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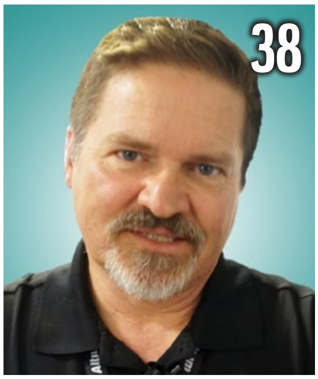
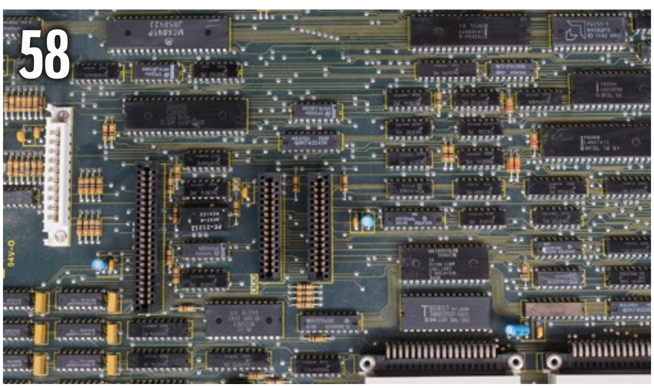
Digital Factory Benefits

There need to be benefits to any change, and transforming the manufacturing floor into a digital factory is a big change indeed. We look at some of the advantages that can be realized as new Industry 4.0 capabilities become available.





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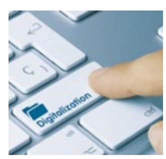

PCB007 MAGAZINE

The Benefits of Going Digital

Nolan's Notes

by Nolan Johnson, I-CONNECT007

I'm writing this column on the heels of IPC APEX EXPO 2020. When we chose "The Benefits of Going Digital" as the theme for February, we expected to find breaking news at the show; we were not disappointed.

A few months ago, I treated myself to a brand-new bathroom scale. This thing is fancy; it not only measures my weight, but it also uses bio-impedance to return much more detailed information, including body fat percentage, bone mass, protein levels, body water, metabolic rate, muscle mass, and more. Moreover, my scale now connects to my smartphone via Bluetooth and delivers all this data to an app.

There are two levels of detail to the app. In one view, I can review the raw numbers for each piece of health information captured. This is useful, but its use is also rather limited in that, unless you know how to interpret the numbers, they're meaningless, or worse, misleading. I certainly don't hold a degree in

sports medicine, so I'm not a good authority on what the different numbers really mean and how they interact with each other to tell a more detailed story. I need help with the analysis, and that's where the second view adds value.

The analysis view puts the numbers into context, along with explanations on how to interpret the numbers. When my data is mapped against a "healthy or not" graph, for example, I have a better idea of how I'm doing with my exercise and health programs. After a few weeks of watching my specific results, I understand what makes me most effective and healthy.

After a week of restaurant food in San Diego, for example, my metabolic rate was down, and my body fat percentage was on the rise. Good to know! Armed with raw data and some analysis, I'm more likely to make different choices on my next show trip. While it's not perfect, going digital has certainly helped me be more aware of keeping my health program optimized. With a little experience, I can already use historical results to predict future performance. And isn't that the point?

This is where we are with the digital factory, as well. The data is there now—if you hook up your line, that is. The work to develop the apps to collect, analyze, and present that data is underway with a vengeance. A CEO I used to work for would often comment, "We need metrics that tell us what's going to happen. We spend all our time driving in the rearview mirror." We're nearly there.

There is so much going on that we expect to be revisiting the topic, with more focused pieces of the digital factory story throughout the year. But for now, let's look at some of the benefits.

Happy Holden, I-Connect007 technical editor, starts the issue with an article overviewing the components of a smart factory implementation. Happy's expertise in this area is direct; he had a hand in most of the manufacturing techniques currently in use in HDI manufacturing. Next, we bring you Dr. John Mitchell's column, where he explores three workforce lessons from manufacturing plants around the world. Then, we move to Happy Holden's excerpt on automation planning from *Automation and Advanced Procedures in PCB Fabrication.*

Agfa's Frank Louwet speaks with I-Connect007 Technical Editor Pete Starkey about advances in the inkjet environment. Following behind is a conversation with LeGrande's John Watson—who is also a new I-Connect007 columnist—about digital security in the digital factory in "Designing Hardware for IoT Security."

Next, I share my conversation with Tim Burke of Arch Systems from IPC APEX EXPO 2020, which outlines the company's work to deliver a unified architecture for digital factories. In the PCB Norsemen column, Didrik Bech explores the true benefits of going digital. And in another interview from IPC APEX EXPO 2020, Michael Ford discusses the natural progression to applications over infrastructure for the smart factory.

Todd Kolmodin's column, "Looking at Digital With 11111100100 Vision," takes a gander (ha!) at how digital has changed over the years. In Part 3 of his column series, Mike Carano discusses via hole filling and plugging. Hitachi High-Tech's Matt Kreiner delivers "XRF: An Essential Tool to Help PCB Manufacturers Meet IPC Specifications."

Then, Lenora Clark talks to me about organizational changes and her new role at Macdermid Alpha. MKS's Chris Ryder shares his perspective on "The Current State of Embedded Active Components." Nikolaus Shubkegel addresses "PCB Surface Preparation Before Solder Mask on Non-copper Finishes," and columnist Steve Williams continues his series, "The Founding Fathers of Quality: Ishikawa and Shewhart."

There's a lot of weight to this digital issue. Enjoy. **PCB007**

Nolan Johnson is managing editor of *PCB007 Magazine*. Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing.To contact Johnson, click here.

The Smart Factory: All the Bits and Bobs

Feature by Happy Holden
I-CONNECT007

"Smart factory" is another phrase that describes Industry 4.0 programs. These programs seem to have replaced CIM and CAM, but it did not make them obsolete. While these topics are getting a lot of press, there is nothing new about them. We have been on a journey to automate manufacturing since the mid-'70s. What has evolved are faster and cheaper computers, and more complex and integrated networking. Meanwhile, the cost of wireless communications has dropped dramatically and labor and materials costs have gone up. These conditions all foster a greater return for automation, with the possibility of lights-out factories with no environmental impact, leading to "lean and green" implementations.

Strategy and Planning

What hasn't changed over all these years is the need for a strategic plan to achieve a smart factory. While the investment in automation may be straightforward, the investment in integrating all these islands of automation clearly is not. The strategic planning for this integration is the major topic in the smart factory. Networking has advanced so much in the intervening years that it has now become an over-riding element of the new smart factory. These elements were introduced in the free I-Connect007 eBook *Automation and Advanced Procedures in PCB Fabrication*.

Figure 1 shows the six stages of planning a smart factory. Most of the elements will be your current equipment and any new islands of automation. The arrows are of significance, as they outline the flow of information that

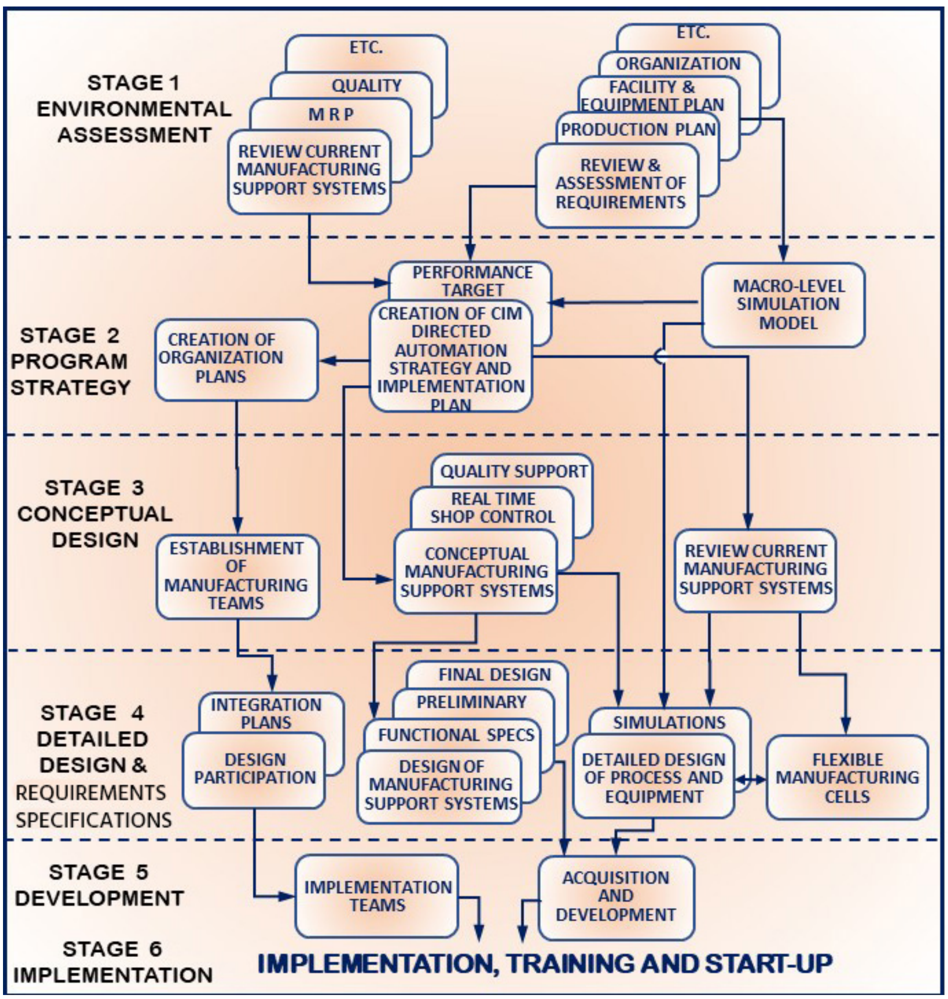

Figure 1: The first priority is to establish a strategy for what your smart factory will look like and how it will operate.

will be an important new part of your smart factory.

Table 1 provides more details on creating your smart factory strategy. The timing is approximate, based on how many resources are assigned to the job.

The Computer Architecture

The computer architecture for the smart factory is the familiar four-level hierarchy (Figure 2). This particular one is the European ISA-95 architecture defined in 1995. The only difference between the earlier architectures is that Level 4 will probably be the cloud.

Another essential feature of the smart factory is the interactive use of data from the many sensors and IoT devices. The data ownership and data structures for both the management environment and the technical environment compose many elements (Figure 2). The activities are straightforward, but the deliverables are essential to having a successful project.

The Digital Twin Model

Increasingly common for Industry 4.0 implementation is the use of the digital twin models. These virtual predictive models for a product, process, or service contribute a predictive model for engineering, manufacturing, delivery, and sustainment.

The pairing of the virtual and physical worlds allows analysis of data and monitoring of systems to head off problems before they occur. This allows for the prevention of downtime, presenting new opportunities and the ability to plan the future by using simulations. The models and simulations are fed by IoT and the internet of systems (IoS) following the data structures and data ownership defined for the planned future networking system.

Automation Protocols

In this section, I will look at the protocols used in some of the most recent smart factory implementations in North America and Europe.

PHASES	ACTIVITIES	DELIVERABLES
1 ENVIRONMENTAL ASSESSMENT (4-8 weeks)	• Conduct Systemization Review (flow, quality, etc) • Conduct "The CAD/CAM Audit" • Perform "The Process Scan" • Perform organization review • Analyze business forecast	• Profile of systemization/mechanization opportunities • CAD/CAM systems specification input • Assessment of organizational impact • Rationale for cost/benefits analysis model
2 PROGRAM STRATEGY (6-10 weeks)	• Perform macro-level stimulation for CBA • Establish performance targets • Create CIM strategy and automation plan • Develop documentation methodology for CIM system	• Documented CIM strategy and implementation plan • CIM architecture • Organization and staffing plan • Database mapping of functional processes
3 CONCEPTUAL DESIGN (6-10 weeks)	• Exploration of preliminary process equipment and automation alternatives • Initiation of requests for information (RFI) • Develop conceptual specs for MFG support systems • Organize manufacturing technology teams	• Budget profiles on equipment/software development created • Documented conceptual specifications for functional approvals
4 DETAILED DESIGN AND REQUIREMENTS SPECS (13-26 weeks)	• Generation of detailed process/equipment designs • Generation of detailed manufacturing support sizing of system specs • Involvement with technology suppliers • Creation of integration plans • Execution of simulation model on automation alternatives • Creation of RFP specs for supplies	• Transaction (I/O level) design document for manufacturing system • REF Specification with functional sizing of system • Detailed cost/benefits model document • Implementation plan
5 DEVELOPMENT (Cycle depends on Phase 4 scope)	• Selection of equipment, hardware and software suppliers • Implementation of development hardware and software • Software programming • Debug and test subsystems	• Completed system software • Installed, operational equipment
6 IMPLEMENTATION (Cycle depends on Phase 4 scope)	• Construct ATP • Execution of system test • Construct system and user documentation • Execute ATP • Trainer of end-users	• Acceptance of test procedures • Operational CIM systems • Technical and user documentation

Table 1: Details for creating the six-stage smart factory strategy.

