	3 to 6 µm [118.1 to 236.2 µin] at ± 4 sigma (standard deviations) from the mean as measured on a nominal pad size of 1.5 mm x 1.5 mm [0.060 in x 0.060 in] or equivalent area.
Electroless Palladium Thickness	Appendices 4 and 9	6.5	4.0	2.5	3.2.2	[illegible] ± 4 sigma (standard deviations) from the mean as measured on a nominal pad size of 1.5 mm x 1.5 mm [0.060 in x 0.060 in] or equivalent area.
Immersion Gold Thickness	Appendices 4 and 9	6.5	4.0	2.5	3.2.3	>0.030µm [1.2 µin] at - 4 sigma (standard deviations) below the mean as measured on a nominal pad size of 1.5 mm x 1.5 mm [0.060 in x 0.060 in] or equivalent area.

Figure 4. IPC-4556 thickness specification for ENEPIG.[16]

The potential for false rejection or acceptance increases when we look at ENEPIG and IPC-4556. As mentioned, from Figure 4, with ENEPIG the standard deviation of the electroless nickel measurements must also be considered. **FIGURE 5** shows a plot of 300 randomly generated data points. In this case, using the measurement standard deviation (1σ) of 0.005µm from Table 4, the part must measure a minimum of 3.02µm to meet a minimum thickness of 3µm ±4σ.

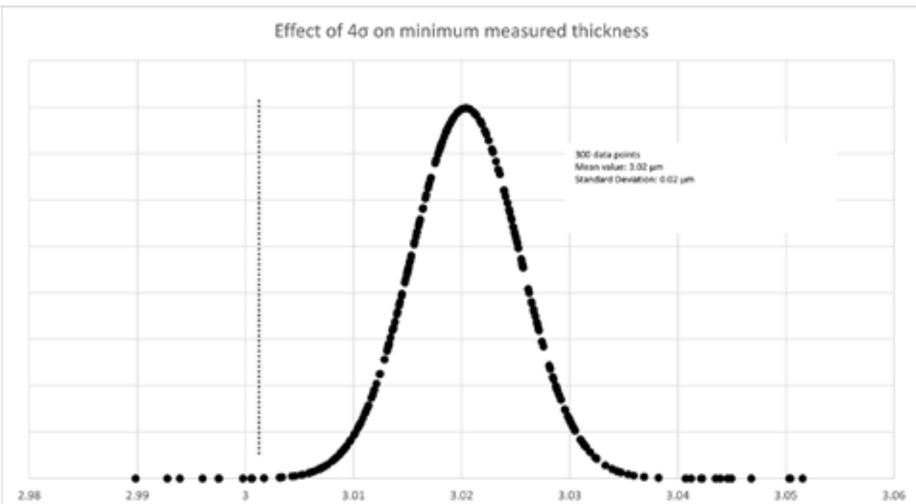


Figure 5. ENEPIG ±4σ consideration on lower EN limit specification.

Conclusion

Both IPC-4552 and IPC-4556 are important industry standards for the manufacturing of reliable electronic assemblies. Much of the attention in printed wiring boards is paid to the precious metals. The electroless nickel layer is also important, for reasons of solderability, shelf life, durability, and dimensional requirements for press fit pins.

Both IPC specifications apply a 3-6µm [118.1-236.2µin] thickness specification to the electroless nickel layer. This creates potential problems for both the PWB fabricator and the end-user; there may be false rejections or acceptance because an incorrect phosphorus content was used to calculate the thickness. This potential thickness measurement error is most relevant for parts with electroless nickel thickness at, or very close to the minimum or maximum tolerances.

Care should be taken to use the correct phosphorus content for the sample being measured or use XRF instrumentation capable of directly evaluating the wt.% P in the sample being measured.

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"Probing" Questions?
Datest has your answers.
There is Flying Probe
And there is Flying Probe
Self-learned MDA or Full Parametric Debug?
A qualifying box-check,
Or a value-adding diagnostic tool?
In the hands of a neophyte, a large paperweight.
In the hands of an expert, comes a masterpiece.
Your choice matters. Choose the Expert.
Test Engineering. Failure Analysis. Answers.
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APCT

‘A Solution for Anybody in North America’

Following its acquisition of ACI, APCT head Steve Robinson is bullish on what’s ahead.

by MIKE BUETOW

APCT in February completed the acquisition of Advanced Circuits Inc. (ACI), a printed circuit board fabricator based in Aurora, CO, and with facilities in Chandler, AZ, and Maple Grove, MN. The acquisition nearly doubles APCT’s annual revenue to $200 million, and makes the company the third largest among PCB fabricators in North America behind TTM and Summit Interconnect.

In March, Steve Robinson, president and CEO of APCT, joined PCEA president Mike Buetow on the PCB Chat podcast to discuss the acquisition, the pending integration, and APCT’s new responsibilities as one of the largest North American PCB fabricators. This transcript has been lightly edited for grammar and context.

Mike Buetow: Steve, regarding the acquisition, why was it the right move at this time?

Steve Robinson: We’ve been working with the Yacoubs [the directors of Advanced Circuits] and the ACI acquisition for about six to seven months. We started to sense a need for APCT to expand beyond our specialty offerings. We have established a business on the more advanced-technology platform. Speed and technology are what we founded APCT on and as we started to saturate that market and really grow with it, our customers started reaching out for us for more capacity and a better solution in the two-to-10-layer technology, what we consider very low technology.

APCT president and CEO Steve Robinson was interested in acquiring ACI for years.

That, along with what we saw, was very intriguing: [ACI's] software, their integration model, their online and Internet-based business were intriguing and something that I had interest in for many, many years. Customer demand, a capability and a capacity expansion of APCT that we just didn't have. When you go into the advanced technology, really HDI-focused arena, which APCT is in, there's a very large expense infrastructure, engineering and capital expense associated. Having a more-economic solution in that lower technology space was a challenge for us, and this vehicle provided us additional, very specific capacity in the two-to-10-layer technology space that our customers were asking us for. In fact, we saw an increase in demand in the industry in general and we really felt the timing was right to do this. Along with that, in the Aurora facility, we added that capacity, but in the Chandler and Maple Grove plants we also added full-blown government certifications in all classifications and some very specialty and niche capacity to support our country and our government, which APCT has been committed to for years.

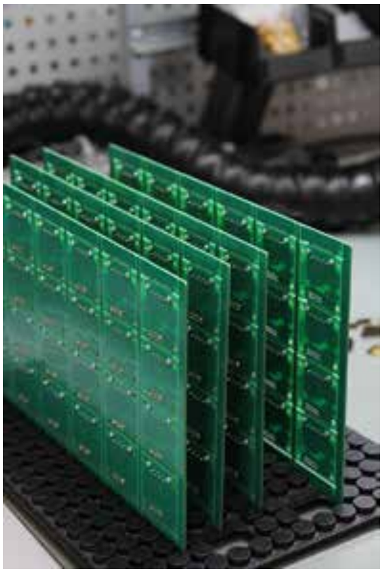
The timing was good. Obviously, the geopolitical storm and the China-Taiwan situation has [sparked] a lot of chatter about onshoring and some opportunities for North America to see an increase in demand, and that increase in demand is going to be cost-sensitive. For us to add capacity in some regions that allow us to be in a more competitive platform really made sense, and my equity partners were very supportive. We launched the attempt to acquire ACI about six months ago, and like you said, closed in February. We're very excited about it.

MB: As we as we go into this conversation about the integration plan, I think you've already now addressed clearly that you have all intents to keep the ACI facilities open.

SR: We have. There is no consolidation or any type of activity. In fact, we're allowing and letting all the ACI facilities to continue to operate as ACI facilities. We're making it very easy for our customers; no challenges whatsoever. The ACI facilities will remain and will become subsidiaries of APCT Holdings. The real focus is creating that additional value. The secret for our success has been providing solutions to our customers: [We] map the trends in the direction of the industry and invest early, not chase technology, invest early in leading technology, which we've accomplished. That's how we were able to grow APCT from my original acquisition in 2008 from $4 million to $130 million last year, and this year the combined companies together will do in the $240 million to $250 million range. A significant step-up in capacity and a significant step-up in revenue and obviously a significant step-up in product offering service. We basically have a solution for anybody now in North America in any aspect of technology. From the acquisition, there's no changes. All the management, the leadership, is remaining intact. The sites will remain intact. We plan to just take advantage of the new footprint and integrate them in the APCT way and launch some really exciting solutions for our customers and the industry in general.

MB: I remember your Data Circuit days; Data Circuit was the first shop in the US I knew of that could do a 24-hour turn. Advanced Circuits is in many ways a unique operation. As you alluded to, it has a specific way of gang-building boards. They have their own design software and tools. It has a truly enormous new customer rate. They told me a few years ago that they aim for something on the order of 2,000 new customers a month. I kept asking: "Are you sure about that? You mean a year?" And they said, "No, a month."

SR: It's very active. You're right, and that's that niche specialty nest – we call it the nesting software – and the automation they have really supports the online and the Aurora facility only. That is the only facility focused on that niche and it's very exciting for us. This was my third go-around reviewing an acquisition of this company. I started back in the early days when I was running Merix globally, after they acquired Data Circuit. We danced with them a little bit back then, so this is something that's always intrigued me. That aspect of the business in Aurora is very unique, very special and niche, a lot of it online and a lot of it very customer-interactive and it's a really cool model. We're excited to expand on that and take some of that intelligence and integrate it into some of our other facilities as it makes sense.



The deal to acquire Advanced Circuits adds much-needed capacity for two-to-10-layer boards.

MB: Would you anticipate that that operations model will be adopted into some of the other facilities or will that stay dedicated to Aurora?

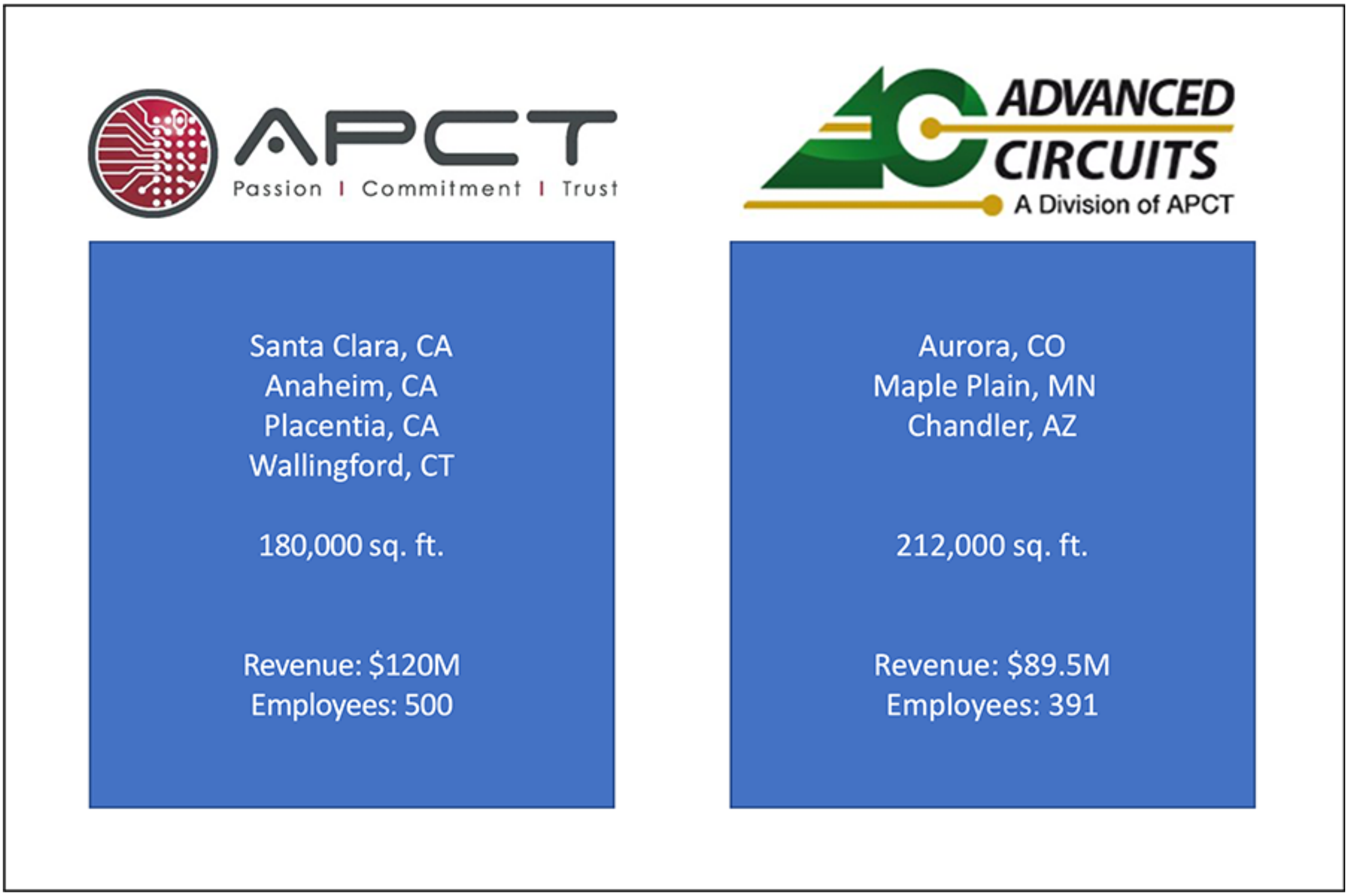
SR: It will stay dedicated to Aurora, but as we exceed the capacity that facility has – we will be open to launching it at a second site. We have seven facilities now in the US, and one currently supports that model only. But my CTO and my COO both are driving, looking at additional facility to launch rev 2 of that, which would be a backup and additional capacity as we see that demand grow. Everything we're hearing, from IPC reports, from industry reports, is a fairly significant growth potential for North America and demand. Should the geopolitical concerns ever come to reality – which we all hope they won't, but if they should – the chatter out there about North America, with continued EMS support and Mexico and those regions as well, we're well-positioned now to be a solution for our customers should that unfortunate event take place. That's really the strategy. Aurora will be our primary focus now on that, but we will evaluate and look, and as the demand exceeds capacity there, we will look at another site if it makes sense.