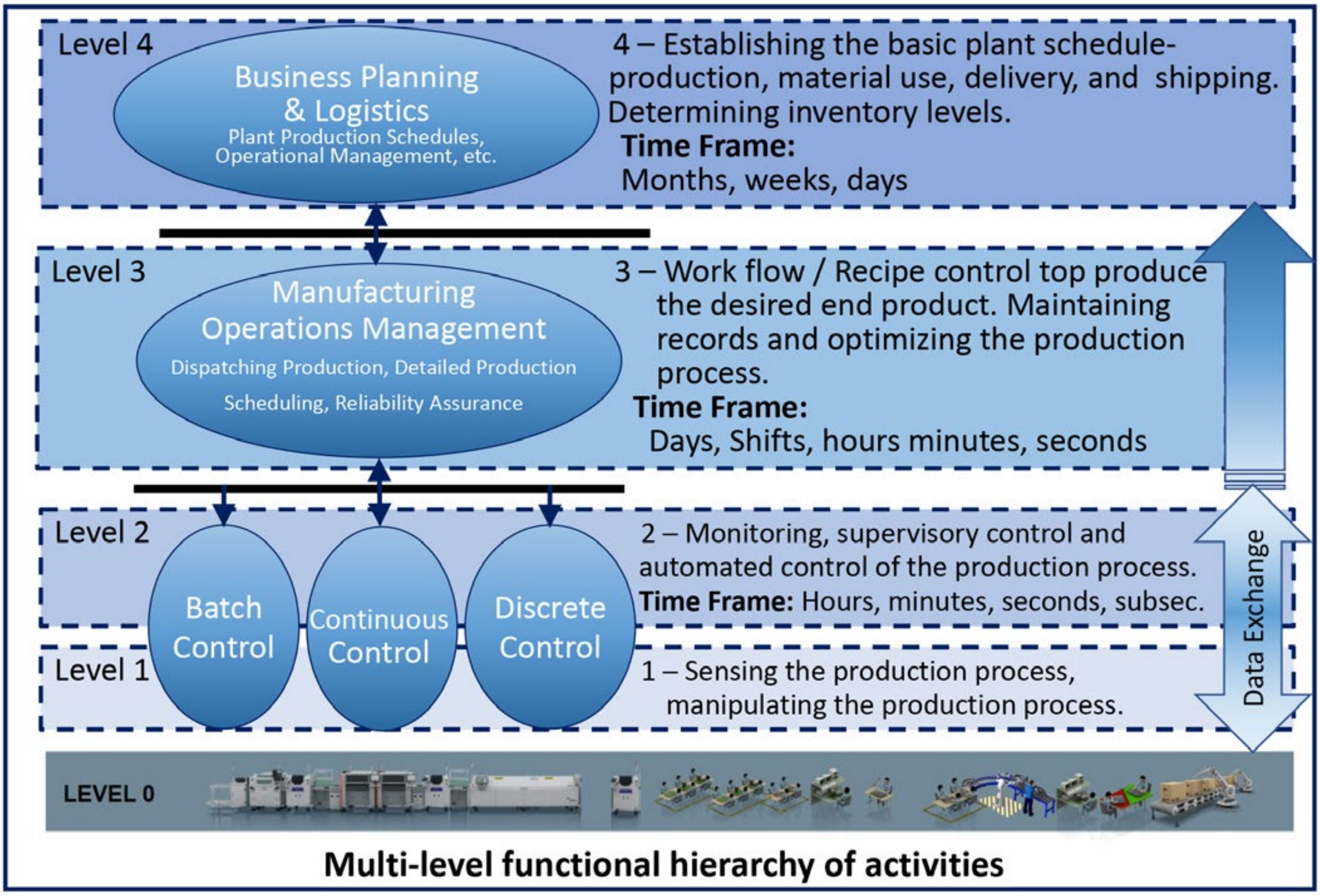

Figure 2: The ISA-95 architecture is still the preferred hierarchy for implementing automation for Industry 4.0.

Programmable Logic Controllers (PLCs)

PLCs, like those produced by Siemens and Allen Bradley, have extensive networking capability. There are at least six to eight open, but proprietary, messaging and protocols used by PLCs, with the Modbus TCP being the most popular and largest installed base. These are used in automation protocols (Figure 3).

PWB/IC Equipment Suppliers

Another equipment manufacturer, Atotech GmbH of Germany, uses PLC-like software in their computers as their control network [1]. These systems communicate over Ethernet using PROFIBUS, with plans to add EtherCAT. Their protocols engage a smart factory network by either SECS/GEM or OPC/OPC-UA.

Atotech takes advantage of the smart factory environment to improve efficiency and yields and minimize the total cost of ownership without compromising quality through:

1. Extending automation with improved process control and intelligent use of production data, including automatic cleaning cycles, dosing systems, etc.
2. Process chemical analysis for improved performance, lower chemical use, and improved yields, as well as Cu/Fe controller for plating, electroless Cu bath controller, etc.
3. Providing industry communication interfaces (PROFINET, OPC, SECS/GEM) to connect the metalization line, desmear line, and plating to customer MES-system enabling a smart manufacturing system.
4. Future solutions to minimize downtimes by collecting process and production data, and predictive models can be created and analyzed to prevent future and unscheduled machine failures.

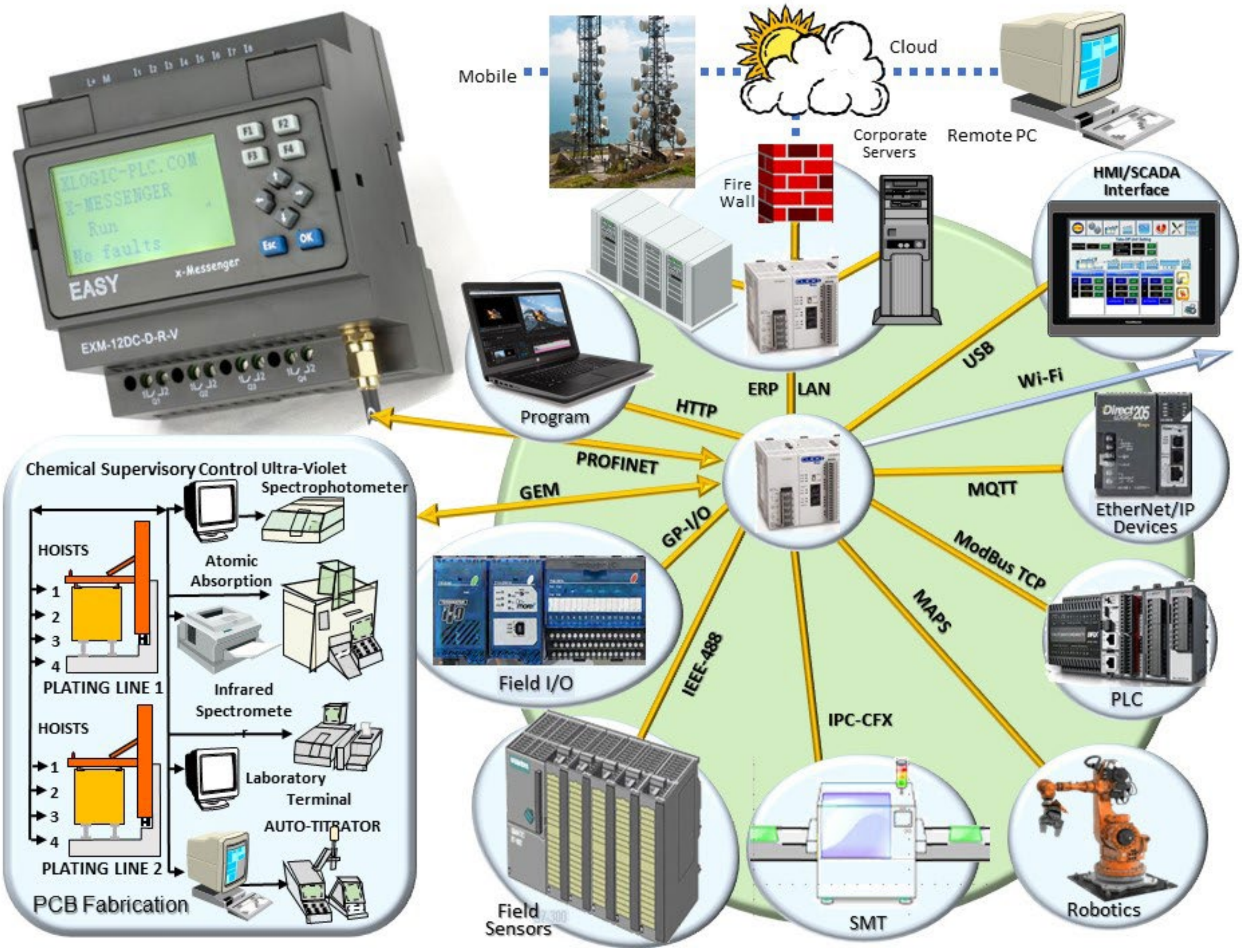

Figure 3: Modern PLCs can provide much of the smart factory's lower-level networking.

Third-party Connection Boxes and Software

A third option to connect legacy machines and islands of automation can be the ShoeBox that Seica is making, which is a small Raspberry Pi computer in a box together with a digital I/O interface that connects to any available data source, including ports, sensors, switches, etc. The box has software, which works as a CFX client, such that any machine can be a part of the CFX network or ModBus TCP that connects to other PLCs [2]. The ShoeBox monitor communicates with two radio channels and one power line channel (Figure 4). The Raspberry Pi 4 has the unique specifications for a computer the size of a credit card, yet under $40.

The ShoeBox industrial monitoring has the monitor that connects to machines, sensors, power lines, and other control signals and sends

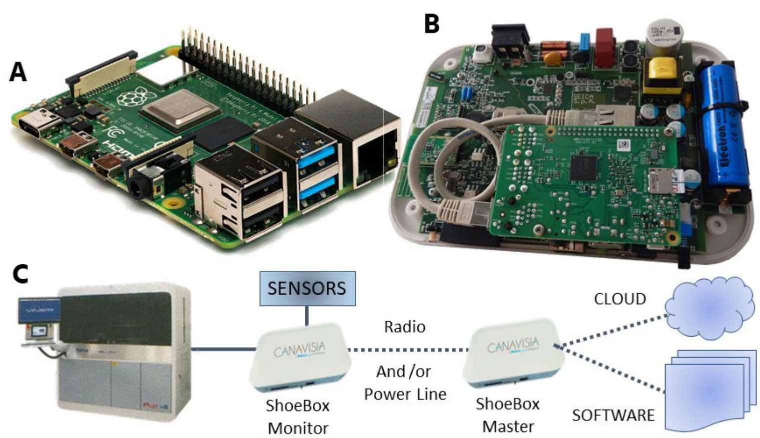

Figure 4: A ShoeBox network connector made by Seica is based on the popular Raspberry-Pi computer (A) connected to its 40-pin GPIO, (B) enabling it to connect to most older non-Industry 4.0 equipment [2]. (Source: Seica)

Characteristics	Monitor	Master
Communication	Power line comm. PLC, wireless, 2.4 GHz and 433 MHz	Power line comm. PLC, wireless, 2.4 GHz and 433 MHz
Connectivity	Sensor management bus 1-wire (max.8 temperatures)	Ethernet LAN 10/100, Wi-Fi (option), 3G/4G (optional)
Analog Inputs	Two channels 0–10 V, two-input current transformer	Two channels 0–10 V, two-input current transformer
Analog Outputs	Two channels 0–10 V	Two channels 0–10 V
Digital Inputs	Eight channels low voltage (5/12/24 V)	Eight channels low voltage (5/12/24 V)
Digital Outputs	Two channels low voltage, max 50 V	Two channels low voltage, max 50 V
Optional	Light power meter to 600 DC/AC, 0–30 V	Multimeter, three-phase and single-phase
Dimensions	H: 140 x W: 200 x D: 40 mm	H: 140 x W: 200 x D: 40 mm

Table 2: Characteristics of ShoeBox industrial monitor.

information back and forth to the master that communicates by radio, power lines, or Ethernet. Their characteristics are shown in Table 2.

Siemens

Siemens has developed a special machine-to-machine (M2M) Ethernet controller to onnect legacy and other surface mounting equipment to their smart manufacturing (Figure 5).

The protocols and messages used by PLCs (using the seven-level ISO communications standards) are like our modern transportation Interstate Highway System. Many kinds of vehicles travel on it, including various makes of cars, trucks, etc., but bicycles, pedestrians, and farm tractors are forbidden. Everything that uses this network obeys a standard set of rules to get to their destination. And like this transportation network, different protocols have different predefined messages but may not be in a language that you understand. For M2M, the messages need a standard language that each machine understands, even if made by different vendors.

Protocols for the Electronics Smart Factory

The one way to shorten the development time of any smart factory automation protocol is to leverage what is already out there. Three protocols have already been established in electronics manufacturing:

1. IPC-2591 Connected Factory Exchange (CFX) with the IPC-9852 HERMES standard.
2. Mentor, a Siemens Business Open Manufacturing Language (OML).
3. SEMI’s SECS/GEM-SEMI Equipment Communication Standard/Generic Equipment Model.

Modeling any PCB fabrication smart factory protocol after one or more of these existing standards will shorten their development time.

Figure 5: Siemens has PLCs and special Ethernet M2M connectivity for electronics assembly equipment. (Source: Siemens)

IPC-CFX/Hermes

An open network standard introduced by the IPC is IPC-2591 [3] introduced in 2018 (Figure 6). It establishes three critical elements for "plug and play" industrial IoT:

1. A message protocol using AMQP
2. An encoding mechanism using JSON
3. A specific content creation element-structured topics and messages

The Hermes standard is a low-level line control protocol that passes information up and down the equipment line, including PCB ID, program name, and key product data. These elements allow for the creation of automatic decision-making and dashboard displays, alerts, and reports. These applications improve productivity, efficiency, capacity planning, and quality while lowering costs. It allows the full traceability of components (IPC-1782) and feedback to design (IPC-2581).

Typical CFX topics and messages are seen in Figure 7. The IPC has established a methodology to add and edit new messages for the CFX standard, the "CFX message submission process," to allow it to grow and be applied by more machines and processes. There is even CFX messaging for hand soldering.

To facilitate adapting machines and applications, there are free software development kits (SDK) available for Windows, .Net, Linux, LabVIEW, JAVA, etc. Already, hundreds of machines have been adapted and demo'ed with native CFX. The goal of the IPC Committee is to facilitate a fully functioning Industry 4.0 digital manufacturing world.

Closed-loop feedback in real-time is now possible and available. IPC-CFX provides the tools and community to implement most of the goals of the smart factory, including DFX feedback via IPC-2581's digital product model (DPM) back to design. An integral part of the success of IPC-CFX is the DPM standard created by IPC-2581.

OML

OML was developed by the Valor Division of Mentor, which is now part of Siemens. OML is the messaging and communications protocols used by the Valor IoT box according to the ISA-95 application hierarchy to connect SMT assembly equipment to the Siemens higher-level factory software and to displays and performance dashboards.

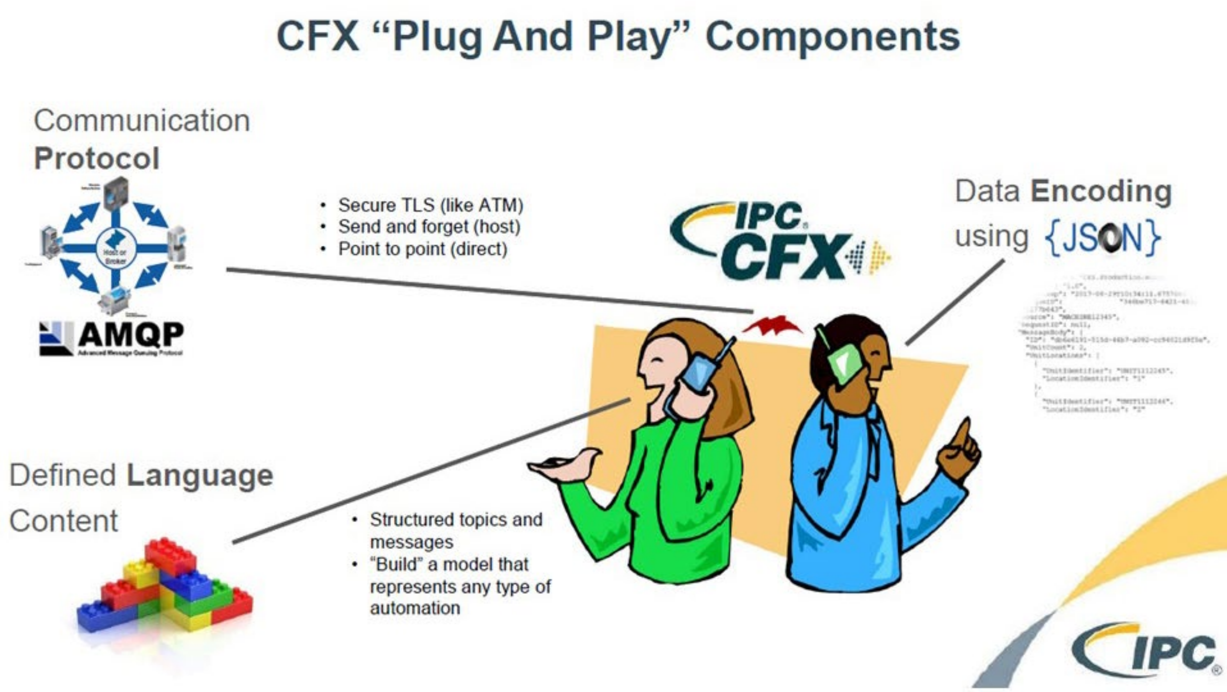

Figure 6: IPC-CFX is an open, free, M2M electronic assembly protocol standard. (Source: IPC)

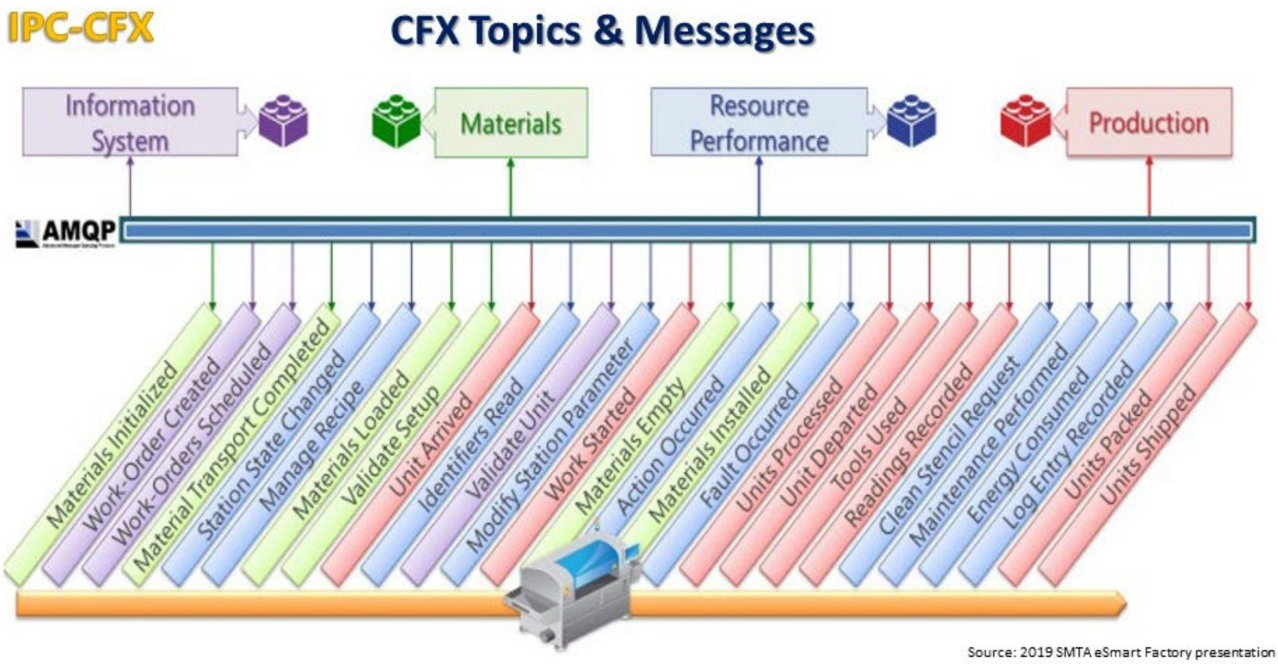

Figure 7: CFX messaging. (Source: IPC)

Hardware

There are two unique pieces of "plug and play" hardware in Siemens' IoT solution. They are:

- System processing unit (SPU): The factory gateway for networking and line controller for connections to machines
- Data Acquisition Unit (DAU): Connects machines and manual processes using a variety of physical interfaces, such as RS232, digital I/O, USB, HDMI, LAN, SMEMA (Hermes), and light tower sensors.

Data Formats

OML uses the JavaScript Object Notation (JSON) standard to represent each message. The use of JSON in the software industry has rapidly increased year on year, with the format now widely used in most web-based technology and across the Internet generally. For example, JSON can represent the same data, using significantly less space than XML, which means performance gains. However, like XML, JSON is still human-readable and can represent complex data. JSON is easily compressed to reduce size for further efficiency.

JSON is a fully open standard with mature future support in most major programming languages and platforms. OML allows equipment suppliers and users to create recipes, control equipment, sound alarms, and collect data to solve problems automatically.

SEMI's SECS/GEM Protocol

SEMI's SECS/GEM was established in the 1980s and 1990s by the semiconductor industry and has been continuously updated to today. There are over 900 English SEMI Standards with many more in Korean, Japanese, and Chinese. SEMI also has standards for other industries like photovoltaic. The standards are open and non-proprietary. SEMI's documentation is useful to establish messages and responses for PCB fabrication protocols. Like IC fabrication, the PCB fabrication process is thermodynamic, so the IC fab model is very useful for PCB fabrication and is different than the kinematic PCB assembly model. It has been updated with current wireless networking and security and is a convenient model for additional PCB automation [6].

SEMI has PCB fabrication and assembly advisory boards working to connect the entire electronics supply chain into one digital thread. Because of accessibility, originality, and security, SEMI is looking at "distributed ledger technologies" (blockchain) as a possible technology to include in their general equipment model (GEM-E30) protocol.

As explained in the *HP Journal* article [6]:

> "SECS I incorporates the use of RS-232-C cabling and pin definitions and a relatively simple line protocol. SECS II defines larger messages (up to 4.3 Gb) to request and send status information, transfer recipe data, report alarm conditions, send remote equipment control commands, and handle material transfer. SECS I uses a simple ENQ-ACK handshake across an RS232-C line with checksums at the end of each message. SECS I also defines time-out intervals between handshake responses, individual message characters, and message responses. Message headers are defined in SECS I to include equipment identifiers, message identifiers, message block numbers, and other system information."
>
> "SECS II defines message types, format, content, and directions. SECS streams are groups of messages assigned to a general set of equipment functionality. Within each stream, the individual messages are assigned function numbers. For example, SECS stream 1 function 5 (abbreviated S1 F5) is a formatted equipment status request, and stream 1 function 6 is the reply with the status information. Similarly, stream 7 function 5 is used to request the transfer of a process recipe, and stream 7 function 6 is used to transfer the recipe. SECS II also defines whether a reply is required or not, the message content and format (including data item definition headers), and whether a message may be used from equipment-to-host and/or host-to-equipment."

The GEM/SECS-II standards are protocol independent. Today, there are two protocols defined by SEMI: SECS-I (E4) for serial communication and HSMS (E37) for network communication. Most systems today are using the HSMS standard. HSMS does not specify the physical layer. Any physical layer supported by TCP/IP can technically be used, but typically everyone just uses an Ethernet network interface controller (NIC) with an RJ45 port.

A major advantage of the SECS standard is that it defines messages and their content; it defines how the messages are used together to perform a function. Equipment manufacturers are left to decide what messages to use to perform functions that were performed manually before. The GEM standard is built on top of SEMI standard SECS-II (E5).

The GEM standard has been adopted by other industries, like the photovoltaic (solar cell) industry, and used by many in the electronics industry. It can serve as a model for the PCB fabrication industry by reviewing these SEMI standards:

- SEMI E4: SEMI Equipment Communication Standard 1 Message Transfer (SECS-I)
- SEMI E5: SEMI Equipment Communication Standard 2 Message Transfer (SECS-II)
- SEMI E30: Generic Model for Communica tions and Control of Manufacturing Equipment (GEM)
- SEMI E37: High-Speed SECS Message Service (HSMS) Generic Services
- SEMI E81: Specification for CIM Framework Architecture
- SEMI E96: Guide for CIM Framework Technical Architecture
- SEMI E128: Specification for XML Message Structures

MAPS Protocol: Message Automation and Protocol Simulation

As explained in an overview tutorial by GL Communications Inc. [7]:

> "MAPS specifies a set of standard communication services for factory automation and has been accepted as an international standard by the ISO. It is a protocol simulation and conformance test tool that supports a variety of protocols for such factory floor controllers as PLC, robots, group controllers, and cluster controllers. MAPS is one of the oldest and most used of the factory floor automation protocols, being pioneered by General Motors and adopted by General Electric for its factories."
>
> "MAPS is based on the reference model for open systems interconnection (OSI)

of the International Organization for Standardization (ISO). It has three main components: file transfer, access, and management services; manufacturing message specification services; and X.500 services. The protocol includes SIP, MEGACO, MGCP, SS7, ISDN, GSM, MAP, CAS, LTE, UMTS, SS7 SIGTRAN, ISDN SIGTRAN, SIP I, GSM AoIP, Diameter, and others. This message automation tool covers solutions for both protocol simulation and protocol analysis. The application includes various test plans and test cases to support the testing of real-time entities. Along with automation capability, the application gives users the unlimited ability to edit messages and control scenarios (message sequences). 'Message sequences' are generated through scripts."

"MAPS is designed to work on TDM interfaces as well as on the IP/Ethernet interfaces. MAPS also supports 3G and 4G mobile protocol standards for testing the rapidly evolving mobile technologies. MAPS can simulate radio signaling protocols, such as LTE (S1, eGTP, X2) interfaces and UMTS (IuCS, IuPS, IuH), GPRG Gb, and GSM A over an IP transport layer."

"MAPS test suite is enhanced to simulate multiple UEs and IMS core elements, such as P-CSCF, I-CSCF, S-CSCF, PCRF, MGCF in IMS core network. With the help of mobile phones and other simulated wireless networks, the VoLTE Lab setup can be operated in real-time for making VoLTE calls and for interworking with PSTN and VoIP networks. MAPS is enhanced to a high-density version and a special purpose 1U network appliance that is capable of high call intensity (hundreds of calls/sec) and the high volume of sustained calls (tens of thousands of simultaneous calls/1U platform)."