MB: You mentioned the need for more capacity, but were there any particular technology or innovations that ACI brings to the table that you don't currently have inside APCT that made it the deal attractive?

SR: Yes, absolutely. The Internet and the online model and the software specialty and the niche capabilities of the Aurora plant were very exciting for us and we wanted that. But also, the Chandler facility. Of our $120 million spend, we already have a very significant $50 million to $60 million defense and aerospace or government spend in APCT. That facility gives us a lot more capacity, to continue to grow and support that demand we're seeing. We're seeing a lot of activity and a lot of demand growth in that as well. The Maple Grove facility, which is a very specialty-focused facility, offers oversize, large form-factor panels, unique programs that are individual and specific for that site only. That's obviously a huge attraction for us as well as we'll open up into special oversized RF and rigid technology. In our space we have a ton of customers now, and it's really about merging the two sets of customers.

You're right: [ACI] wasn't exaggerating the numbers. My IT and software staff were staggered at the 8,000 active accounts we have our database. We thought APCT was rich with 1,100, but we just finished integrating that 8,000 active – not active every day – but 8,000 active accounts worldwide into our database, which is exciting for us.

APCT specializes in advanced HDI flex and rigid-flex. Those customers never had that offering through ACI. There's a handoff both ways. We're adding the advanced technology, flex, and rigid-flex capabilities into the ACI customer base. For our APCT customer base, we're excited about the specialty capabilities and oversize and special RF capabilities we now offer out of our Maple Grove facility, and the quickturn, low-tech, competitive solution that we now can offer from our Aurora operations.



MB: Are the ACI software tools flexible enough and scalable so that they could be adapted to the higher tech that APCT offers?

SR: Potentially. It's early, Mike, as you know, we're two weeks into really getting under the covers now finally and really see that, and my IT team is working now with the developers and the scriptwriters. Ultimately, yes, we would look to take some of that automation up the technology curve. That's really where we see the advantage and the interaction with our customers. The more automation we can develop and software that we can introduce to make it more efficient up the curve, yes, but right now it's really focused on the two-to-eight-layer technology range, a very limited menu, and that's how it works. We'll look to expand that as it makes sense in the future.

Short term, to be honest with the acquisition right now, in 2023, no changes. I'm not a believer in coming in and making changes. We're going to spend 2023 getting familiar, getting to know everybody, getting the ACI people to understand the APCT ways and APCT to understand the ACI ways, and then 2024 will be the year where we'll start to look at making some adjustments or tweaks to the models as it makes sense, and that will come from the industry direction and customer feedback. What are they looking for? What they need? I've always based my business decisions on value to customers, whether they want, what do they need? What are they lacking? What's what we'll focus on: understanding the industry, understanding the technology, understanding the demand and trying to provide a solution that differentiates us.

MB: This type of investment, this size, this implies a certain confidence in the future of the North American market, wouldn't you agree?

SR: Yeah, I do. You know, I'm a PCB rat. My junior year in high school, 1971, was my first year working as the graveyard electroless operator. That's when I fell in love with this industry. My mentor and my early [coworkers] who trained me taught me a great respect for this industry. I've always been a big advocate of the PCB industry and focused on understanding the direction and trying to be out in front and not chasing it. So yes, I think, in all our analysis, we believe there is opportunity and that the North America industry has a chance for some decent growth, and I think we're going to be in the leading position to take advantage of that. Our speed and technology and capacity really allows us to offer a nice solution to just about any aspect of need and demand from our customers and that's important, not only my dedication to our country, our dedication to this industry, but most important, our dedication to our customers. They've been loyal and stuck with me since I started this business in 2008 and this acquisition was really focused to provide more value to them, and to provide a better menu of solutions that we were hearing they wanted and needed. That's what we've done, and my investment partners have been very supportive and are very excited about this. They stepped up and we got the deal done.

MB: Do you feel there are a different set of responsibilities that come with your [larger] market position?

SR: Yes, I think there is. We take it very seriously, with that position, to go out and try to attract and hire some young talent and bring some new blood into our industry. I don't know if there's many of "me" left who have five decades committed to this industry. We continue to look at programs, and attracting and hiring young talent; hopefully someday we'll get some support in doing that. But absolutely, I think it's important to represent our industry and provide value to our customers, to listen and understand that, and then to mentor as many as we can and that that's what APCT has always based our core competence on trying to do that, and now we have the ability to do that to a little larger scale.

We're no. 2 in size and PCB product, but we're by far no. 1 in value and offerings and capabilities. We stay committed to quickturn. We stay committed to nimble. We will continue to support customers – they don't have to be big. All customers are important and that's our commitment to this industry.

And secondly, we have a huge commitment to our government and our country. Our country and our government need to be educated on how to build printed circuit boards and how to support new and emerging technologies the right way. Our engineering and design support all the way through fab is commit, but we will continue to fortify and invest in as necessary and continue to hopefully drive success, a competitive landscape, and drive North America PCB success and growth. That's the model. That's the role you play as an industry leader. And while we're not as big as no. 1 [TTM], they're huge; we are absolutely the industry leader in speed, technology, engineering, customer value, customer satisfaction, and customer support. We base our long-term relationships on customer trust, and we expect to earn that and do whatever it takes to sustain that. That's how we differentiate ourselves.

Let's do everything we can to fortify the North America PCB industry. Let's do some things to make it more attractive to attract young, smart talent and get some youth and younger generations interested to work again. Hopefully, we'll start to see a workforce that's willing to work again. That's been a challenge through the pandemic and through all the challenges we've had in our country for the last few years. Hopefully we'll see that eager workforce ready to go out and touch things and build things again. That's we're excited about. But I'm really excited about this. I think our customers are going to be very happy with the value and the solutions we now can provide beyond the many that we provided before. And I'm looking forward to a very exciting 2023 and beyond.

MIKE BUETOW is president of PCEA (pcea.net); mike@pcea.net. To listen to the podcast, visit https://upmg.podbean.com/e/pcb-chat-110-steve-robinson-of-apct/.

INSPECTION

An AI Method for Early Detection of Failures Caused by Corrosion on Components During Assembly – Correlated to Field-Failure Analysis Cases

Does lead roughness correlate to corrosion content?

by EYAL WEISS, NAVEH BARTANAH, ALON SHACHAR and MICHAEL DOLKIN

The electronics industry perceives corrosion on soldering leads as a potential risk to the solderability of the components.[1] Several traditional methods assess the solderability of an electronic component.[2] In the defense industry, samples from a component batch that is suspected of poor solderability must be inspected according to MIL-STD-202, Method 208,[3] and SAE 26262 used in the automotive industry. Typically, samples of the tested components are selected and tested under specified conditions to gauge solder wettability on the component leads and the bond strength. The current procedure is practiced on a very small sample of components within a batch under the assumption that few samples represent the entire batch. This is not the case, however.[4] Yet, the effect of corrosion on soldering leads on product quality is rarely considered, despite numerous evidence and research on the impact of corrosion on the bond strength and its reliability.[5-8]

This work presents a method to detect defective soldering leads on components during assembly.[9-11] It demonstrates how components with corrosion and contamination in the soldering leads can be detected early during production and avoided. Failures caused by corrosion on components during assembly are presented and correlated to field-failure analysis cases as proof of the method's effectiveness.

Inspection was performed based on data processed by novel electronic component authentication and qualification software.[12] The software interfaces with pick-and-place (PNP) machines during production and collects component images.[13] The images are then processed using a deep network algorithm that is looking for visual defects in the components and flags every suspected component.[10,14] In addition, another network is used to evaluate the texture of the soldering leads and estimate their solderability.[11]

The method is put to use on real-life assembled components. Examples of electronic components VSON-12 gate drivers NexFET in 12-VSON-CLIP package **(FIGURE 1)**, and QFN-12 power switch **(FIGURE 2)** are presented, with corrosion that was detected by the presented method in conjunction with the failure analysis of the components performed employing x-ray analysis, SEM and EDS microscopy, and visible light microscopy. The analysis clearly shows a correlation between the AI detected corrosion and the failure analysis reported corrosion and failure mode. The AI- method is then calibrated to detect corrosion that may result in failures.

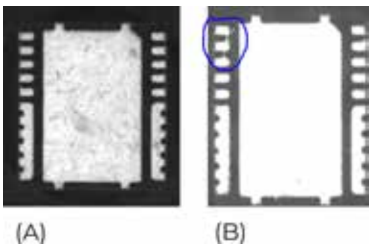


Figure 1. VSON-12 Gate Drivers NexFET images captured by an ASM Siplace SX placement machine and detected by Cybord.ai system with quality issues: a) corrosion, b) shorts.

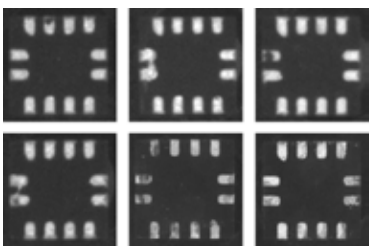


Figure 2. QFN-12 Power switch images captured by an ASM Siplace SX placement machine and detected by Cybord.ai with quality issues: Terminal contamination, corrosion, shorts.

Effects of Corrosion on Quality

Corrosion is the most predominant failure mode in electronic products. Numerous published works on electronics reliability show ionic contamination on the PCBA surface can cause serious corrosion reliability issues.[5-8] Some cases of failures in electronic systems are due to corrosion powered by the formation of a water layer on the surface of the PCBA where a high level of humidity and temperature variations took place.[15,16] These failure modes start with untainted soldering procedures that are later arranged in conditions that favor corrosion development. Corrosion already present in solder leads before the soldering process has a far more devastating effect because they become a breeding seed of the corrosion epidemic.

Contaminations on the surface of the PCBA and residues left from the manufacturing process, as well as corrosion previously present on the solder leads before the assembly, affect the reliability of the device. Electrochemical migration (ECM) also affects the functionality of devices.[5,17] A major contributing factor to this is the flux agents used in the soldering process, and the residue contains ionic activators that are hygroscopic. Hygroscopic residues on the PCBA decrease the relative humidity and results in moisture adsorption at lower relative humidity levels.[18,19] These residues absorb moisture from the atmosphere until its deliquescence and dissolve in the condensed water film, and produce an electrolyte solution with a higher conductivity level.[20] Consequently, the electrolyte layer sandwiched between the conductors may have a reduced surface insulation resistance, elevated leak current, and finally corrosion contamination like ECM.[21,22]

These reported issues rarely affect solderability. This is because during reflow only a little amount of corrosion is in place and therefore the effect on bond strength during production is small. The described phenomena affect product reliability during its life cycle, however, and sometimes also during the post-assembly inspection as the corrosion propagates.

Corrosion Detection During Pick-and-Place

The algorithm interfaces with the pick-and-place machines during production and collects images of all the components.[12] Images are then processed using a deep network algorithm that authenticates the components, looks for visual defects in the components, and flags every suspected component.[10,14] In addition, another network is used to evaluate the texture of the solder leads and estimate the presence of corrosion and lead solderability.[11]

Detecting corrosion evidence in components is an image classification problem, in which images are classified as either normal or defective (in some cases, defective ones may be further classified into finer levels such as minor, moderate or major).[23]

The new network architecture is tuned to handle corrosion contamination[4] instead of the serial architecture used in popular image classification models, in which multiple layers of small filters, often 3×3 in size, are serially connected to each other, a set of filters with different window sizes which are concatenated in parallel is used. Each filter tries to detect a type of defective region in the components' images and generates a feature that indicates the possibility that the component images contain such kinds of defects. The overall feature is the concatenation of all features produced by the set of filters. This feature is then fed to a dense layer which produces the final defects score.[4] By using this parallel architecture, the defects detection engine is efficient (can process to 3,000 images per second on a Tesla T4 GPU), while requiring fewer samples of images to train (a few hundred samples are enough). This architecture is also inspired by the template-matching method in traditional computer vision, which is used for object detection when there is not much data. In this architecture, the defected templates represented by the filters are learned from the training images, rather than manually chosen as in the traditional template matching method. The size of the filters should be approximately the same as the size of the defected spots in the components, since there are a variety of defects with different sizes, there are different filter types with corresponding sizes. For large defect spots, filter sizes can be large, and the processing will be slow; therefore, the filters are downscaled. The method was trained based on a dataset of more than 1 billion inspected components.