Challenges of the Digitization of Design

The ongoing challenge is the digitization of the CAD product model and all its specifications so that it can drive setup and recipes in the new smart factory (Figure 8). ECAD tools and product specifications ensure a certain

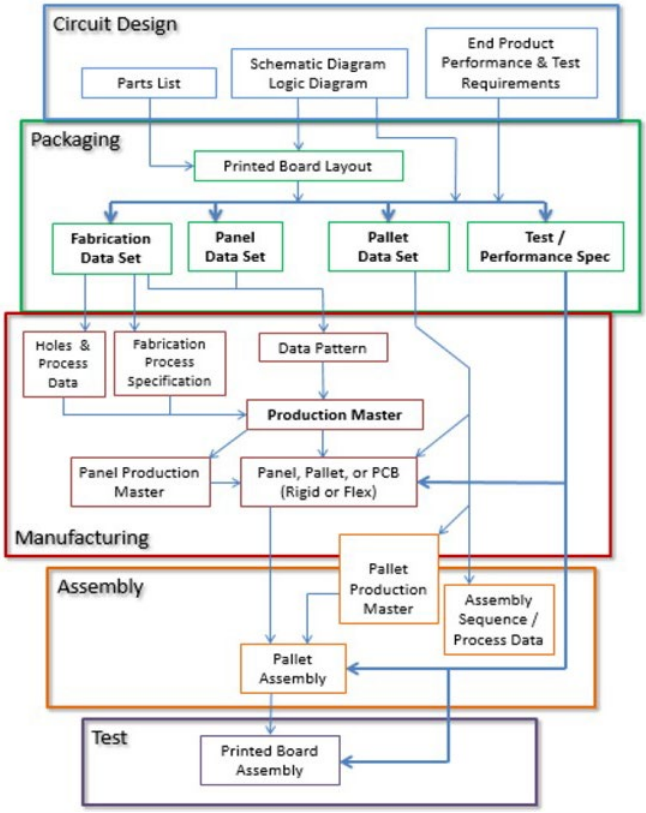

Figure 8: Historic data description hierarchy breakdown. (Source: IPC)

level of accuracy and repeatability; however, this information is still non-intelligent and non-digitized. The notes, specifications, and dimensions added to the single PCB or panel only convey a static and potentially incorrect representation of the manufacturing requirements. Even in the best case, where all this additional information is created correctly, the non-intelligent information is still subject to potential misinterpretation or not even being understood. IPC-2581 is the evolving industry standard focused on achieving the goal of a complete DPM exchange (DPMX), but ODB++ also plans to evolve to fill this need.

IPC-2581

The evolving IPC-2581 standard is one reason that IPC-CFX-2591 was developed so rapidly. The DFM standard has been an IPC focus for nearly 30 years. The CAD-to-CAM data transfer has been one of multiple files, specifications, and notes (Figure 9). First, it was Gerber to EDIF, IPC-D-350, ODB, GenCam,

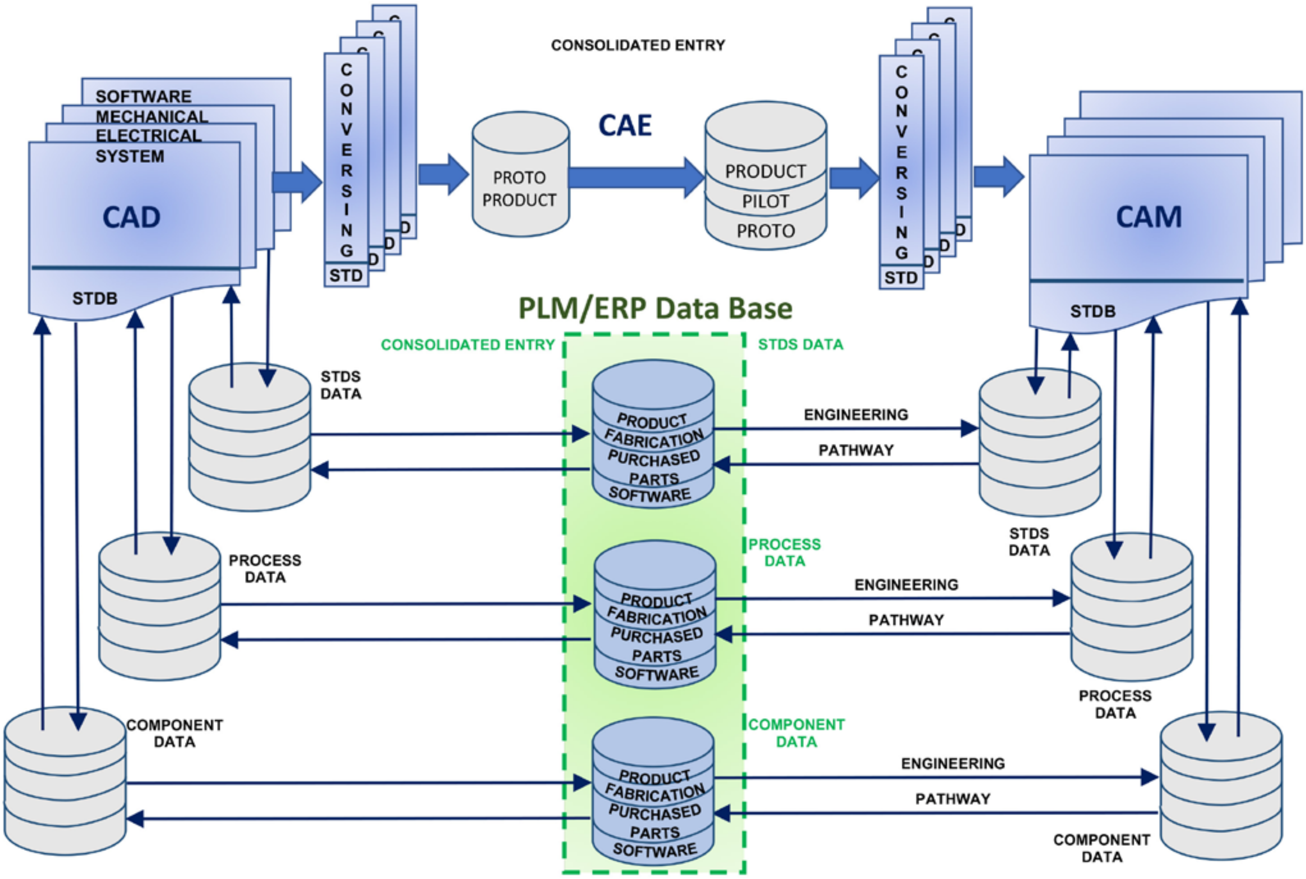

Figure 9: The new challenges for Industry 4.0 is the digitization of product data (CAD and BOM plus specifications) to drive automated smart factory systems.

ODB++, IPC-2541, GenCam 2.0, GenCamX, IPC-2581A, and now IPC-2581B with extensions. But the digitization of all product and manufacturing information has compelled the industry to create universal, open, product standards, and IPC-2581B is the closest thing we have to a consensus standard. The rapid implementation of CFX highlights that fact.

Progress has been rapid on IPC-2581 but focused on electronics assembly. The process and CNC requirements for PCB fabrication have taken a back seat. As seen in Figure 10, several data requirements have not been digitized yet. Progress on IPC-2581 has been extended

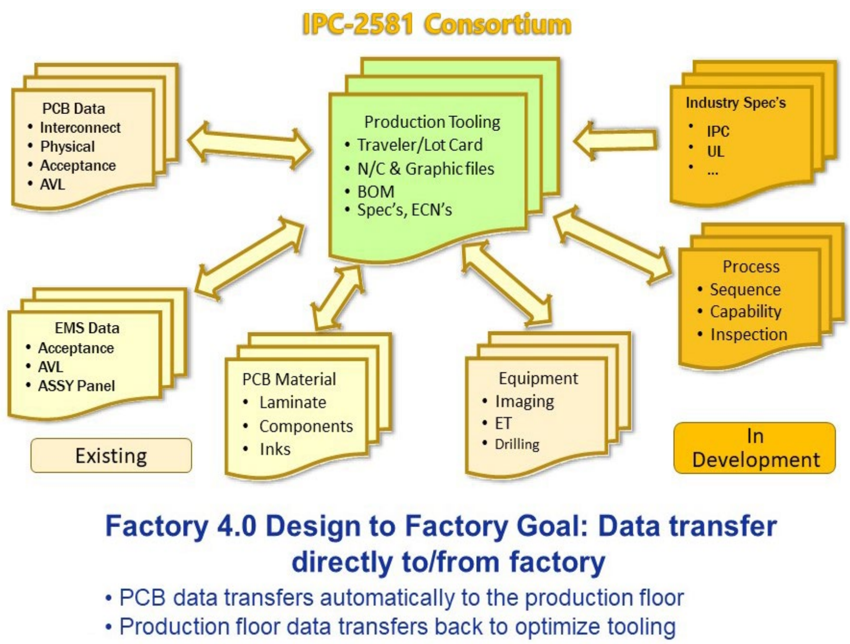

Figure 10: IPC-2581's goal is the complete digitization of the PCB product into a data-driven standard. But a number of areas have, as yet, not been addressed by IPC-2581. (Source: Korf Consultancy)

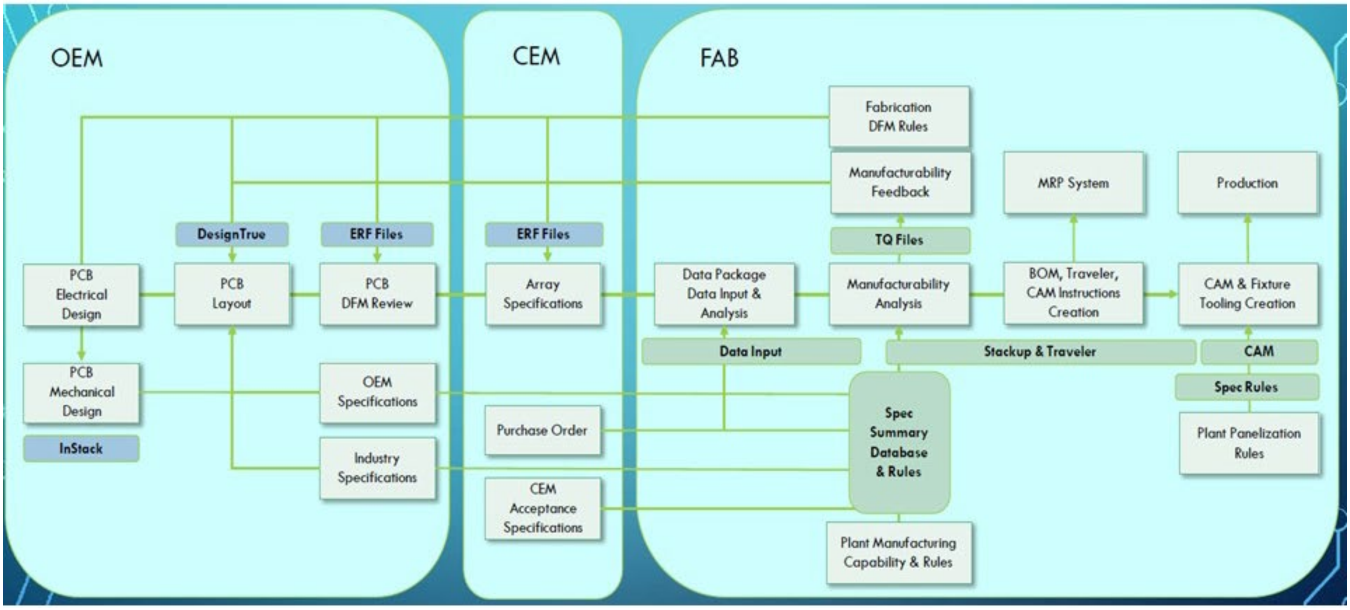

Figure 11: DFX is a complex set of rules and capabilities, but IPC-2581 can supply the information for AI to learn these complex rules. (Source: Korf Consultancy)

to meet electronic (SMT) assembly needs for IPC-CFX.

The ongoing work by many IPC-2581 participants is to complete the DPMX with the full digital information required for the bare board fabrication process. For many, the DFX information is paramount (Figure 11). Once this is accomplished, then the standard can be used by a deep-learning AI system to learn the many rules for designing a PCB right the first time.

IPC's efforts at establishing an open, descriptive format for DFM was Dieter Bergman's paramount effort. But, alas, only the few that worked on the standard ever used it. This time, over 100 companies are combining their efforts to see that IPC-2581 is adopted and used (Figure 12). The drive to establish IPC-CFX is a clear indication of the new resolve by OEMs.

CircuitData Language

CircuitData, as Jan Petersen of Elmatica explains, is an open-source language for communicating specifications on a printed circuit, mainly PCBs. It can be used to interchange information on the specification (fabrication data only), a profile (requirements and default values when exchanging data), and capabilities (the production facility capabilities of a supplier). It can also be used to exchange a material list or other needed related data.

This grass-roots organization started in 2016 to provide a digital language for the fabrication of bare PCBs. Using the facilities of GitHub to amend, review, and enhance the CircuitData Language, which uses the "open trade transfer package" to define a structure of how information is to be passed in either JSON or XML format. The current version (1.0) was released in 2018. Since this is not a standard but the result of a lot of work by dedicated individuals, it may be doing a lot of pioneering work for the IPC-2581 committee or SEMI/PCB committees. To join, comment, or get updates, visit www.circuitdata.org.

Smart Factory Example

An example of the smart factory comes from Atotech GmbH [1]. By collecting process and production data, they are developing models (like the digital twin). The historic data leads to predictive algorithms that lead to a digital model for predictive maintenance. Predictive maintenance is a technique to predict future failures of a machine component so that routine replacement or service, based on a plan,

Figure 12: The IPC-2581 open standard has now achieved critical mass with the participation of over 100 companies and a rich DPM.

can be conducted, preventing unscheduled downtime.

The highly automated smart factory is susceptible to any downtime machine failure. As the complexity of the smart factory increases, the potential upside is:

1. Reactive: Maintenance is simple. If it's not broken, don't fix it. The best cases are where equipment failure is rare, easy to fix, and with limited impact (e.g., switching a lightbulb in a warehouse).
2. Preventative: Maintenance (or planned maintenance) uses routine maintenance to diagnose equipment for failure. It works and is widely employed, but it's costly and doesn't capture asset-specific conditions.
3. Predictive: Maintenance leverages data from an individual asset to predict failure. This way, repairs can be done when needed (and avoided when not). It offers the best upside, but at the cost of complexity.

The smart factory is in its infancy, and much more is to come! **PCB007**

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Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa/Westwood, Merix, Foxconn and Gentex. He is currently a contributing technical editor with I-Connect007. To read past columns or to contact Holden, click here.

Three Workforce Lessons From Manufacturing Plants Around the World

One World, One Industry

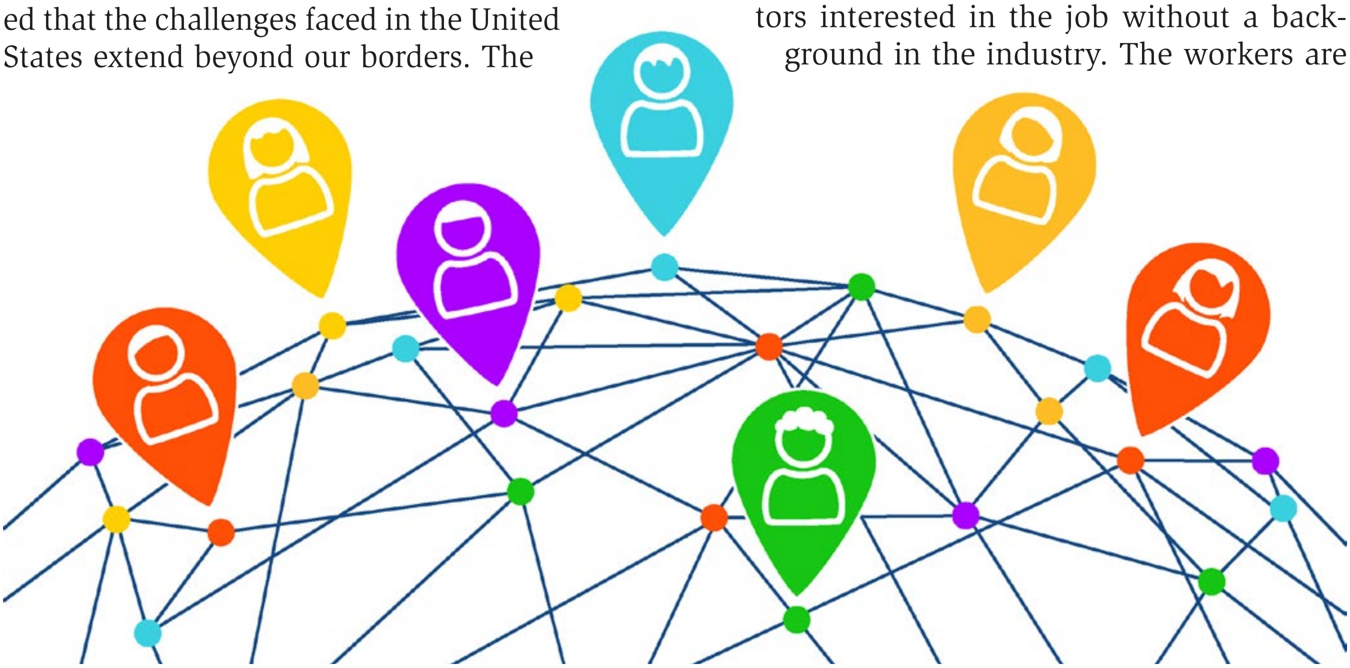
by Dr. John Mitchell, IPC—ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

The U.S. economy has remained surprisingly resilient, and the result has been that the country's unemployment has continued to inch lower. It's now at 3.5%, the lowest rate since 1969 [1], and that rate could go even lower as the U.S. boasts more than 7 million job openings [2]. Those job openings suggest an opportunity for workers but a tight labor market for employers. For the electronics manufacturing industry, talent and retention have always been top concerns, but the situation is worsening. Today, more than 60% of U.S. manufacturers say that an inability to find and retain skilled workers is constraining their growth and undermining their global competitiveness [3].

The same story is true around the world. During my latest international listening tour of manufacturing plants in France, Germany, India, Japan, Taiwan, and Thailand, I again noted that the challenges faced in the United States extend beyond our borders. The good news is that, through shared experience, we can develop shared insights and solutions. In that vein, I'd like to offer the conclusions I've drawn from my meetings with operators and managers across the electronics industry about the current labor environment.

Lesson 1: An open-minded approach to hiring based on industry interest, not just skill, can result in new long-term talent.

During the recruitment process, seeking out potential employees who hold genuine interest and passion for the industry even if they don't yet pose the skills can provide a new source to fill long-term workforce gaps. It's okay to hire an employee with minimal training; that's where company education programs come in. In Japan, one manufacturing plant hires operators interested in the job without a background in the industry. The workers are



trained with pay for a full year before joining the assembly line. Once thoroughly vetted and trained, operators have the avenue to move up through the ranks to become managers. Among the factory managers with whom I spoke, none of them had college-level training; their education was solely completed through intracompany training. As an added bonus, the longevity and loyalty of this workforce are impressive, but more on that in Lesson 3. This model, used in some Japanese companies as well as others in Europe, underscores the point that we can find talent by embracing workers with little to no experience—but with industry passion—to build the worker pipeline. That is where the next key lesson comes in.

Lesson 2: Career progression is important to workers.

Hiring is the first step, but companies need to keep thinking of new ways to keep employees engaged and motivated by prioritizing both their personal and professional growth. Job security and location to home remain pillars for workers within the industry. However, with a younger generation entering the workforce, convenience isn't enough to retain workers. Workers want to know they have a career path they can build in their companies.

In Thailand, operators who lack a college education, along with management staff from top schools, can grow within their roles and continuously be promoted. The job culture there exposes workers early on to self-improvement paths that help them attain specific knowledge or capabilities. Having this type of transparency helps create trust among employees and companies, where the workers invest in the companies and the companies invest in the workers (Figure 1).

During my latest trip, I spoke with college-educated engineers who expressed appreciation for their companies' focus on personal growth. One manager emphasized that it was during his time as a quality engineer that he learned how to meet his goals and prioritize learning additional skill areas, allowing him to become a senior production manager.

Lesson 3: Worker retention relies on effective workplace communication to maintain worker happiness.

As I engage with workers and management, I'm always reminded that companies address

Figure 1: Visiting Fabrinet in Thailand, John Mitchell, along with Phil Carmichael, president of IPC AP, viewed activities on the factory floor and met with staff members to discuss career progression, collaborative problem-solving, and opportunities available for new employees.

and troubleshoot challenges in the workplace in a variety of ways, and how they do so impacts the employee experience. A successful environment champions collaboration to lessen the stress placed on employees closest to the supply chain or any other production issues at hand. In Bangalore, India, I saw how deliberate and collaborative employee interaction could solve product processing challenges.

Figures 2 and 3: Molex Taiwan serves the automotive, consumer, datacom, industrial, medical, networking, and telecommunications industries. Molex staff embodies the mantra of "zero defects," ensuring high quality throughout the production process.

For more arduous job tasks—such as accommodating factory capacity, maintaining various product delivery schedules, and facilitating cross-department collaboration—one company systemized its procedure review. When they encounter an issue, operators stop the production process, brainstorm solutions, bring these potential solutions to a quality assurance team and then implement the changes through a management system in place, fostering a new type of learning environment with its people and collaborative problem-solving at the core. The success this brings isn't just apparent through workers' happiness and loyalty; their mantra of "zero defects," helps ensure their products demonstrate the highest quality standards through their production process (Figures 2–3).

Conclusion: Lessons can be learned on a global stage to ensure company efficiencies and worker satisfaction for future growth.

Seven million jobs unfilled is a staggering number, but U.S. economic growth and innovation hinges on addressing this workforce need. Companies are stepping up through commitments to hire interested—but untrained—workers, employee initiatives geared toward career progression, and a C-suite focus on finding ways to retain workers. These initiatives are helping to drive record growth in the electronics industry.

But the U.S. industry should take note of the lessons I saw around the world. For too long, countries have been resistant to learn lessons from others. But with our ever-shrinking globe and ever-expanding workforce, our neighbors have solutions that should be embraced. **PCB007**

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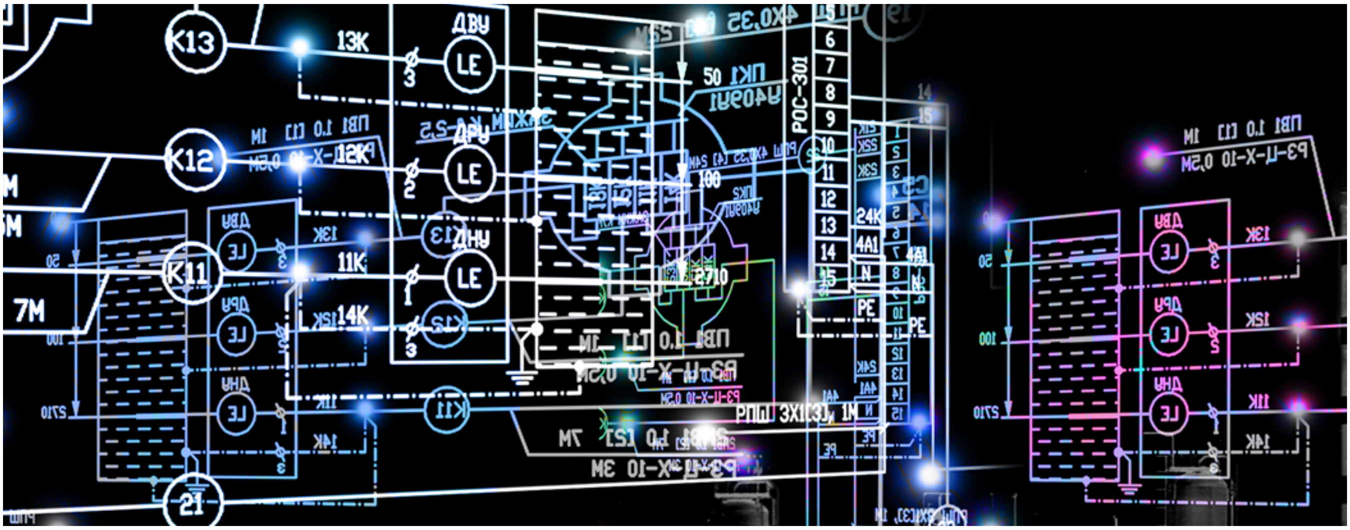
Dr. John Mitchell is president and CEO of IPC—Association Connecting Electronics Industries. To read past columns or contact him, click here.



Automation Planning: An Excerpt

Article by Happy Holden
I-CONNECT007

Editor's Note: In this excerpt from Automation and Advanced Procedures in PCB Fabrication, Happy Holden discusses how to break down the planning process using a technique called automation methodology to clearly define the current processes and the impact that automation will bring.

Automation, in a working context, means more than just automatic machinery. Machinery implies mechanization. Automation also means that system information directs and controls people, materials, and machines, also known as systemization. Therefore, automation is made up of two components, like a vector: mechanization, or material flow, and systemization, or information flow.

Mechanization Classes

Mechanization can be divided into six classes, which indicate the amount of sophistication of machines and machine interactions with humans. The classes are rated based on the percent of the work done by machines (Table 1).

Systemization Levels

Similarly, systemization can be divided into six levels that indicate the amount and sophistication of blueprints, information, data, scheduling, and control that take place (Table 2).

Each level has an increasing percentage of machine/computer content handling the information required to fabricate, schedule, test, or move a product.

	Mechanization Class	Percentage Mechanized
1	Manual	0%
2	Semi-manual	10-25%
3	Machine-assisted	25–50%
4	Human-assisted	50–75%
5	Semi-automatic	75–99%
6	Fully automatic	100%

Table 1: Mechanization classes.

	Systematization Level	Percentage Collected by Sensors or Computers
1	Manual information collection distribution	0%
2	Batch computer/human collection distribution	10-24%
3	Online computer/human collection distribution	25-49%
4	Real-time computer/machine interface	50-74%
5	Dedicated supervisory control	75-99%
6	Fully automatic gateway/network control	100%

Table 2: Systemization levels.

Automation Matrix

When both measures are applied to any activity in the process to tool or build a printed circuit, an automation matrix is created about that work center. This matrix allows for the current situation and future objectives or plans to be appraised, even if it is all manual (Figure 1). It is quite common for automation objectives to be made up of a number of steps or phases, allowing each step to be stabilized before the next one is taken. The automation matrix lends itself to this step approach.