Experimental

To demonstrate the method on real-life data, two cases of failure analysis for two different electronic components are presented. Case 1, the VSON-12 gate drivers NexFET (Figure 1 and **FIGURE 3A**), is rated at moisture sensitivity level (MSL) 2, and hence is sensitive to moisture and must be kept according to standards in vacuum during storage and handling. Case 2, the QFN-12 power switch (Figure 2 and Figure 3b), is MSL 1.

Figure 3a. VSON-12 image taken from the top side by a Cybord KingFisher authentication system (an image of similar components from a different production batch).

Figure 3b. QFN-12 image taken from the top side by a Cybord KingFisher authentication system (an image of similar components from a different production batch).

Failure analysis timeline. The method is deployed at a full-scale, high-volume SMT production line at Flex in Migdal HaEmek, Israel. The novel authentication system inspects all components assembled on all PCBs in real-time using the vision system on an ASM Siplace-SX placement machine. Although the novel platform is giving alerts in real-time, during the test period, the system only reported on deviations after assembly, and no actions were taken in real-time. Retrospective analysis was performed only after analyzing the post-assembly test results. The post-assembly test conducted is in-circuit test (ICT), a basic electrical test performed on the PCB. The test consists of resistance, capacitance and basic electrical signals in order to find shorts, disconnections or other faults. This test provides the first level of quality assurance and gives preliminary insight into whether there is a problem. In this case, a high failure rate was reported on two different part numbers, in two separate production lines. The involved reels were isolated and a retrospective analysis was performed.

The involved reels were also inspected before they were used by the production line to ensure the components are authentic by a reel-to-reel Cybord.ai KingFisher authentication system. The pre-production tests reported the reel is authentic.

The reels were then used during production. Images of the components are obtained by harvesting them from the pick-and-place machines.[14] The placement machine picks the components and then takes their picture using a monochrome camera with a resolution of 17µm. All components' images are extracted and processed by a Cybord.ai Aquila defects and corrosion detection algorithm. This test found a large ratio of the components originating from these reels to be contaminated with corrosion. In production, the alerts are used during production and detected faulty reels and components are blocked.

Results

Case 1. The VSON-12 package case is sensitive to moisture (MSL-2) and the failure is related to this sensitivity in a few different ways. The presence of corrosion on the soldering leads is an indication that the components were exposed to humidity during storage and handling. Exposure to humidity results in corrosion growth on the exposed metallic parts on the component surface. In addition, corrosion on the soldering leads is a failure mode by itself as it propagated over time into the package case. Third, the corrosion also affected the wettability of the soldering leads, resulting in a partial bond. **FIGURE 4** presents an image of the component taken by the SMT mounting camera during placement (A), with evidence of corrosion visible, and an image of a failed component after removal from the board (B). In Figure 4B the top side of the image shows residues of the wetted area while the bottom side of the component appears to not contain paste, only a rough surface finish consistent with corrosion.

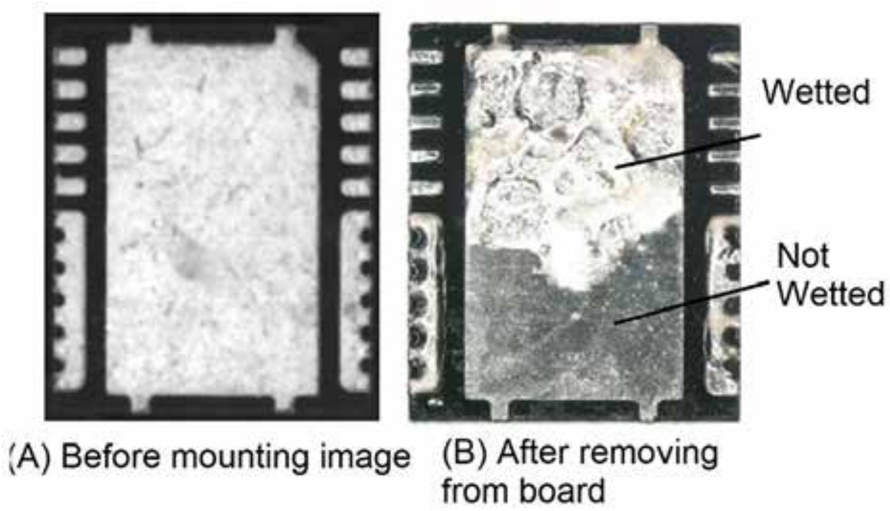


Figure 4. VSON-12 images of a component taken by the SMT mounting camera during placement with evidence of corrosion visible (A), and a failed component after removal from the board (B). In B, solder paste residue is visible on the top side, whereas the bottom side shows no evidence of wetting.

To verify the condition of the inner parts of the component, scanning acoustic tomography (SAT) was performed. SAT is a method for analyzing materials by measuring the reflecting speed and energy of an ultrasonic wave which is transmitted through a material of a certain thickness. A C-scan inspection with horizontally cross-sectioned 2-D image after focus, and a thorough T-scan **(FIGURE 5)**. The delamination is presented in red.

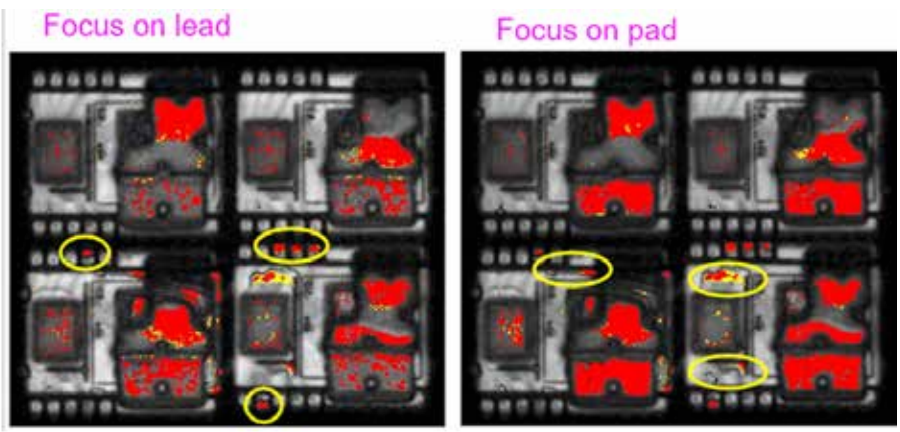


Figure 5. VSON-12 scanning acoustic tomography image. Red indicates delamination. Internal delamination appears on the inner part of the soldering leads.

It is apparent from Figure 5 that there is degradation in the internal part of the component that attacked the chip's internal metallization. Surface corrosion on the leads (Figure 4) appears to have attacked the inside part as well. From Figure 4, it is apparent that the metallic pad lacked good wettability (only the top side here was wetted well), therefore the other side did not have good heat removal capability from the component to the board via the thermal pad. The failure's root cause is corrosion affecting wettability as well as propagating into the package case and causing internal delamination.

As can be seen, the corrosion evidence was visible earlier in the image taken by the ASM vision system during the mounting (Figure 4A, and Figure 1). The AI detection algorithm described in Weiss[4] detected corrosion evidence by analyzing the light reflectance from the soldering leads. The rough surface texture created by the corrosion on the leads was detected by the Aquila algorithm and cross-referenced with the failed units in the post-assembly tests where the failed units were also predicted as contaminated by the algorithm.

Case 2. The QFN-12 package case is MSL-1 and is not sensitive to humidity. Nevertheless, the component was six years old at the time of the assembly and contaminated with severe corrosion and mold that affected the performance of the board. The components were inspected during the SMT process, flagged as contaminated with corrosion by the Aquila algorithm, and then failed in the post-assembly tests. The failure mode was shorts, solderability and opens. Some 6-11% of the components suffered electrical failures.

The batch was then analyzed for the root cause by performing x-ray analysis, SEM-SED, cross-sectioning, and microscopy. The failure mode is evident from the cross-section of the component bond to the PCB **(FIGURE 6)**, where a crack appears in the bond, resulting in an open or an unreliable bond.

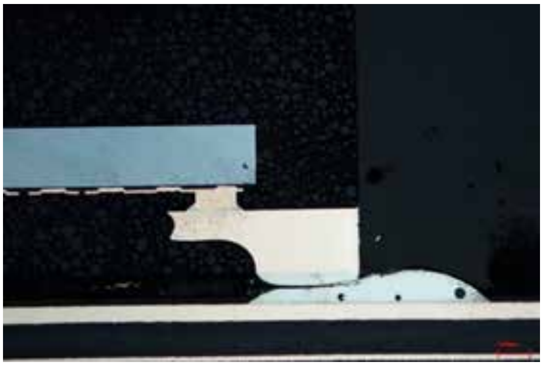


Figure 6. QFN-12 solder bond with the PCB cross-section. A crack is visible between the lead and the paste.

X-ray example analysis of the component did not reveal mounting issues, except for a short. The short is also visible on the bottom-side image of the component taken before mounting. Shorts are easily detected automatically by the AI algorithm as there is a strong contrast between the light soldering leads and the dark component body. The x-ray shows a metallic short between the pads after assembly. It is impossible to say if the short was already in place before mounting, or created during placement. By examining the bottom-view image of the component before it was mounted on the PCB, it becomes apparent that the short was there even before the assembly **(FIGURE 7,** left).

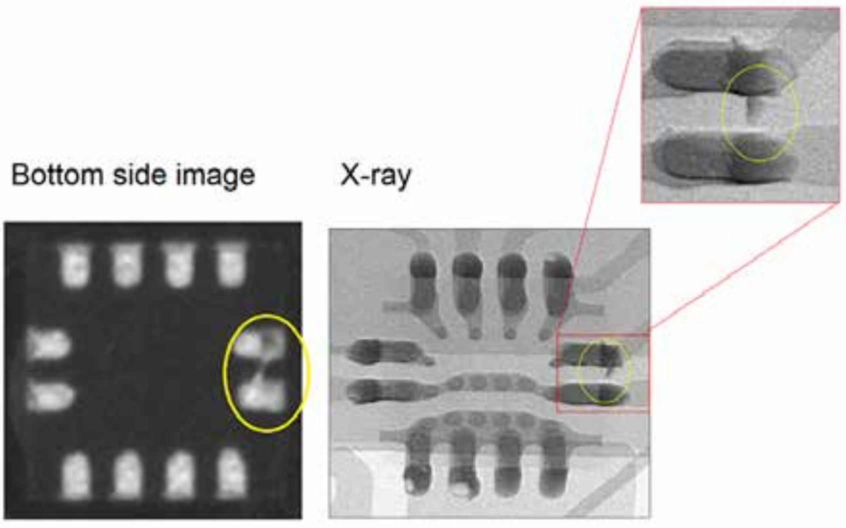


Figure 7. QFN-12 short is visible on the bottom view image taken by the pick-and-place machine during mounting (left), later to be also detected by the X-ray post-failure analysis (right).

In addition to the x-ray, more analysis was performed as the x-ray could not explain the massive failure rate. The failed boards were analyzed by SED-SEM microscopy. The analysis revealed contamination on the soldering leads, visible in **FIGURE 8** where QFN-12 SED SEM analysis example shows a soldering pad with a black spot taken by the SMT pick-and-place machine during mounting (left), compared to a microscopy image taken by the SEM-SED (right). The black marks are visible on both the pre-assembly Cybord.ai detection (Figure 8, left) and the SEM-SED post-failure analysis (Figure 8, right).

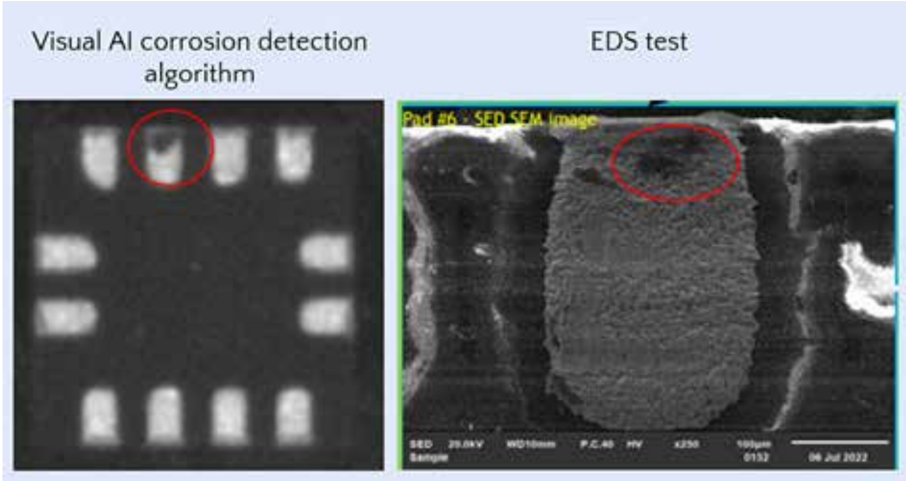


Figure 8. QFN-12 SED SEM analysis of a soldering pad with a black spot as imaged by the pick-and-place machine during mounting (left), compared to a microscopy image taken by the SEM-SED (right).