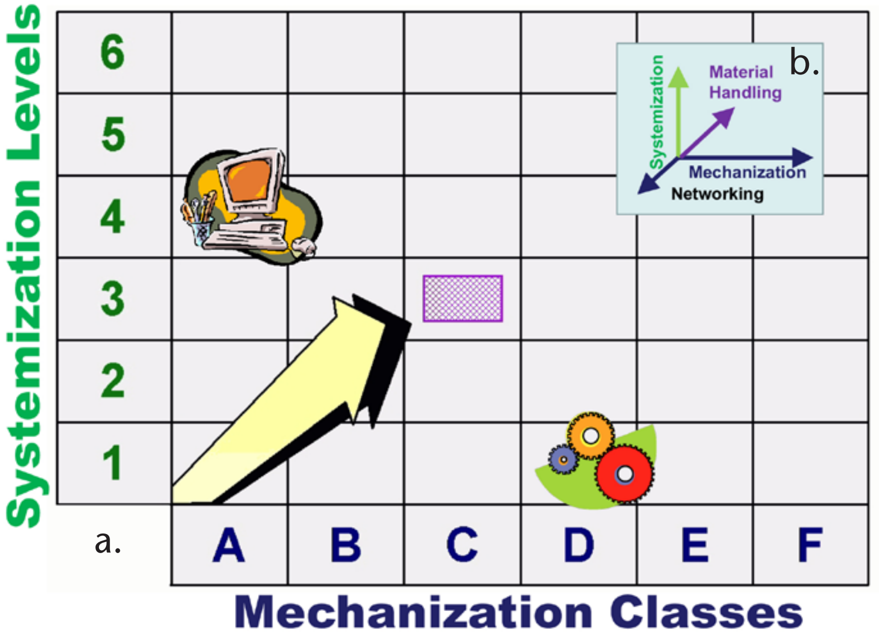


Figure 1: (a) Automation vector is defined as systemization and mechanization, (b) including material handling and networking between work centers.

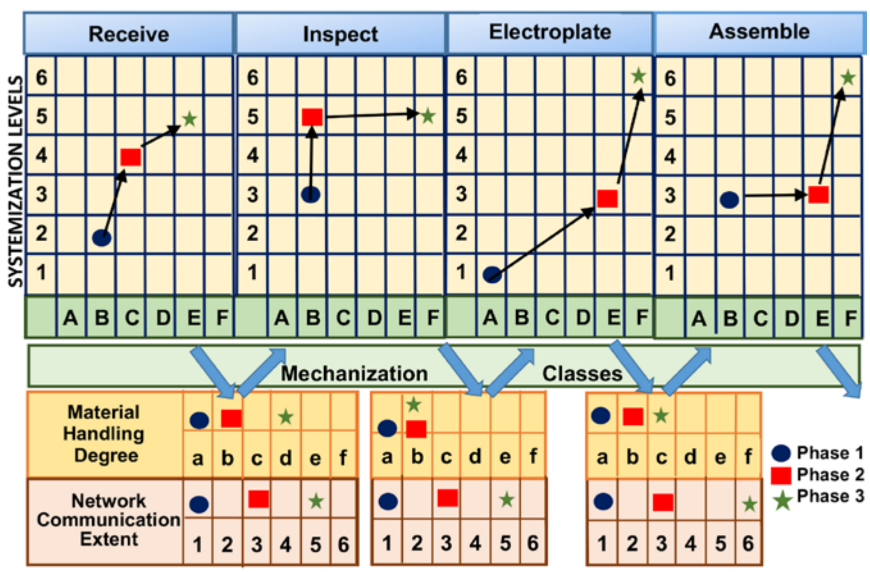


Figure 2: The automation methodology consists of automation plans for each work center plus plans for material flow and information flow between work centers.

Automation Methodology

Automation methodology is a formal procedure for planning, designing, and implementing automation. It is particularly important when you want to start integrating several previously independent production tasks into one or more automated systems. The methodology stems from the previously defined automation matrix (Figure 1). Additional axes are added to the matrix to cover material handling (mechanization) and network communication (systematization) between cells or work centers, as seen in Figure 1b. A simplified diagram is illustrated in Figure 2. The actual methodology will take up several drawings and utilize a number of worksheets to analyze and plan the data.

This methodology was used to design the automated Hewlett-Packard's printed circuit facilities for Hewlett-Packard in Sunnyvale and Palo Alto, California; Boise, Idaho; Loveland, Colorado; Waltham, Massachusetts; Boeblingen, Germany; Tokyo, Japan; and Puerto Rico. It was also used to plan and implement the 37 SMT assembly facilities worldwide. **PCB007**

For more details on automation, download *Automation and Advanced Procedures in PCB Fabrication.* Visit I-007eBooks.com to download this and other free, educational titles.

Agfa on Advances in the Inkjet Environment

Feature Interview by Pete Starkey
I-CONNECT007

Pete Starkey speaks with Frank Louwet, general business manager of electronic print within Agfa Digital Print and Chemicals (DPC) at productronica, about the continuing progress of inkjet techniques in volume PCB manufacturing. Frank further describes how the company's portfolio of specialist inks is enabling innovative approaches to overcome technology challenges.

Pete Starkey: Frank, it's great to see you again. Today, we will be discussing developments in inkjet inks, primarily for solder masks, as well as marking inks and etch resists. We had a very interesting conversation one year ago at the electronica show. Tell me about what has happened since then.

Frank Louwet: My first remark is that if you walk around this productronica show, there are a lot of developments in the inkjet environment, both on the equipment and the ink side. A few players are now offering or starting to offer inkjet inks, and on the equipment side, you see companies like Meyer Burger, Notion, Orbotech, and MicroCraft bringing in machines with multiple heads to increase the speed. Also, systems with higher resolution printheads are now available, so the technology is maturing. From our side, compared to one year ago, we have deepened and widened our portfolio of materials that we offer.

On the side of the marking inks or legend inks, we had inks mainly for rigid applications. Inks for flexible white applications were added, which completes our portfolio for marking inks. In Asia, there is a huge drive to replace the classical screen printing process with inkjet printing. Printing machines with multiple heads, even more than 10, have become available. They can run at higher speeds than screen printing. It becomes a mass-production or mass-volume market, which is a good development to see.

On the side of the etch resist inks, our DiPaMAT ER01 has been commercially available for two years. It's an ink designed for etching

in iron chloride or copper chloride and alkali stripping. It strips in flakes and works in the same etching and stripping lines that are used with dry film. We have also added a new series of materials that are soluble in the stripping solution for some industries where that is important. I have to admit that the main application today is not in PCB, but more in products like chemical milling, photochemical machining, decorative etching of metals, etc. It's a good market that is developing nicely.

Starkey: Is this an acid-etch resist?

Louwet: Yes, both inks are for acid-etch. The newest materials in our portfolio are plating resists. There's an interest from the market to do selective ENIG plating. For that reason, they cover part of the PCB with a plating resist through the ENIG process and then strip away the resist for applying a different finish, such as OSP on the rest of the board.

Starkey: We're not looking for critical edge definition; effectively, we're using the solder mask as the pattern-defining resist, but we're using your plating resist to mask the already-patterned areas that we don't want to plate with ENIG.

Louwet: Exactly. It's not an easy process (Figure 1)!

Starkey: You have to resist the ENIG process, which can be very aggressive chemistry, and then strip the plating resist without damaging the solder mask?

Louwet: We are succeeding in that, but the challenge has been to find the right balance.

On the side of the solder mask ink, we have commercialized our green solder mask, SMG01. Last year, we put in the hard work to optimize the ecosystem, including what kind of pre-treatments can be used, which printing and curing

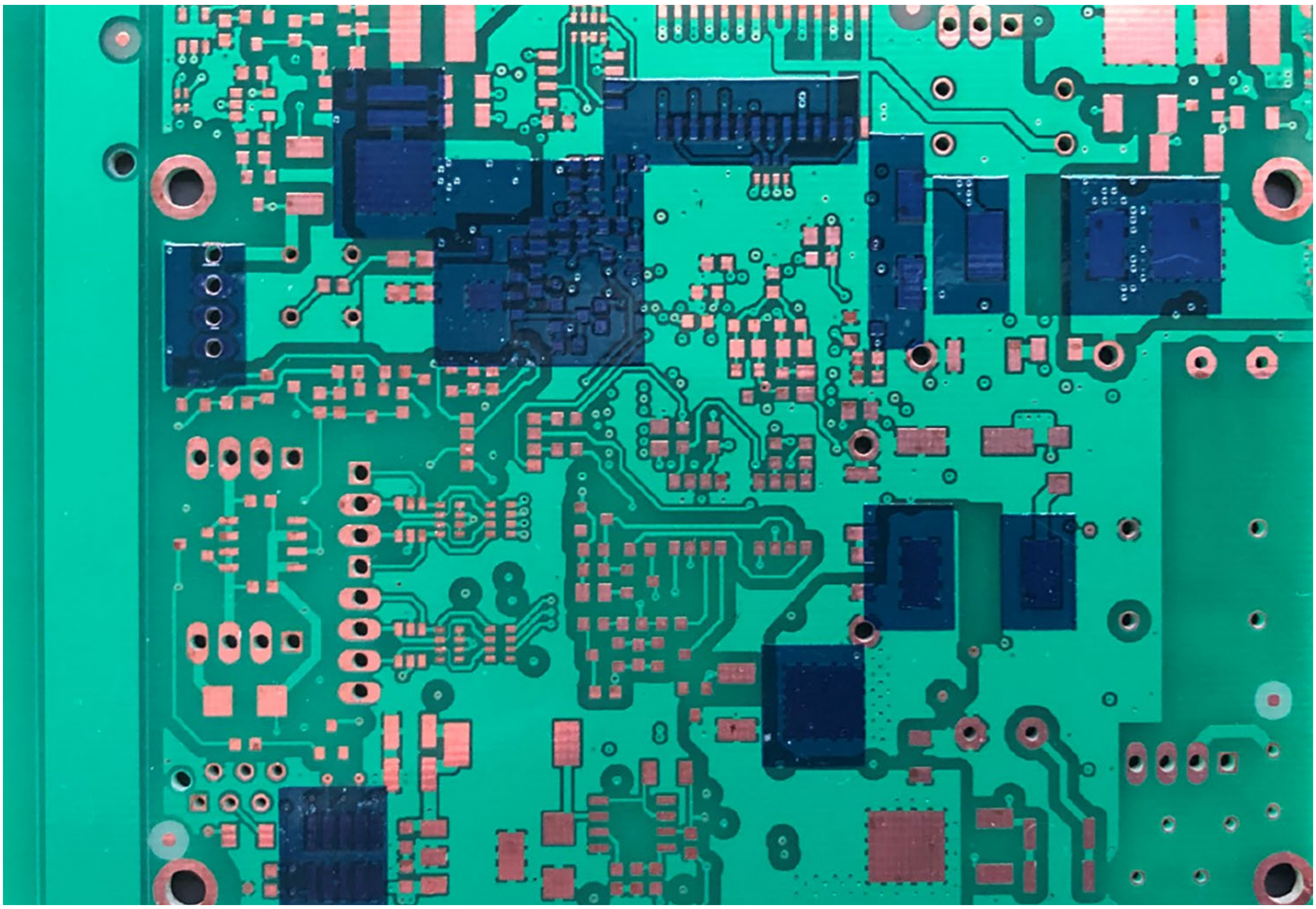


Figure 1: DiPaMAT PR01 plating resist.

strategy is best, and the post-treatments afterward. We can state that we have much more control now, which resulted in an operational installation running in Germany, and there is also a customer in the U.S. It's becoming commercial; people are starting to use it, and we see a lot of attention at productronica.

Starkey: That has been my experience at the show over the past few days. Talking to the ink suppliers, all of a sudden, people are asking for information about material supply for inkjet solder mask. People can see the benefits of inkjet solder mask, not just from materials consumption or the environmental point of view, but from a technical point of view. A good inkjet process can put ink where you want it and in the thicknesses that you want, and—particularly for critical conductors in 5G applications—avoid putting ink where you don't want any because it could interfere with the signal characteristics.

Louwet: If you were to apply solder mask and then remove it afterward, it would not be good enough for some 5G application, so customers don't want solder mask there at all.

Starkey: With inkjet, you have the benefit of being able to selectively place the material exactly where you do and don't want it; you don't place any material at all, which is probably not so good for tonnage sales of solder mask.

Louwet: Even if applied selectively, solder mask is used in big volumes. Also, for Agfa, it's the switch from analog to digital. Today, Agfa has a big share in the analog space since phototooling is still mainly used in solder mask imaging. That will go away sometime, so Agfa is aiming to replace the film by ink for applying direct digital solder mask.

Starkey: Walking around the exhibition, the whole manufacturing procedure in this industry is becoming a digital, data-driven process rather than analog. And we're not only talking about the data that drives the equipment and creates the images, but also the data that is fed back to the statistics, process control, and process improvement. I think that not only is digital the key to the future, but also the environment.

Louwet: The trend is a digital data-driven process, but today, and even tomorrow, the analog process is important. Agfa focuses on film and will support its customers until the end with it while also supporting their transition to the digital era. I agree that the environment is also a key benefit of the digital process.

Agfa focuses on film and will support its customers until the end with it while also supporting their transition to the digital era.

Starkey: Your original identity in the industry was as a primary supplier of film. It's good to know that although the utilization of film is progressively fading, you have new concepts, products, and materials that can take its place in another form.

Louwet: Innovation is important for a company like Agfa. With respect to solder masks, the newest developments Agfa is bringing are flex solder masks.

Starkey: Does this mean that we may see an end to the polyimide coverlay, piercing and punching holes, and sticking it on?

Louwet: That could be. We have two prototypes at this moment: one green, and one black (Figures 2 and 3). The green is in test at several customers in Asia, and it's looking very promising. It may even take off faster than rigid solder mask. Flex solder mask is a new product that we are presenting for the first time at pro-

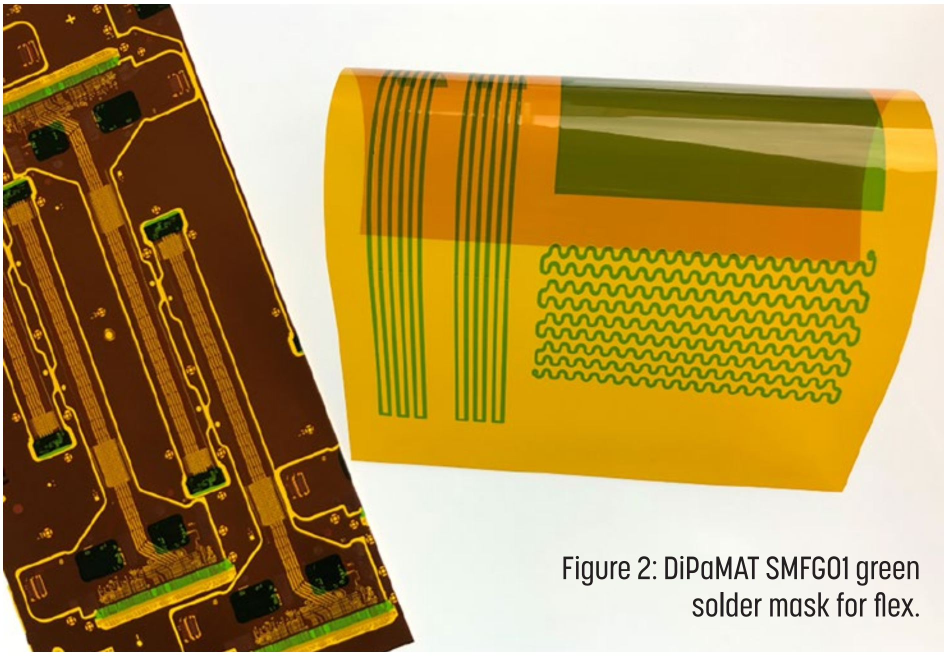


Figure 2: DiPaMAT SMFG01 green solder mask for flex.

ductronica, but we also continue our work with rigids. New versions are coming, and they are looking very good.

The next stage in the innovation is printing the metal, although this is probably more for printed electronics. We have developed a portfolio of silver inks, including screenprinting inks, but also an inkjet ink. It's a nanoparticle-based technology. It's an ink with very good conductivity and curing behaviour. Although the development was primarily for printed electronics, we have seen interest at productronica for applications in the PCB environment.

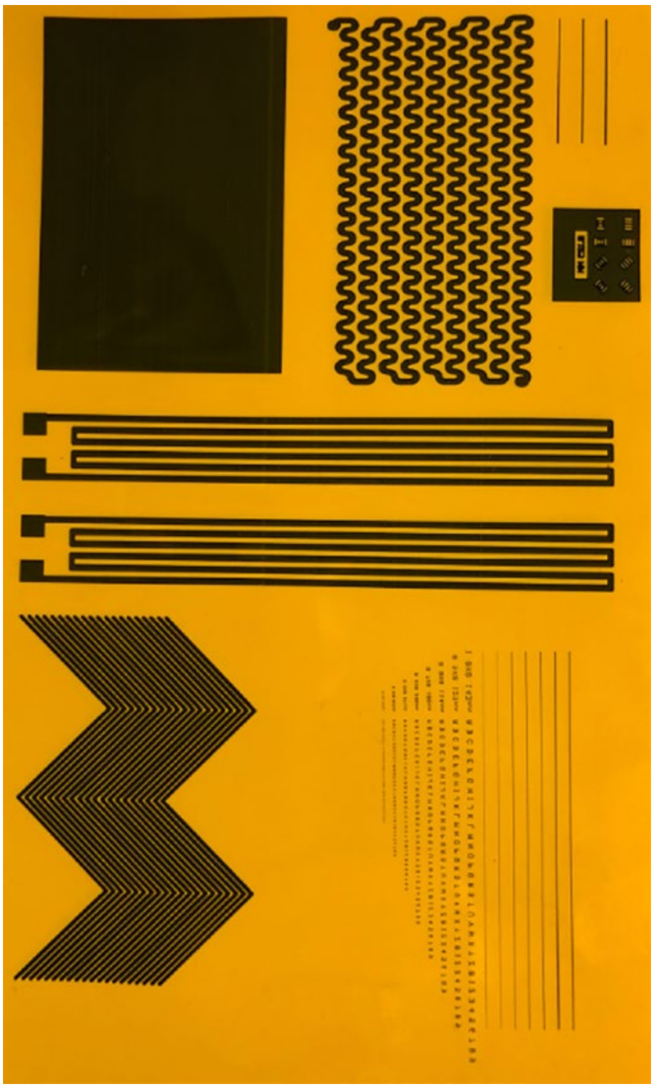


Figure 3: DiPaMAT SMFBl01 black solder mask for flex.

Starkey: I see a lot of the traditional boundaries fading away, and a lot of the technologies are supplementing and complementing each other, as well as combining with each other.

Louwet: I strongly believe that PCBs will become printed.

Starkey: You already have some products in place. Is that an area of continuing development?

Louwet: It certainly is. I summarized what we have done in the past year and where we are now and will keep you informed on our progress.

Starkey: Frank, thank you for your time and clear explanation.

Louwet: Thank you, Pete. **PCB007**

Further Reading

1. *PCB007 Magazine,* February 2017: Inkjet Printing Solder Mask.
2. Agfa: From Film to Inkjet Solder Mask.
3. Agfa: Staying Ahead of the Technology Curve.
4. Agfa Wins IPC Innovation Award.


John Watson

Designing Hardware for IoT Security

Feature Interview by Andy Shaughnessy
I-CONNECT007

Sure, smart technology is pretty handy. For instance, a moment ago, I said, "Alexa, play John Coltrane," and the Village Vanguard show came on. But how vulnerable are we to hackers who want to steal our data through these connections, and what can be done to secure these devices?

Happy Holden and I put this question to John Watson, CID, of Legrand, a company that makes smart lighting systems, among other things. Watson describes some of the techniques Legrand uses to keep their systems from being hacked and explains why each new IoT device is a potential target. Maybe Happy has the right idea; he's still using a 3G flip phone.

Andy Shaughnessy: John, Legrand does smart lighting systems, and IoT security is a big concern for you. Tell us about that.

John Watson: Part of the business at Legrand is lighting systems, but we also control lights, data, and power. We revolutionize the places where people work, live, and play. We are an international company with 96 sites around the world. Our site in the U.S., the one where I work, produces building control systems. My office is in Carlsbad, California, and we do anything that is involved with revolutionizing smart homes, IoT, and getting all those kinds of devices into a home that control lights, shading, special power sockets, etc.

Shaughnessy: You work with technology that turns the lights on, automates the controls, etc. You mentioned earlier that you worry quite a bit about security. How do you keep these smart systems secure?

Watson: Security is big. We have gone over to wireless. We're able to take a sensor that controls any of the series of lights in a building and control that through a central hub. It used to be hardwired with a CAT-5 connection from the hub to the light controller itself. We've gone over to a wireless setup to where they communicate under a protocol wirelessly.

The big problem with that is that this is an open signal that could be tapped. Several years ago, a casino in Reno was robbed. The hackers got into the mainframe through a fish tank, of

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R-5775	3.8	0.005

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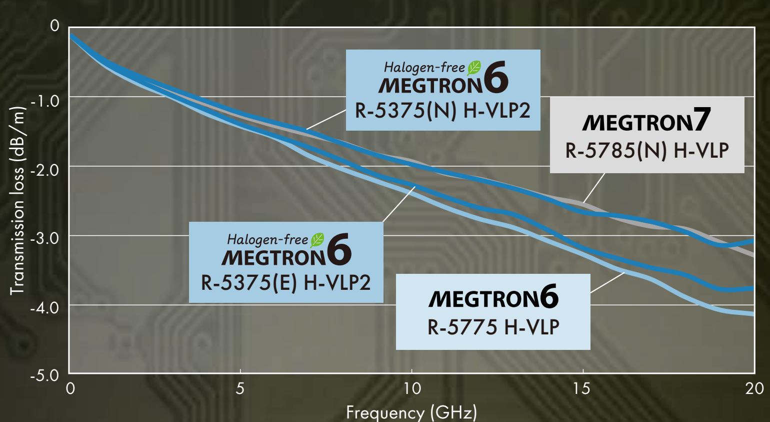
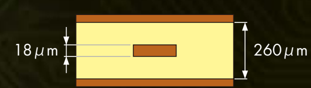


- Construction



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all things. It was a smart fish tank that someone could monitor or control remotely, and it was unsecured. From there, they were able to start transferring funds from the casino. It was huge.

Shaughnessy: Without a gun.

Watson: Right.

Shaughnessy: You have to admit that was kind of clever.

Watson: Sure. With these great hardware advancements, how we secure these networks has now become a major issue. We have a hardware identification embedded into our hardware so that each one of those is controlled by a Mac address. That's all I can say about how we've done this, but it's something that has to go hand in hand with design now. We can't depend on firmware to secure our systems.

Shaughnessy: IoT is a cool idea, but on the other hand, all of these things that are connected are going to have an identity that hackers can find, if they take the time to look.

Watson: I don't know if it's a cool idea or not. It's a cool-sounding idea. I bought a smart refrigerator that can tell me what I'm out of, and updates are sent directly to my phone. My concern is that I also have a smart scale. What will happen when my refrigerator starts talking to my smart scale, and I say to my refrigerator, "Add a dozen donuts to my shopping list?" It will be like a scene from "2001: A Space Odyssey." The fridge might say, "You know, John, I've been talking to the scale, and we've decided to put you on a diet, so I can't do that. I'm sorry, John."

Shaughnessy: "I'm doing it for your own good. Trust me (laughs)."

Watson: IoT is a huge industry. I understand there are supposed to be 20 billion new products installed, such as sensors. All these different items are going to be sensing and monitoring everything, which comes with a warning, because it all has to be secured.

Shaughnessy: Are there standards for security for this?

Watson: There are security standards in place, but you don't want someone to be able to pull up in front of a skyscraper, tap in, and start controlling everything.

Happy Holden: That reminds me of the 36-year-old science fiction movie called "Runaway," starring a young Tom Selleck as a cop whose job is to catch runaway robots, including office robots delivering mail that were going berserk. It was extremely humorous in 1984, but if you were to watch that movie today, you would be very much alarmed. However, 36 years ago, it was science fiction.

One of the funniest things was Selleck's character was having a conversation with a for-hire guard in his seventies in a language that only those of us with a Ph.D. in networking could understand, but it was common jargon. Even the 70-year-old guard talked about protocols and handshakes and things like that, but the audience didn't appreciate it because they didn't know enough about what they were talking about.

Watson: Now, that's common knowledge. There's even a tractor that can connect to the internet.

Holden: I've seen those. I love them.

Watson: Also, the whole autonomous vehicle industry is a space where everybody wants it. Some people look at these vehicles as a challenge; they say, "I'm going to try hacking into that autonomous vehicle," and some hackers have.

Holden: Over the last two years, I've been given four Echo Dot devices, which are always on and listening so that you can talk to it.

Watson: But they say they're not listening, Happy. They wouldn't lie (laughs)!

Holden: Unless they came with infinite batteries, I'm okay. I haven't plugged any of them in. Unfortunately, or fortunately, I have two smart television sets that are now connected to the internet, but I still have a 3G flip phone. I can make phone calls without worrying about things, but people keep giving me devices that, frankly, I don't know if I can trust.

Watson: That's true. There's a whole trust issue with security and these smart innovations, and there's a level of pain that people are willing to accept for the convenience of the IoT experience. In my home, I placed a dozen smart bulbs that I can operate from my phone, which is a lot of fun because I didn't tell my wife that I was putting them in. It worked out so that I was able to sit on my sofa, control the lights, and she didn't know what in the world was happening.

Holden: I worked on the printed circuit design of one of the first internet thermostats for heating and air conditioning, which were particularly useful for remote cabins, etc. When you left home, you could tell it to start heating the place up so that it wouldn't be ice cold when you arrived. And it was only by accident that we discovered that the thermistor we used for the temperature sensing was sound-sensitive. We found we could, through the internet, under the temperature mode, listen to anybody in the area. That wasn't by design.

Watson: And as soon as you realized that, I'm sure you stopped the design process immediately and did not proceed.

Holden: We put it on our high-priority to-do list to fix that bug and find another thermistor. However, we didn't change the product line because the schools had bought it to have classrooms that automatically turned the temperatures up or down. It provided energy conservation. Everyone says, "We're not listening," but maybe they are.

Watson: Legrand controls lights a little bit more like what you're talking about. We change the color of the light as we monitor outside and ambient light. We also change the color of the light to change the mood in the room. This is all done automatically.

When these devices are controlled manually, that's great, but now we're getting into where they're automated. We have enough sensors out there monitoring that we adjust it automatically as different parameters and situations change, such as the weather. It comes down to a dual-pronged design approach. It involves hardware development being secured, and there are multiple ways that can be done. You must have firmware security involved as well because some people see these devices as challenges for their hacking skills.

Shaughnessy: You have to stay one step ahead. You're like TSA; you have to be right all the time. The bad actors only have to make it once.

Watson: Exactly.

Shaughnessy: This has been great, John. Thank you.

Holden: You have to watch "Runaway."