SED analysis reveals the contamination contains oxygen, silicon and carbon, whereas clean lead does not contain any of these materials. Mold contains silicon (Si), carbon (C) and oxygen (O), and oxidation (corrosion) contains oxygen. From the microscopy images, it is apparent the black marks are from mold and corrosion. Both are created by exposure to humidity under environmental stress, and both degrade the bond reliability and solderability **(FIGURE 9)**.

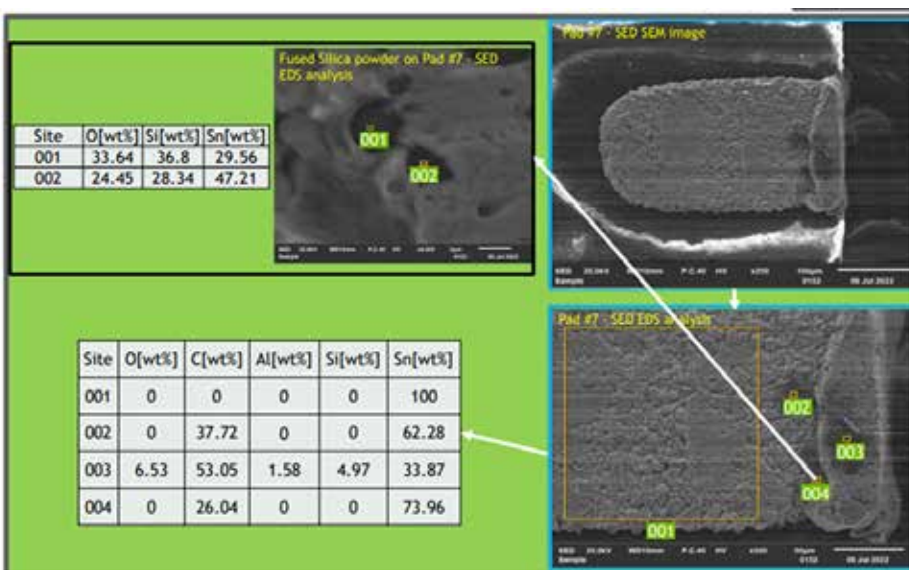


Figure 9. QFN-12 SED SEM analysis example of a soldering pad with the black spot analyzed. The black spots contain silicon (Si), carbon (C), and oxygen (O), which indicate the presence of mold and oxidation (corrosion). Both are the result of exposure to humidity and environmental stress.

Further microscope inspection of components that did not go through production is presented in **FIGURE 10**. It shows the QFN-12 SED microscope images. A and B show the rough surface finish caused by corrosion, and evidence of mold and corrosion is seen at the lead edges. C is a zoom on mold at the edges of the soldering leads. As depicted, the surface finish, corrosion marks and mold are also visible during assembly by the SMT pick-and-place vision system.

Figure 10a. QFN-12 SED microscope image showing rough surface finish caused by corrosion and evidence of mold and corrosion at the edges of the leads.

Figure 10b. QFN-12 SED microscope image showing rough surface finish caused by corrosion and evidence of mold and corrosion at the edges of the leads.

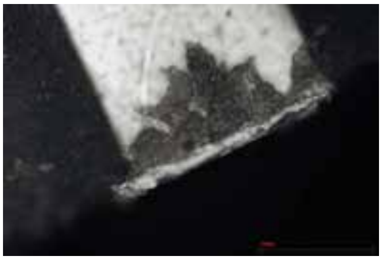


Figure 10c. Zoom on mold at the edges of the soldering leads.

Discussion

As seen in the results section, the surface finish quality of soldering leads can be evaluated based on their image. Soldering leads and balls are made of inherently chemically unstable materials that age faster than all other parts of the electronic component. The surface of the leads grows an oxidation layer. In addition, intermetallic reactions in the leads are progressing with time.[24] Both degrade solderability in time. The degraded oxidation layer and the metallic morphology have a different appearance and reflectivity than that of the surface of a fresh lead.

The change in color and roughness changes the way light is reflected from the surface of the lead. The change in reflectance is like the difference in reflectance between clear and tainted mirrors. The reason for the change in apparent texture is the morphology alterations occurring with aging. This was simulated and presented by Wang, *et al.*[25] with the gradual change in surface morphology during thermal cycling, which simulates aging of the leads. The surface is initially smooth, then during aging it becomes curvy by the shifting of the metallic alloys and the growing of a brittle corrosion layer. It eventually produces breaks in the surface finish.

We classify the corrosion level of the leads by learning how the soldering leads of a component reflect light versus that of a lead with corrosion. In addition, the component's apparent age can be approximated based on the gradual degradation of the lead's reflectance.

This information is available by examining the surface of the soldering leads. We have found that visual analysis of the component image using artificial intelligence methods can detect the degradation of the soldering leads, which causes corrosion. To train a model that correlates the image of the leads and its solderability, we have designed a neural network based on multiple images of leads. The corrosion level is estimated by deep learning methods performed on the images of the soldering leads of the components. It is imperative to note that the manufactured year does not directly reflect the real quality of the lead. This is due to differences in storage and handling conditions that may cause accelerated aging of the soldering leads, thus, degrading the "age" of the leads. In addition, there is a distribution of the conditions of the leads in both leads with good and poor leads conditions.

The neural network is designed to fit a linear regression model so that the distance from the input dataset to the line is minimized. The next step is to use the regression model to infer the age of components from the validation set.

We compare the predictions of the described algorithm with the failure analysis results in the production line to simulate real-life full-scale production. The detected failures in the components match the failure analysis results indicating that the method can be used to prevent failures caused by deteriorated soldering leads to corrosion contamination.

In addition, the presented cases demonstrated failure within the production site and during the post-assembly testing. Most corrosion-related failures will ensue after more extensive exposure to environmental stresses the product will encounter in the field. It is therefore imperative to determine a threshold that will prevent not only failure in the production site, but also in the field. The presented method detection threshold can be calibrated to detect solderability issues that will fail in the production site and corrosion contamination that will fail in the field.

Conclusion

A nondestructive mass volume method for assessing the condition of the soldering leads of electronic components on deep visual inspection is presented. The method permits real-time assessment of all assembled components. It may be deployed during the SMT mounting process. Corrosion contamination level is correlated to surface reflectance and degradation in reliability caused by corrosion and intermetallic reactions on the surface of the leads. This may be illustrated as the reflection of a smooth mirror compared to an age-dulled mirror.

The inspected components' corrosion level is obtained by a multi-tier classification network that is looking into microfeatures in the component's images. The network classifies leads to good and poor corrosion levels based on their apparent age and contamination detection. The method was trained based on a dataset of more than 1 billion inspected components.

The method was deployed in full-scale production state-of-the-art production facility at Flex in Migdal HaEmek for evaluation. Two cases of failures during the post-assembly tests were cross-checked with the Cybord.ai inference results. The method was able to predict the failures and the failure modes on over 30,000 components with accuracy exceeding 99.5% tested on over 2.5 billion components.

The failure analysis revealed evidence of corrosion that penetrated the inner package of the component in one case, and corrosion and mold deteriorating the wettability and thus solderability in another case. The presented method predictions were in-line with the analysis report.

The described method eliminates placement of components with solderability and corrosion issues and verifies that only qualified components are used in production. As such, field failures, recalls and rework are avoided.

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Real-time X-ray Video Imaging of Pb-Free Solders Under Simulated SMT Reflow*

Imaging of hidden solder pastes under MLF-100s revealed joint and voiding formation mechanisms differed from each of the solder pastes evaluated.

by NORMAN J. ARMENDARIZ, PH.D.

SnPb (tin/lead) is considered the most reliable solder alloy for aerospace/defense (IPC Class 3) applications because of its ability to withstand shock and vibration and mitigate Sn whiskering. SnPb components, however, are becoming obsolete from increasing restrictions of Pb in commercial applications. Presently waived for AD, these solders are increasingly expensive, with increasing supply constraints and reliability limitations. Moreover, current SAC 305 alloys also fall short of commercial performance objectives, especially in automotive (electric vehicle) end-use environments. As a result, the Raytheon Lead to Lead-Free (L-LF) team evaluated two current baselines and seven next-generation LF solder paste alloys based on three major "pathfinder" studies on representative SMT assembled test samples, to identify the best LF alloys for the next phase for production prototypes. An L-LF working subgroup was formed to outline a path forward to better anticipate and prepare the transition to a "pure" LF metallurgical system for circuit card assemblies (CCA). Raytheon has been successfully mixing SnPb paste and LF SAC 305 parts with ~225°C processing temperatures without having to reball from SnPb to Pb-free; this is ~15% of product today. The strategy is to transition from SnPb to next-generation Pb-free solder paste alloys to mix-assemble with SAC 305 or Sn surfaces between 200° and 240°C or melting ranges between 183° and 220°C for minimum transition disruption, but not too low; e.g., low-temp (~150°C) solders (LTS) that risk reflowing material with lower temperature processing used in subsequent next higher assemblies (NHA) **(FIGURE 1)**.

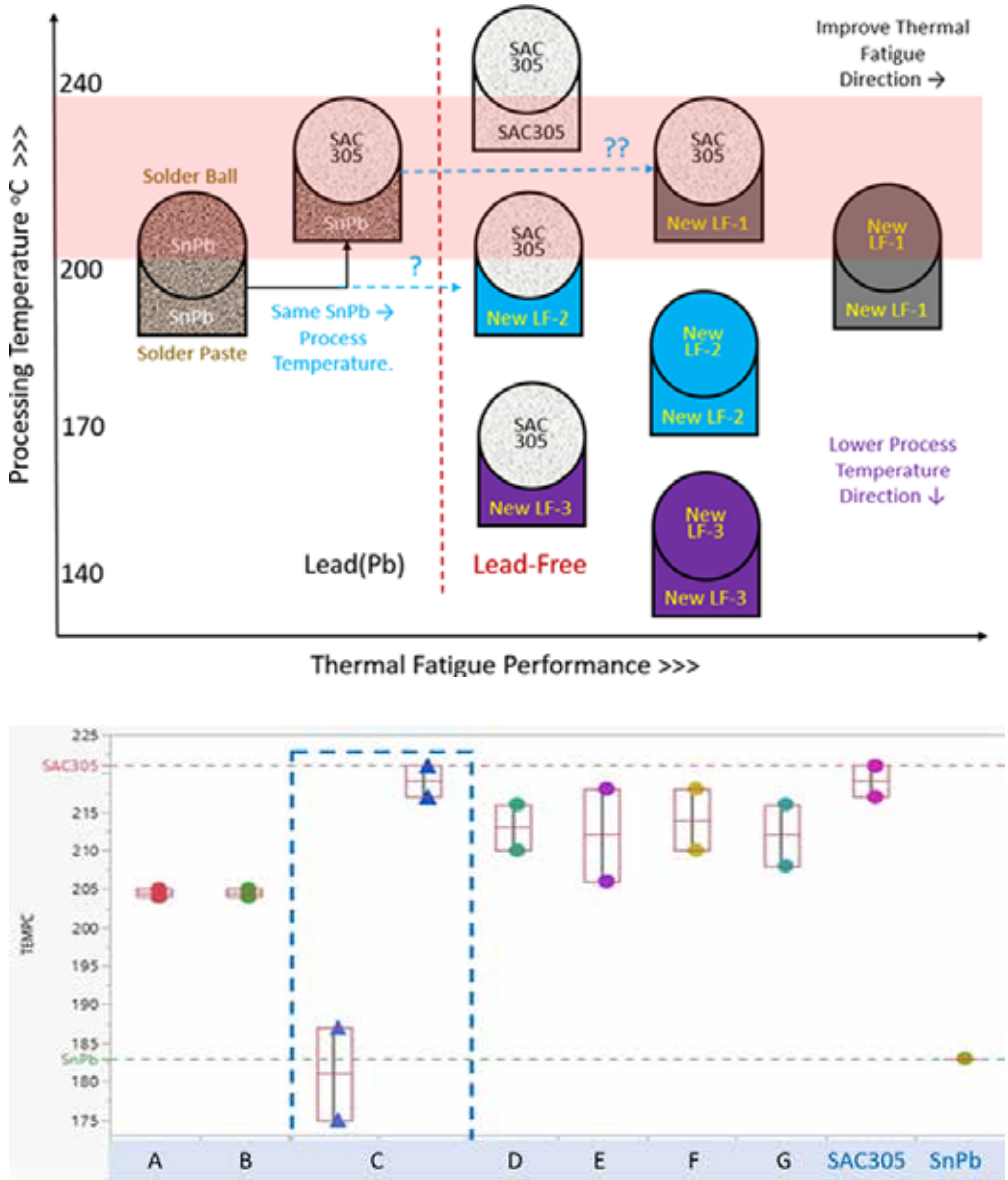


Figure 1. Lead to lead-free transition approach from SnPb to SnPb + SAC 305 to next-generation LF solder pastes + SAC 305 (top). NG LF solder pastes evaluated lower melting ranges compared to baseline SAC 305 and SnPb solder pastes, followed by LF A and B solder pastes (bottom).

Real-time X-ray Thermal Analysis

The heated or "hot-stage" stage installed on the current radiographic transmissive x-ray machine was used for real-time radiographic analysis as part of the evaluation of the next generation Pb-free solder pastes. The hot-stage permits emulation of thermal environments such as SMT reflow profiles to capture real-time x-ray video images as a function of time and temperature of materials and devices. Test PCB/samples were printed with baseline and candidate LF solder pastes to then transfer to the x-ray machine hot-stage for thermal x-ray analysis. The test PCB/samples are suspended centrally on guides between the top and bottom heating elements, which are both programmed for specific temperature ramp rates, dwell times and reflow processing times **(FIGURE 2)**. The temperature of the sample is recorded from a thermocouple attached to or near the area of interest.

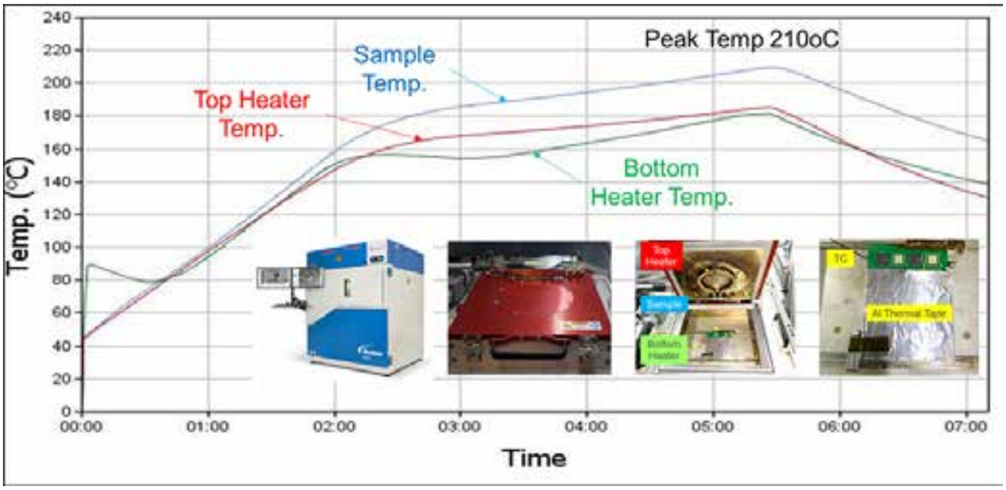
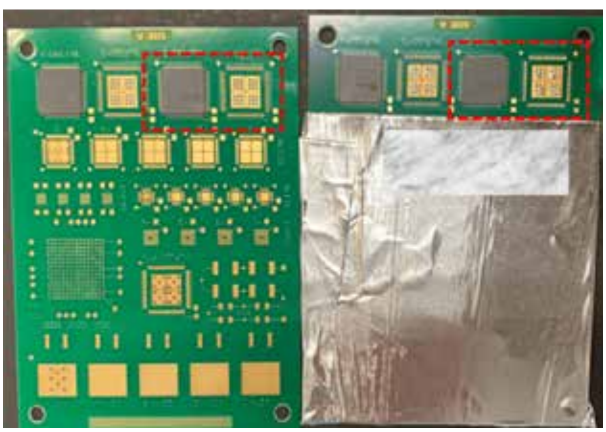


Figure 2. Simulated thermal profile in x-ray hot-stage, showing top, bottom and sample profiles.

Test Sample Fabrication

Samples were fabricated on 108 x 78 x 1mm PCBs for the solder paste under the device as well as the solder paste by itself to then be x-ray-viewed simultaneously or next to each other in real time during simulated SMT reflow. Each paste type was printed with 9 x 9 solder paste deposit pattern dots on each of the pad quadrants per MLF-100 thermal pad. Two pads had dummy 10 x 10mm MLF100 components placed, and two pads were left alone, with only the solder paste printed **(FIGURE 3)**.



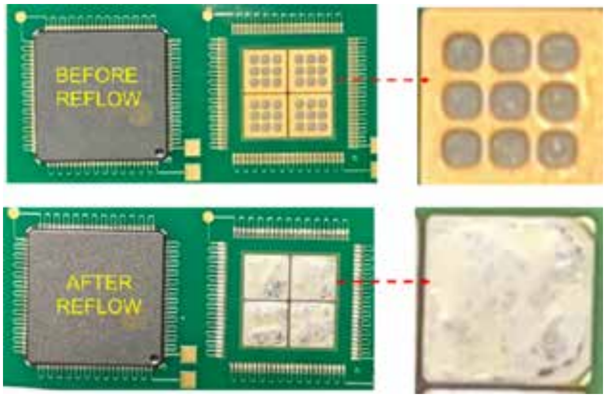


Figure 3. Optical microscopy images of MLF-100s next to SnPb solder paste printed-only pads before and after reflow in x-ray on hot-stage (top). Only one device and one solder paste-only combination were analyzed at same time under real-time video (dashed red lines) (bottom). Other areas near heating elements were protected by aluminum tape to prevent excessive heating or burning. Note the excellent wetting and coverage of SnPb paste.

X-ray Analysis Thermal Profiles

FIGURE 4 shows SnPb solder paste snapshot x-ray images at different times during simulated SMT reflow on MLF-100 devices. The sample is hotter because the top and bottom heaters both contribute heat to the sample in between.

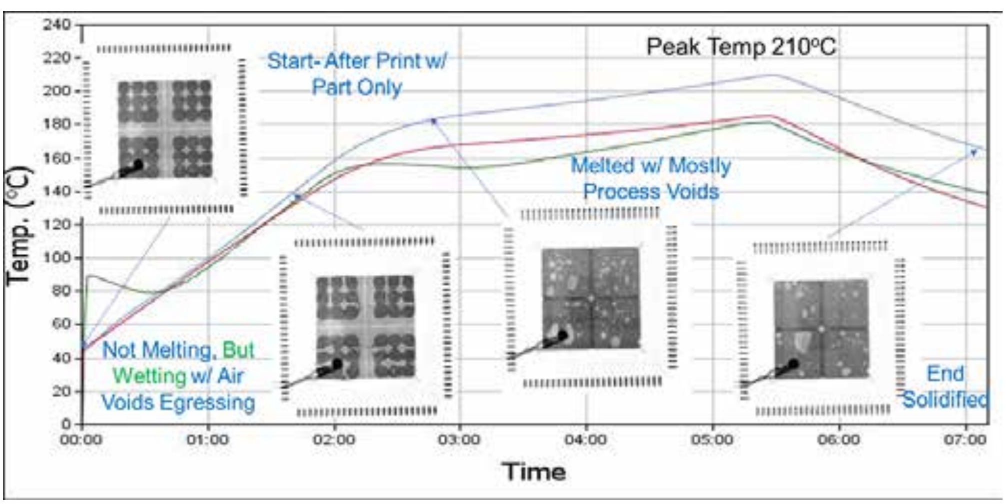


Figure 4. SnPb solder paste x-ray images at different times during simulated SMT reflow on MLF-100 devices.

FIGURE 5A shows the LF-B solder paste snapshot x-ray images at different times during simulated SMT reflow on MLF-100 devices.

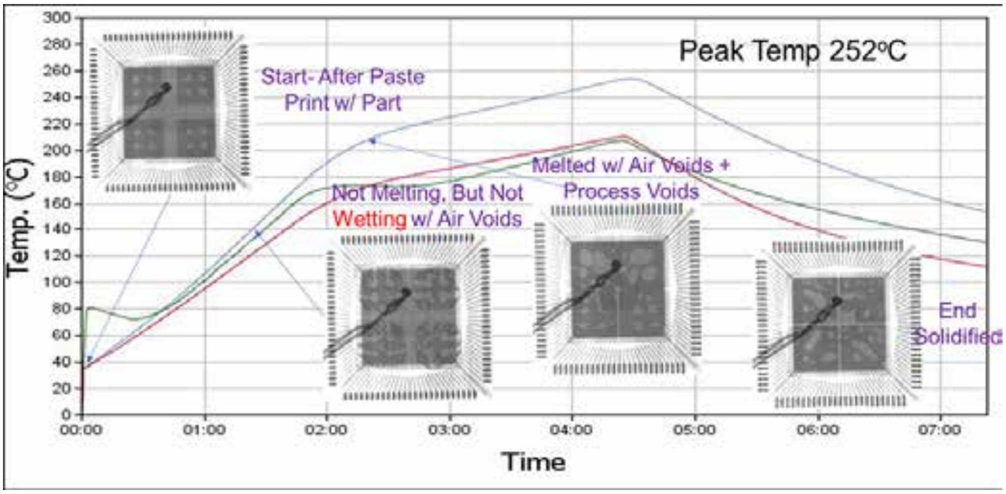


Figure 5a. LF-B solder paste x-ray images at different times during simulated SMT reflow on MLF-100 devices.

FIGURE 5B shows the LF-C solder paste closeup snapshot x-ray images at different times during simulated SMT reflow on one of four thermal pad quadrants of a MLF-100 device using two separate solder paste compositions.

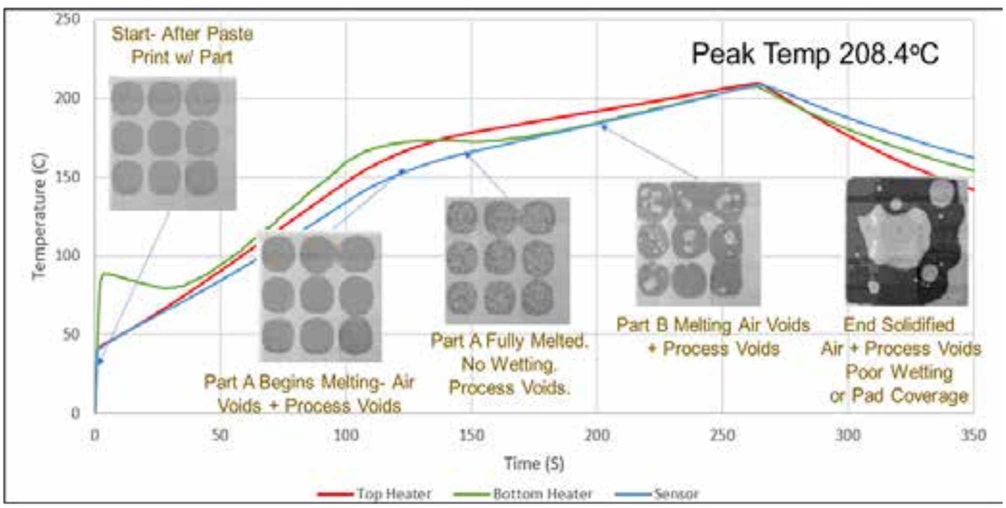
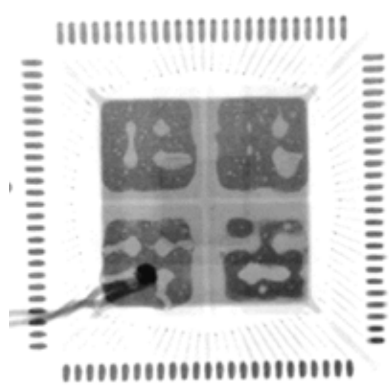


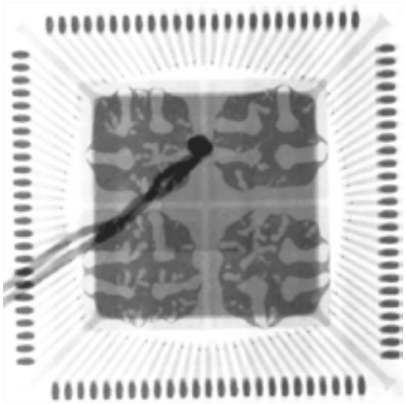
Figure 5b. LF-C solder paste x-ray images at different times during simulated SMT reflow on one of four thermal pad quadrants of a MLF-100 device using two separate solder paste compositions.

Solder paste wetting vs. void percentage results. **FIGURE 6** shows solder paste-only printed on MLF-100 thermal pads without the device attached (x-ray top and optical microscopy center). Solder pastes that wetted better resulted in less void percentage under MLF-100 device thermal pad regions, as shown in x-ray images after SMT reflow on hot-stage (bottom).

Figure 6. Solder paste-only printed on MLF-100 thermal pads without devices attached (x-ray top) and (optical microscopy center). X-ray images at bottom show solder pastes that wetted better resulted in less void percentage.

Void formation mechanism. SnPb, LF-B and LF-C solder pastes showed different amounts of air voids and process voids forming just before reflow or melting **(FIGURE 7)**. The solder pastes with better wetting before melting were shown to more readily flow and move and permit the air voids to more easily escape or egress through solder paste. By comparison, solder pastes that exhibited poor wetting did not readily move and prevent air voids from escaping **(FIGURE 8)**.





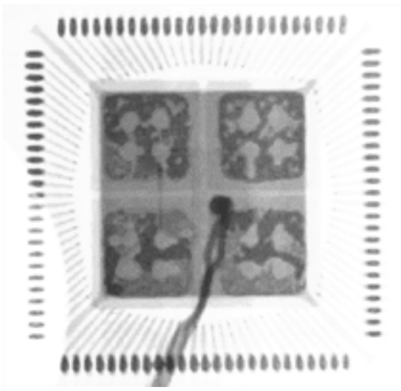


Figure 7. SnPb, LF-B and LF C solder pastes showing different amounts of air voids and process voids forming just before reflow or melting.

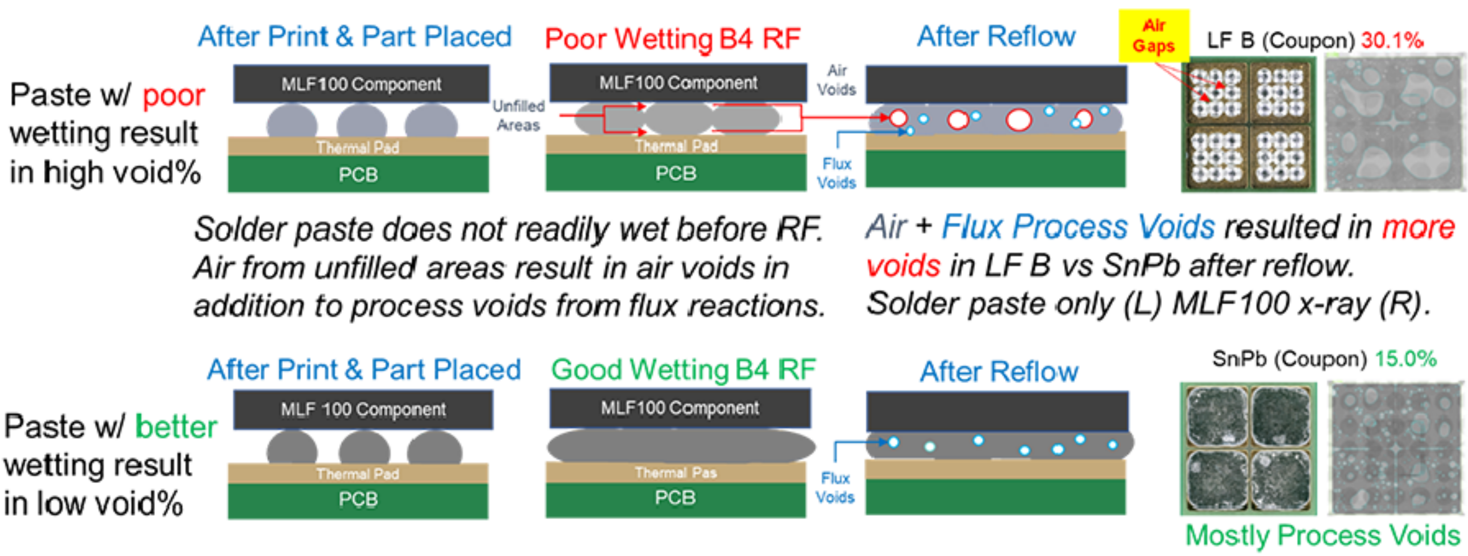


Figure 8. Solder pastes with better wetting before melting more readily flowed and moved and permitted air voids to more easily escape or egress through solder paste than did pastes that exhibited poor wetting.

Solder paste void percentage vs. shock performance: All solder pastes. All three radiographic studies after actual SMT reflow; circuit card assembly (CCA), coupon and after SMT reflow on x-ray hot-stage for each solder paste are shown in **FIGURE 9** (top). LF solder pastes A, B and C with >25 void% are compared to LF solder pastes E, F, G and SAC 305 with <25 void%. (A 25% void density is considered a maximum "guideline" by commercial industry.) A strong statistical correlation was observed between void percentage and shock performance, as shown in the plot at the bottom.

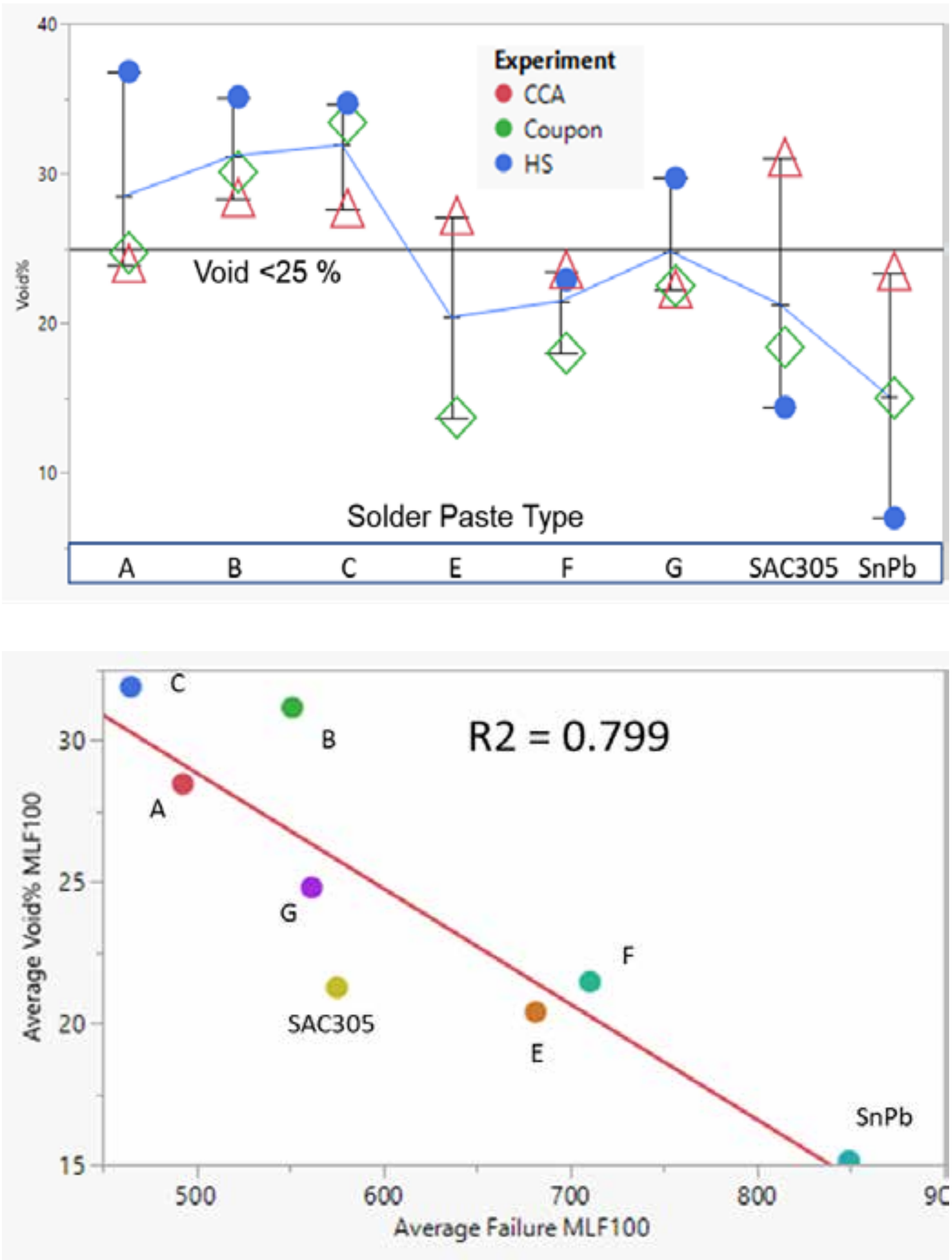


Figure 9. Radiographic studies after actual SMT reflow; CCA, coupon and post-SMT reflow on x-ray hot-stage for each solder paste are combined (top). Note the statistical correlation between void percentage and shock performance (bottom).

Summary

The hot-stage was successfully used to visually analyze the thermal effects on solder paste on CCAs using radiographic imaging in real time during SMT thermal reflow. For the L-Lead (Pb) to LF-Lead-Free Solder Paste pathfinder program, the tool was invaluable to evaluate the solder formation processes of next-generation lead-free solder pastes. After SMT-simulated x-ray hot-stage reflow, the solder pastes with higher void percentage correlated with solder pastes that exhibited less wetting or coverage. It was radiographically demonstrated that solder pastes with low wetting and higher void percentage resulted in a combination of entrapped air voids and process voids from typical flux reactions. Moreover, a strong statistical correlation observed between low void density and high shock performance provided quantitative data that helped determine which LF solder paste alloys to pursue for production.

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4. M. Jansen, A. Sciarratta, N. Casilli, and C. Boucher, "Nordson Dage Quadra 7 Void Analysis and Heated Stage," 2020.

*This article does not contain technology or technical data controlled under either the US International Traffic in Arms Regulations or the US Export Administration Regulations.

Ed: This article is adapted from a paper of the same title first presented at the IPC Apex Expo Technical Conference in January 2023, with original work published within conference proceedings.

NORMAN ARMENDARIZ is an Engineering Fellow at Raytheon Technologies (raytheon.com) responsible for materials engineering design, materials analysis, process equipment development, production support and technology roadmaps associated with the manufacturing of circuit card assemblies used in missiles, smart munitions, ground-based radars, and mobile sensors across

multiple US and international sites. He has over 25 years of industrial experience, having worked for LTV, Lockheed/NASA, Motorola, Intel, Texas Instruments and American University. He holds an interdisciplinary doctoral degree in chemical engineering from New Mexico State University, a master's in materials science engineering from the University of Illinois, and bachelor's in metallurgical engineering from Colorado State University, with nine US patents and 29 peer-reviewed publications.

Spring Cleaning

Getting your printing house in order this season – and beyond.

AS YOU READ this, hopefully spring will have sprung wherever you are. It's an agreeable time of year and one of renewal, refresh, and the annual "spring clean." In that vein, I thought it would be an excellent opportunity to remind readers to take this same approach regarding the printing process, equipment and components. Maintaining all elements of the stencil printing operation is vital for good results, but these essential maintenance tasks are often overlooked in busy factories with even busier staff. If you're reading this, tick these items off your printing spring cleaning list and watch the process flourish.

Squeegee mechanism. Check the deflectors! First, using paste deflectors is highly recommended. They are simple tools mechanically set to the edge of the squeegee to prevent material from spreading beyond the active print area, drying, and being integrated into the paste roll. Setting them correctly is important, as I often see them set too high to be effective or so low that they damage the stencil. The height should be just above the stencil, at the point where squeegee pressure is applied. Ensure they are correctly positioned, or invest in automatic paste deflectors. And use them! You'd be surprised at how many operations don't.

Second, ensure the squeegee blades are damage-free with the "rule of thumb" test. For a good print result, squeegees need a reasonably sharp edge. If the blade is bullnosed or there are nicks, get rid of it. Run your thumb across the blade's edge (it won't cut you; it's not razor-sharp) and expect to feel a true edge with no breaks. If that's not the case, the blade edge is rounded or nicked and needs to be taken out of service.

Stencils. Again, if there is any damage, do not use the stencil. Any coining or damage around the artwork means the stencil is a no-go. In the modern micron world, where a 100µm print height is standard, don't risk a bad result from a damaged stencil. Second, confirm the integrity of the fiducial alignment marks. Over time, the contrast can diminish or become impregnated with solder paste. Once fiducial finders can no longer locate the complete edge, it's game over and accept scores will start to drop. Have a look with a loop, and if the fiducial doesn't look right, discontinue that stencil's use.

Also important is stencil tension. Automatic tensioning systems help mitigate against lost tension. For the traditional and incumbent mesh-mounted stencil, however, it's a fact that it will lose tension over time. If the stencil can move easily in the z-axis or has visibly less tension than a newly sourced stencil, it may cause issues with separation and lead to bridging defects. Better to replace the stencil.

Solder paste. Like the food in the fridge, check the "use by" dates on solder paste materials. Follow the basics of stock rotation, not reusing material from shift to shift, and other standard – and common sense – material protocols for the best result. This is especially important as the industry moves toward smaller particle sizes (Type 5).

Understencil cleaner. The cleaner needs cleaning, too. Elements such as the solvent dispenser can become blocked by dissolved fluxes that wick back through the fabric onto the dispensing bars, so check that all dispense openings are clear. In addition, subpar understencil fabric can put lint and debris in the apertures and present problems. Use high-quality fabric for the best results. Finally, high-volume sites that often employ the understencil cleaner after every print should also check the vacuum ports to ensure no blockages.

Tooling. The. Tooling. Must. Be. Flat. It's that simple. Operators should also inspect the tooling block for damage and dried material. Correctly labeling the tooling is important as well, especially if your operation creates its labels. There are often engineering change orders (ECO) to tooling that may be undetectable to the naked eye, so ensure the proper tooling is used and retired tooling blocks are moved out of rotation. Verify, verify, verify.

Machine. Last, but certainly not least, is the machine itself. Is it calibrated? If the machine's calibration maintenance is out-of-date, calibrating the equipment should always be step one, before any other troubleshooting commences. Other things to check include the rising table, which can become the repository for material drips off the squeegee if the equipment isn't fitted with a catch mechanism, and the clamping system. The clamping system sometimes gets bent or damaged, preventing the PCB from being tight and flush to the belt.

These simple but often skipped or overlooked maintenance checks should become routine – and not just in the spring, obviously. Hopefully, the headline got your attention, though, and got you thinking about procedural fine-tuning for a more robust printing operation.

CLIVE ASHMORE is global applied process engineering manager at ASMPT (asmpt.com); clive.ashmore@asmpt.com. His column appears bimonthly.

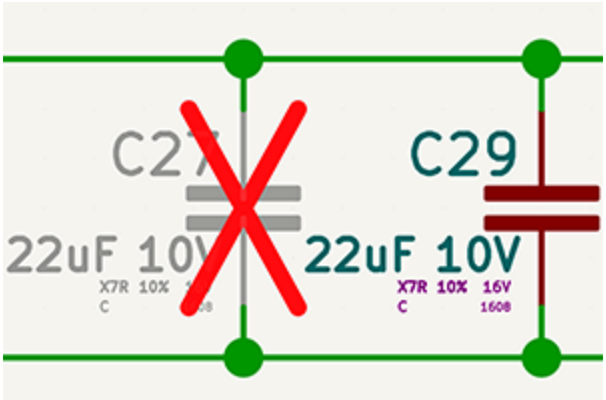

TUNING

PCD&F

DIS DATALIGN PCB LAY-UP SYSTEM

Datalign series front-end automated lay-up system is for multilayer printed circuit board fabrication. Accepts all inputs including cores and prepreg. Robot automatically picks up the cores in correct order, including the prepreg, and lays up the panels.

DIS Inc.
distechnology.com



KICAD 7.0 ECAD SOFTWARE

KiCad 7.0.0 features custom font support in the schematic, PCB and worksheet editors, as well as text box support was added in both the schematic and PCB editors. Also includes support for 3Dconnexion's SpaceMouse in the schematic, symbol library, PCB, and footprint editors and 3-D viewer, and an option for Sentry crash reporting data collection for Windows users. Plugin and Content Manager can now automatically check if an updated version of an installed package is available and prompt the user to update, and drag and drop handles have been added to several editors and viewers. Can now be packaged correctly as native Apple silicon processors (M1, M2, etc.), meaning it no longer has to run in emulation mode under the latest Apple hardware, and a separate command line interface has been implemented to allow scripting of many of the editor outputs.

Board and Footprint Editors now include optional check to determine if footprints have deviated from the library they are linked to, as well as a separate tab for ignored DRC tests. Two new DRC rule constraints have been added to custom rules, and custom rule severities can now be defined per custom rule. PCB Layout Tool enhancements include the addition of background bitmaps so that PCB traces and footprint layouts can be copied easily from some original reference PCB or footprint being reverse engineered, and it is now possible completely unroute a footprint. Traces can now be partially drawn, and the board editor can complete the trace the rest of the way to the nearest rats nest end. Selected items in board editor can attempt to automatically route traces between them. New search panel and properties panel have been added, and the algorithm that placed footprints on the PCB was improved to result in a more compact layout. STEP exporter also now uses the same PCB parsing engine as the rest of KiCad, which adds relative 3-D model paths to the footprint.

KiCad

kicad.org

KYOCERA AVX RADIAL-LEADED ALUMINUM CAPACITORS

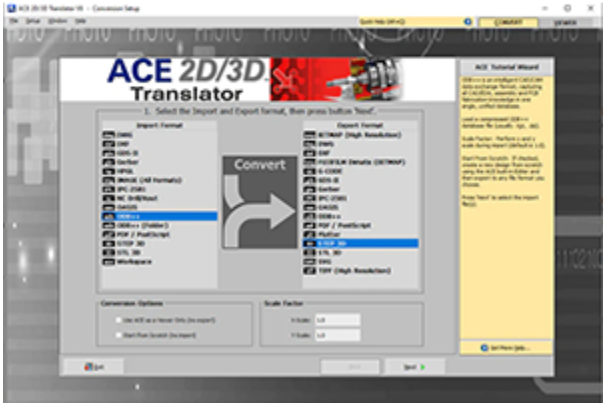
REA Series radial-leaded wet aluminum electrolytic capacitors exhibit high endurance (3,000-5,000 hr. at 105°C). Come in 28 capacitance values extending from 0.47μF to 22mF ±20%, 14 voltage ratings from 6.3VDC to 450VDC, and two rated operating temperature ranges: -40° to +105°C for 6.3–250V parts and -25° to +105°C for 350-450V parts. Are RoHS-compliant and lead-free compatible.

REF Series radial-leaded wet aluminum electrolytic capacitors exhibit low impedance, high ripple current capabilities, and high endurance (3,000-6,000 hr. at 105°C) in industrial applications including power supplies and filtering circuits. Come in 31 capacitance values from 6.8µF to 6.8mF ±20% and 10 voltage ratings from 6.3VDC to 120VDC and are rated for operating temperatures from -40° to +105°C. Are RoHS- and halogen-free compliant and lead-free compatible.

REH Series radial-leaded wet aluminum electrolytic capacitors exhibit high temperature, low impedance, and high ripple current capabilities as well as high endurance (2,000-3,000 hr. at 125°C) in industrial applications including power supplies and filtering circuits. Come in 24 capacitance values from 1.0µF to 4.7mF ±20% and 15 voltage ratings from 10VDC to 450VDC and are rated for operating temperatures from -40° to +125°C. Are RoHS- and halogen-free compliant and lead-free compatible.

Kyocera AVX

kyocera-avx.com

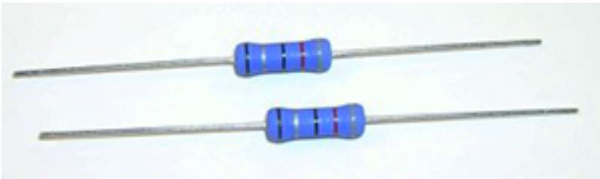


NUMERICAL INNOVATIONS ACE 2D/3D TRANSLATOR VERSION 8.3.0

ACE 2D/3D Translator Version 8.3.0 includes improvements to 3-D Step Export- optimized B-Reps curves detection to minimize outputted STEP file size; New Export as Wireframe- fast and useful for reference in various 3D Software tools; IPC-2581 Export- new option to export compressed files (*.tgz, *.zip); SVG Export- easily output optimized SVG files which can be useful for hundreds of purposes. Also includes full support for flex and rigid-flex designs by including new layer subtypes, stackup zones and more; open/save numerical workspace files (*.wrk) that are 100% compatible with FAB 3000 and CloudDFM.com; align layers in ACE Editor (menu: Edit | Align Layers) to easily align any input data before export.

Numerical Innovations

numericalinnovations.com



STACKPOLE ASR/ASRM ANTI-SURGE RESISTORS

ASR/ASRM series of resistors offers high working voltages, high pulse voltage handling, and well-defined pulse behavior for high voltage applications such as HVAC controls, appliance and white goods controls, metering, automation, medical devices, digital storage, and surge protection devices. Handles surges ranging from 2KV for the ASRM14 up to 10KV for the ASRM1 and ASRM2. Is said to be a viable replacement for carbon composition resistors, providing improved electrical and environmental stability, better tolerance and TCR, with better long-term availability.

Stackpole

seielect.com

UCAMCO INTEGR8TOR AND UCAMX V2023.01

Integr8tor v2023.01 pre-CAM tool's new features include yellow solder mask color, plated/non-plated/backdrill-to-copper clearance analysis, conditional formatting, agile job queue handling, improved performance and security, and DPMX import. UcamX v2023.01 CAM tool now features

YELO Mask Adjuster, Object Summary Table, Magnifier II, Rout Manager, Input GDSII, SmartTest, CAD Output Gerber X2/X3, Input Drill/Rout, and check for update.

Ucamco

ucamco.com

VISHAY 172 RLX CAPACITORS

BCcomponents 172 RLX series of capacitors combine high ripple currents up to 4.9A, high temperature operation to +105°C, and useful life to 10,000 hr. in 14 case sizes ranging from 10mm by 12mm to 18mm by 40mm. AEC-Q200-qualified, and offer lower impedance, higher capacitance for a given case size and voltage, and up to 54% higher ripple current at the same capacitance-voltage (CV) rating in smaller case sizes than previous-generation solutions. Feature radial leads and a cylindrical aluminum case with pressure relief, insulated with a blue sleeve, and offer rated voltages up to 50V, capacitance from 150µF to 15 000µF, and impedance down to 0.011Ω at +20°C. Are charge- and discharge-proof, and suited for smoothing, filtering, and buffering in switch mode power supplies, DC/DC converters, motor drives, and control units for industrial, automotive, telecommunications, audio-video, and electronic data processing (EDP) applications.

Vishay

vishay.com

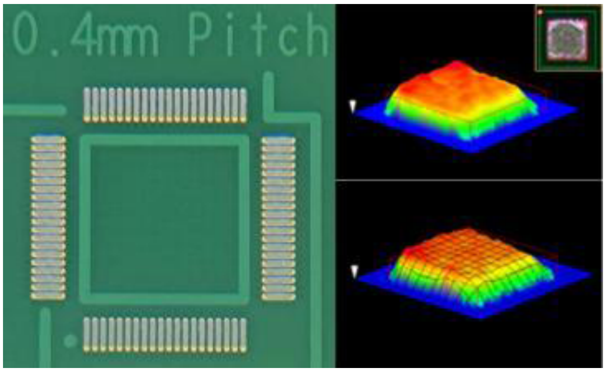
WÜRTH WCAP-FTXH CAPACITORS

WCAP-FTXH series of capacitors is ENEC 10, cULus, and CQC certified and belongs to the X2 safety class capacitors according to IEC 60384-14. Designed for 310V rated voltage and is said to pass a 1000 hr. test at 85°C and 85% relative humidity with the rated voltage applied. Operating temperature range extends from -40° to +110°C. Has self-healing properties through polypropylene dielectric and is available in 21 variants with different capacitance values (from 33nF to 10µF), voltage ramp-up rates, and insulation resistances. Has different sizes depending on values, and a pin pitch from 15mm to 37.5mm.

Würth Elektronik

we-online.com

CA



AIM H10 SOLDER PASTE

H10 halogen-free no-clean solder paste is capable of transfer efficiency greater than 90% on area ratios of 0.50 and a stencil life of more than 8 hr. Is said to eliminate NWO (HiP) defects and improve pad coverage on all surface finishes. Reduces voiding on BGA, BTC and LGA and offers enhanced electrochemical reliability on all low stand-off devices. Zero halogen per EN14562 and halide-free per IPC J-STD-004 and is compatible with AIM's full line of no-clean flux chemistries. Fit for automotive, LED and aerospace assemblies.

AIM Solder

aimsolder.com

BUGANG M/C NOZZLE CLEANER SERIES

M/C Nozzle Cleaner series offers simultaneous cleaning of up to 24 nozzles at a speed of 12 seconds per nozzle. Offers leaning of the inside and outside of each nozzle and includes drying function. Can complete partial cleaning cycle based on dirtiness of nozzle, as well as timed drying option. Also includes push-button automatic mode. Features a convenient location to load cleaner supply and alerts when cleaner is low. Includes 3" LCD screen to monitor operation, and notifies when cleaning is completed.

BuGang ENP

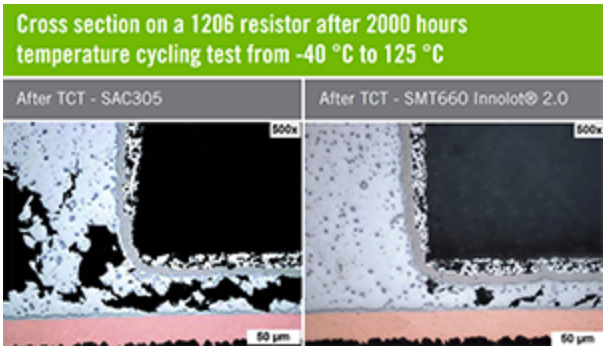
bugangenp.com

DYMAX 9200-W SERIES ENCAPSULANTS AND ADHESIVES

9200-W series of light-curable encapsulants and structural and optical-positioning adhesives is made without materials of concern known to cause skin sensitization. Formulated with low-sensitizing ingredients and have recognized irritants, such as IBOA, intentionally removed. Can be used alone or together in one device to create a total protective solution. Standard formulas can also be customized to meet specific application requirements. Can be used for structural bonding, sensor encapsulation, lens alignment, and selective coating, to secure and protect parts and eliminate component movement. Cures “on-demand” when exposed to UV/LED light energy, and some products feature secondary moisture cure for shadow areas. Not designed for direct skin contact, but is suitable to assemble applications worn on the body for short- or long-term periods, where extractable or leachable materials may be a concern.

Dymax

dymax.com



HERAEUS INNOLOT 2.0 SOLDER PASTE

Microbond SMT660 Innolot 2.0 no-clean printing T4 solder paste is a high-reliability, high-performance solder paste that provides a competitive TCO offering. Permits a wide process window, enabling soldering in air with a low defect rate, and is designed to offer an optimized formulation for lower costs. Offers reduced cost while maintaining higher creep resistance, resulting in longer product life cycles at higher operating temperatures. Also performs in the air without additional N_2 during reflow, while keeping defect rates low. Uses an acrylic-based synthetic resin eliminating potential batch-to-batch variations when using natural raw materials, and due to its low impurities and flux design, high SIR performance is achieved, reducing risk for electrochemical migration.

Heraeus Electronics

heraeus-electronics.com

ITW EAE VITRONICS CENTURION+ REFLOW OVEN

Vitronics Centurion+ is an upgrade to the Centurion reflow soldering oven with added features to minimize maintenance and keep the process chamber cleaner. Features greater accessibility to components that require maintenance. Easily removable blow boxes with removable side plates make cleaning easier in the cooling area, and easily removable baffle boxes on infeed and outfeed reduces downtime for cleaning. Can be configured with Ultra Cathox to handle more than 50kg of solder paste per week while reducing maintenance requirements and keeping a clean process environment.

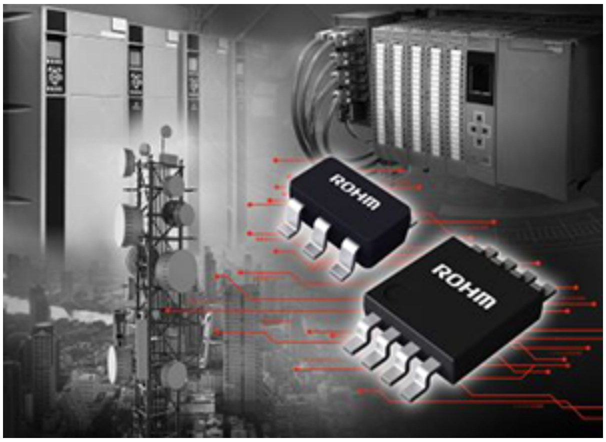
ITW EAE
itweae.com

JOT M12 TEST HANDLER

M12 Test Handler is a compact and modular test handler that features a capacity for up to 12 test boxes in a footprint of 0.25 sq. m. per test space. Uses the same M Test Boxes as the M1 and M5 and offers full interchangeability and independence when using manual test boxes, enabling an instant shift from prototype testing to fully automated inline testing. Features I4.0 autonomous interconnectivity, as well as the ability to use reusable, application-specific test boxes that also work fully independently offline.

JOT Automation

jotautomation.com



ROHM BD14210G-LA CURRENT SENSE AMPLIFIER IC

BD14210G-LA current sense amplifier IC simplifies current sensing by connecting a shunt resistor and a bypass capacitor, which reduces the number of components from 11 to just three compared to conventional configurations. Decreases the mounting area by 46% (SSOP6 package) and achieves current detection of ±1% over the entire temperature range (-40° to +125°C). Internal circuitry prevents current detection accuracy from decreasing even when an external RC filter circuit for noise suppression is added. Features wide input voltage range (-0.2V to +26V) making it ideal for current sensing applications operating from 12V/24V power supplies. BD1421x-LA series will include a total of eight models, featuring both single-channel and dual-channels variants in four different gain settings (20, 50, 100, 200V/V).

Rohm Semiconductor

rohm.com

ROHM BD7XXL05G-C PRIMARY LDOS

BD7xxL05G-C series of primary LDO regulators features a rated input voltage of 45V and 50mA output current optimized for redundant power supplies. Features compact size (2.9mm × 2.8mm), support for 125°C (ambient temperature) operation, qualification under the AEC-Q100 automotive reliability standard, and low current consumption demanded of automotive redundant power supplies. Can also be used as primary power supplies (45V rated input voltage). Also said to be highly resistant to disturbance noise, suppressing output voltage fluctuations to less than 50mV (<±1%) over the entire frequency band under ISO 11452-2 antenna irradiation testing.

Rohm Semiconductor

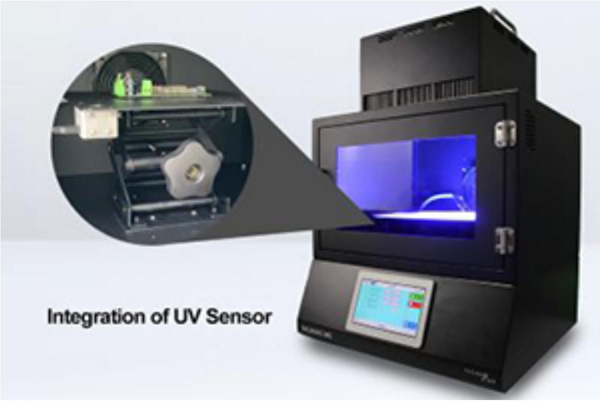
rohm.com

SHENMAO PF735-PQ10-10L SOLDER PASTE

PF735-PQ10-10L is a low melting point lead-free solder paste designed for SMT and is meant to increase production capacity in high-speed printing. Can reduce reflow temperature to below 190°C. Compared with SAC, reduces peak reflow temperature, energy consumption and warpage of PCBs and components. Compared to Sn42/Bi58 eutectic alloy, is said to offer better ductility, finer microstructure, and increased drop and thermal reliability. Suitable for precise electronic products, such as laptops, PCs, servers and LED modules. Halogen-free and complies with RoHS, RoHS 2.0 and REACH.

Shenmao

shenmao.com



TECHNODIGM LED UV CURING SYSTEM

All-In-One LED UV curing system now includes optional integrated UV sensor. Features the ability to set a desired UV intensity in absolute figures instead of just percentages, real-time monitoring of UV intensity, and real-time auto compensation to ensure accurate results with a +/-2% intensity accuracy.

TechnoDigm

technodigm.com

TECHNICAL
ABSTRACTS

In Case You Missed It

Lead-free Solder

"The Impact of Intermetallic Compound on Microstructure, Mechanical Characteristics, and Thermal Behavior of the Melt-Spun Bi-Ag High-Temperature Lead-Free Solder"

Authors: Rizk Mostafa Shalaby and Musaeed Allzeleh

Abstracts: This study aims to study the impact of intermetallic compound on microstructure, mechanical characteristics and thermal behavior of the melt-spun Bi-Ag high-temperature lead-free solder. In this paper, a new group of lead-free high-temperature Pb-free solder bearing alloys with five weight percentages of different silver additions, Bi-Agx (x = 3.0, 3.5, 4.0, 4.5 and 5.0 Wt.%) have been developed by rapidly solidification processing (RSP) using melt-spun technique as a promising candidate for replacement of conventional Sn-37Pb common solder. The effect of adding a small amount of Ag on the structure, microstructure, and thermal properties of Bi-Ag solder was analyzed by means of x-ray diffractometer, scanning electron microscopy (SEM), differential scanning calorimetry (DSC) and Vickers hardness technique. Applying RSP commonly results in departures from conventional microstructures, giving improved grain refinement. Further, the grain size of rhombohedral hexagonal phase Bi solid solution and cubic IMC Bi0.97Ag0.03 phase is refined by the addition of Ag. Microstructure analysis of the as-soldered revealed that relatively uniform distribution, equiaxed refined grains of secondary IMC Bi0.97Ag0.03 particles about 10μm for Bi-Ag4.5 dispersed in a Bi matrix. Addition of trace Ag led to a decrease in the solidus and liquidus temperatures of solder, meanwhile; the mushy zone is about 11.4°C and the melting of Sn-Ag4.5 solder was found to be 261.42°C, lower compared with Sn-Ag3 solder (263.6°C). This means silver added to Bi enhances the melting point. The results indicate that an obvious change in electrical resistivity at room temperature was noticed by the Ag addition. Also observed was that the

Vickers microhardness (Hv) increased with Ag, increasing from 118 to 152 MPa. This study recommends use of Bi-Ag lead-free solder alloys for higher temperature applications. (*Soldering & Surface Mount Technology,* Feb. 28, 2023, https://doi.org/10.1108/SSMT-03-2022-0015)

OECTs

"Vertical Organic Electrochemical Transistors for Complementary Circuits"

Authors: Wei Huang, *et al.*

Abstract: Organic electrochemical transistors (OECTs) and OECT-based circuitry offer great potential in bioelectronics, wearable electronics and artificial neuromorphic electronics because of their exceptionally low driving voltages (<1V), low power consumption (<1µW), high transconductances (>10mS) and biocompatibility. Successful realization of critical complementary logic OECTs is currently limited, however, by temporal or operational instability, slow redox processes and/or switching, incompatibility with high-density monolithic integration and inferior n-type OECT performance. Here, the authors demonstrate p- and n-type vertical OECTs with balanced and ultra-high performance by blending redox-active semiconducting polymers with a redox-inactive photocurable and/or photopatternable polymer to form an ion-permeable semiconducting channel, implemented in a simple, scalable vertical architecture that has a dense, impermeable top contact. Footprint current densities exceeding 1kAcm-2 at less than ±0.7V, transconductances of 0.2-0.4S, short transient times of less than 1ms and ultra-stable switching (>50,000 cycles) are achieved in, to the authors' knowledge, the first vertically stacked complementary vertical OECT logic circuits. This architecture opens many possibilities for fundamental studies of organic semiconductor redox chemistry and physics in nanoscopically confined spaces, without macroscopic electrolyte contact, as well as wearable and implantable device applications. (*Nature,* Jan. 18, 2023, https://doi.org/10.1038/s41586-022-05592-2)

PCBA Reliability

"Effect of the IMC Layer Geometry on a Solder Joint Thermomechanical Behavior"

Authors: Paulina Araújo Capela, *et al.*

Abstract: In a printed circuit board assembly (PCBA), the coefficient of thermal expansion (CTE) mismatch among solder joint materials has a detrimental impact on reliability. Mechanical stresses caused by thermal changes of the assembly lead to fatigue and sometimes the failure of the solder joints. The purpose of this study is to propose a novel pad design to obtain an interrupted solder/substrate interface, to improve PCBA reliability. An interruption in the continuous intermetallic compound (IMC) layer of a solder joint was implemented, by the deposition of a silicone film in the pad, changing its geometry. That change permits a redistribution of stresses in the most ductile zone of the solder joint, the solder. The stress concentration at the solder/substrate interface is reduced, as well as the general state of stress at the solder joint. A new way was developed to reduce stress on the solder joints caused by thermal variations because of the different components' CTE mismatch. This new method consists of strategically interrupting the IMC layers of the solder joint, redirecting the usual stresses to a more ductile area of the joint, the solder. This innovative method increases the lifetime of PCBAs. (*Soldering & Surface Mount Technology,* Feb. 28, 2023, https://doi.org/10.1108/SSMT-04-2022-0035)

"Effects of Concentration of Adipic Acid on the Electrochemical Migration of Tin for Printed Circuit Board Assembly"

Authors: Yi Sing Goh, *et al.*

Abstract: Closer interconnection spacing and higher electric field density increases the risk of electrochemical migration (ECM)-related failures. The ECM of tin (Sn) attracts great interest due to the wide use of Sn on the surface of the printed circuit board assembly. In this work, the authors investigated the effects of adipic acid (1ppm–saturated concentration) on the ECM of Sn using the water drop test (WDT) at 5V. In situ observation and ex situ characterization of ECM products were carried out using optical and electrochemical techniques. Results show that ECM failure probability is higher at intermediate adipic acid concentrations (10ppm, 100ppm and 1000ppm). The major ECM reactions include anodic corrosion and the formation of dendrites, precipitates and gas bubbles. ECM failure does not occur at higher adipic acid concentrations (≥5000ppm) although the anodic corrosion becomes more severe. The complexation of Sn with adipic acid to form Sn adipate complex is suggested as the main factor suppressing ECM failure at higher concentrations (≥5000ppm) by retarding ion transport. The electrochemical parameters (Ecorr and Icorr) do not correlate with the ECM failure probability. They affect the anodic dissolution stage, but not the

subsequent stages in the ECM mechanism. In this study, the ion transport stage plays a more significant role in determining ECM failure probability. (*Journal of Electronic Materials,* Jan. 12, 2023, https://doi.org/10.1007/s11664-022-10155-2)