Watson: I will. Thank you both. **PCB007**

Industry 4.0 Data for Legacy to Modern Machines

Feature Interview by Nolan Johnson
I-CONNECT007

At IPC APEX EXPO, Nolan Johnson and Tim Burke, CTO at Arch Systems Inc., discuss the need for software—and hardware, in some cases—to pull process data out of traditional silos and make it available for optimization and business decisions.

Nolan Johnson: Tim, tell me about your company.

Tim Burke: We are an Industry 4.0 provider. We partner with large enterprises with many factories and help them accelerate their Industry 4.0 transition through a variety of things.

Johnson: Is Arch Systems a relatively new company?

Burke: We have been around for about five years.

Johnson: Where do you fit in?

Burke: One of the unique services we provide is we work with large manufacturers that have a lot of different machines—both legacy and modern machines from many vendors and systems—across many factories, which is pretty typical. We provide a couple of different products. One is we can get data out of any machine. We can work with machine vendors, even with old machines that aren't supported anymore. We can provide a standard way to get data out of any machine. Once we have that data, we unify it into what we call a data broker, which allows you to feed it into your various systems in a standardized way. We also provide focused global applications on top of that data that can solve some cross-sectional ROIs a lot of our customers are looking for.

Johnson: Let's walk through that step-by-step because that's a lot of good information you started with. You can get data out of any machine, new or old?

Burke: Correct. We have a variety of techniques we can use. For example, many modern

SMT machines have interfaces with plenty of ways of getting data; we integrate with those. There are also machines on the mechanical and assembly sides that are older and more legacy; maybe they're just purely mechanical machines like presses. We also have some hardware components for those particular machines to get data out of them. We can interface with PLCs directly with industrial protocols. Whatever is required to get data out of any machine, whether it's modern or legacy, we're never blocked.

We can interface with PLCs directly with industrial protocols. Whatever is required to get data out of any machine, whether it's modern or legacy, we're never blocked.

Johnson: Now, you can get all the data from all the machines, regardless. You now have this heterogeneous manufacturing floor all wired up and your data collection correct. You can do something with that.

Burke: There are a couple of things we find our customers really want to do with it. One is they want to be able to provide it on-demand to their own internal applications in a way that doesn't require them to duplicate the work of the direct machine connection every time. We call this our data broker. No matter where the data came from—if you are a home-built MES, a local site application for dashboarding, or a traceability application that is home built for a customer—rather than each one of those individual products going back to the same machine, asking for the same data from the same vendor, and getting the same support, slightly different but basically the same, they get it from the broker. It's one connection with one system, and it feeds the data to the various people. That's one thing we help our customers do.

Johnson: That means that if you have a heterogeneous software environment—using different software tools in different sites—by working with the broker, you not only have a unified place to bring the data together on the hardware sensor side but also on the analysis software side. This starts to make a lot of sense. One major challenge that seems to show up for factory automation is having the data end up in silos. You have been talking about getting past that.

Burke: Let me give you some very specific examples of what we mean by that. Let's take, for example, MES data. MES data is very focused on products, so that's very critical for a factory. What happened to my product? It went through machine A, then machine B, and then machine C. If that's the only way you store your data, it's very easy for you to track across a single product what conditions it saw, which is critical for your factory.

What's hard in that case is seeing what happened for a given machine. What are all the products it saw? And if you only look product by product, you don't see trends like the machine is slowly getting out of alignment, slowly getting out of process control. By putting together the data in a vertical rather than horizontal way or vice versa, suddenly, you can develop different insights from the same information.

Imagine doing that with MES and specific data augmented from the machine as well as ERP data and other data from SPC and process control databases at the customer. It's impactful, putting all that together and starting to see what new insights I can draw that weren't present in any given system because it wasn't a job of any given system, but it was a new thing for Industry 4.0, looking across these big data sets with modern tools that excel in this large data environment.

Johnson: Who are your customers at this time?

Burke: We partner closely with a number of large EMS companies. In particular, we have a global role with Flex that we're going with connecting up all of their machines across the world.

Johnson: How is that integration process rolling out? How much time seems to be involved in implementing this? It would seem on the surface like this could be a significant project.

Burke: A global rollout definitely takes time to get everything in place, but what we're finding is that some of the modern techniques we bring to bear can accelerate it because you don't upgrade machines, and you don't need to install hardware on all the machines. It's just software and connections, and it can happen very quickly once you get the right sort of alignment of what we're doing and going to roll out. Then, it's about going from the class of machine to machine.

Johnson: To get data that I can use for business decisions, what's involved there? I'm just imagining being a manufacturing manager.

Burke: I was talking about a couple of different levels. One level is the site level—ultimately, lines in a building in a site. It starts with the data broker, so this is a software product that can live on the site, depending on different customers; they may prefer it differently. They might prefer regional versus local, but it can be either. Then, there's the aggregation point where data goes. From there, you start connecting individual machines. At that point, you have information that you can use to feed dashboards at the site level or to aggregate site by site.

Johnson: On the business decision side, is the set-up process fairly straightforward and quick?

Burke: Absolutely. Often, we find that we're able to install much faster than it took us to have the meeting to decide to install. It's a very straightforward, modern software application; it's not a week-long process. We have access, put it on the server, and it's up and running. We go to the machine, connect it, and it's done. It's very fast.

Johnson: With customers already starting to roll this out, are they starting to see an ROI for this?

Burke: Yes. We have seen a couple of specific ROIs. One case that's very interesting is unifying different ways of getting the same data from the same machine rather than having each individual system connect directly to the machine and duplicate a lot of work and have a lot of silo knowledge site by site. You have one application, and now your internal applications can be standardized and rolled across many sites because there's no difference from site to site. Rather than a per-site dashboard, you can have a global dashboard and can roll it out to a site or to another site.

Rather than a per-site dashboard, you can have a global dashboard and can roll it out to a site or to another site.

Johnson: That sounds like there's significant progress toward taking the data that we can now collect in Industry 4.0 and making it an analyzable part of the decision-making process.

Burke: Exactly.

Johnson: Fantastic. Thanks for your time.

Burke: Thank you very much. It was my pleasure. **PCB007**

To watch this *Real Time with...* video interview from IPC APEX EXPO 2020, click here.

What Are the True Benefits of Going Digital?

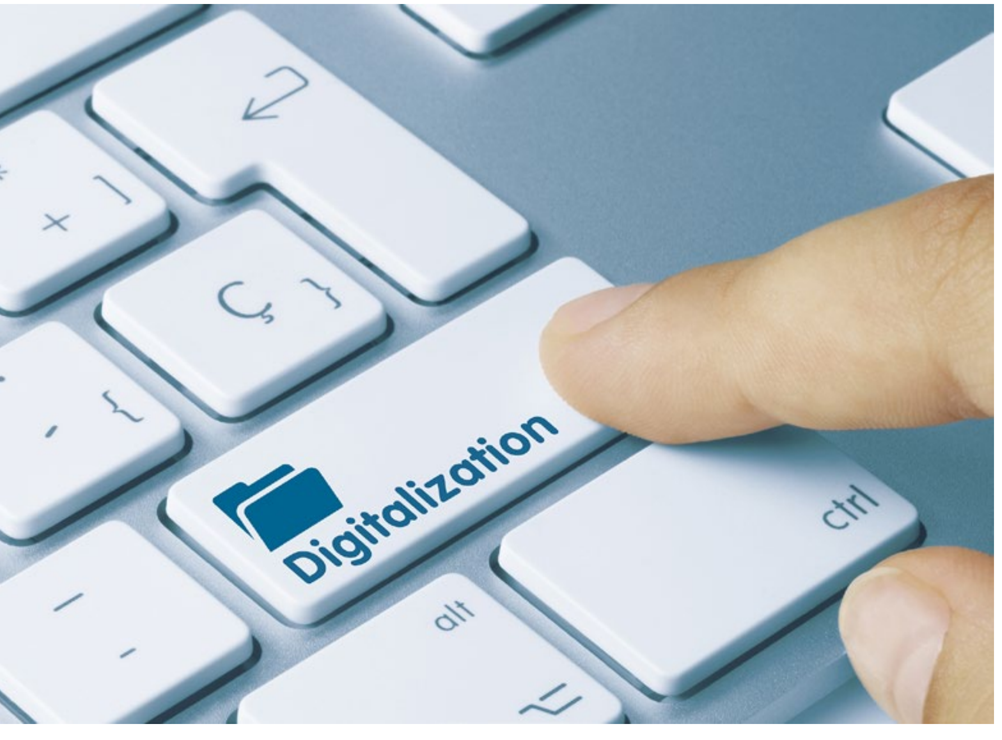
The PCB Norsemen
Feature Column by Didrik Bech, ELMATICA

2019 might have been the year when the trend word digitalization really kicked off and transitioned from being a buzzword to aligning with keywords and concepts as AI and IoT. These are terms we already are familiar with and trying to implement into our day-to-day business operations. The future of digitalization is not coming; it's already here, so the questions many pose are, "How will it affect me and my business, and what can and should I do"?

What is "digital," and how do you define it? If you do not define it, then what is it, and how can you utilize and understand it? Digital should not be seen as a thing; rather, it's a way of doing things. To make this definition more concrete, one can break it down into three attributes [1]:

1. Creating value at the new frontiers.
2. Creating value in the processes that execute a vision of customer experiences.
3. Building foundational capabilities that support the entire structure.

1. Creating value at new frontiers requires a reexamining of your way of doing business and understanding where the new frontiers of value for your customers (I would recommend reading the book *Great at Work* by Morten T. Hansen in regard to understanding customer values). This simply means understanding how you can improve your customer experience, share relevant data, and ensure that your customers have a higher valuable input from using your systems and methodology compared to your competitors.



2. Creating value in the processes that execute a vision of customer experiences is rethinking how to use new capabilities to improve how your customers are served. Thinking about how digital capabilities can design and deliver the best possible experience across all parts of the business to your customers. For example, digitizing your supply chain is critical for developing the flexibility, efficiency, and speed to deliver the right product efficiently to your customers as they want.

3. Building foundational capabilities that support the entire structure means using data to make better and faster decisions, devolving decision making to smaller teams, and developing more iterative and rapid ways of execution. A key feature of digitizing IT is the commitment to building networks that connect devices, objects, and people.

Once digital is defined, the next question is determining how the process of digital transformation can be executed. First of all, there are four types of digital transformation to be utilized

- Business process
- Business model
- Domain
- Cultural/organizational [2]

1. Business process transformation has been the main focus so far by using data, analytics, APIs, machine learning, and other technologies to offer corporations valuable new ways to reinvent processes throughout the corporation—with the goal of lowering costs, reducing cycle times, or increasing quality.

2. Business model digital transformation focuses on finite areas of the business, aimed at the fundamental building blocks of how value is delivered in an industry. Examples of this kind of innovation are well-known, from Netflix's reinvention of video distribution to Apple's reinvention of music delivery (iTunes) and Uber's reinvention of the taxi industry.

3. Domain transformation is an area with little focus as new technologies are redefining products and services, blurring industry boundaries, and creating entirely new sets of non-traditional competitors. For example, as Amazon, the online retailer, expanded into a new market domain with the launch of Amazon Web Services (AWS); now, the largest cloud computing/infrastructure service is in a domain formerly owned by the IT giants like Microsoft and IBM.

4. Cultural/organizational transformation requires redefining organizational mindsets, processes, and talent and capabilities for the digi-

tal world. Best-in-class corporations recognize that digital requires agile workflows, a bias toward testing and learning, decentralized decision-making, and a greater reliance on business ecosystems.

When we have defined what digital is and four different processes of digitalization, then how can this be used in mature industries such as PCBs? The PCB industry will reach 80.1 billion USD by 2023 [3], and the production and data handling processes have practically remained the same over the last decades. Numerous independent systems, global standards, and self-developed systems exist, and few, if any, can speak the same language or automatically/digitally transfer data from one format to another.

Are We Set for Digitalization in the PCB Industry?

Is the industry ready for digitalization? I believe so, and I will point out some challenges to overcome and opportunities to be grabbed for the brave actors, wanting to further develop an entire industry.

Significant challenges and opportunities in the PCB industry are specifically related to how we handle, interpret, and transfer data. There is no global standard for how we should understand the data we receive or how it should be constructed or summarized. Various actors create their independent files and "languages" for conveying PCB data, and the inevitable consequence is that every PCB article requires a tooling procedure (non-repeating expense). This allows all the actors involved in the procurement and manufacturing of an article to agree on how to construct the PCB and how the data should be interpreted. This is the major challenge in regard to digitalizing the PCB industry, and this further reduces the possibility of optimizing and integrating automatic supply chain management.

Reduction in Errors, Handling Time, and Quality Issues: A Dream?

If there was a global standard for data handling the consequence for all the actors in the industry, there would be a reduction in errors and quality issues, reduced handling time, and increased transparency. One would easily be able to verify that what one has specified and ordered was what the manufacturer has produced and delivered. Correct quoting in regard to price would also be a consequence as all actors would have interpreted the data in the same way. Further positive elements of the digitalization of the PCB industry would be elements such as verifying environmental standards, sharing data from audits to ensure that there is no child labor in certain countries, and detecting quality issues automatically, based on data mining.

There are simultaneously global elements and megatrends, which are starting to affect the data handling and digitalization of PCBs on certain levels. In this respect, I am specifically referring to compliance and cybersecurity. Compliance in regard to proving and documenting what has happened, who has accessed the data, where the data is, and if all international laws and regulations are followed.

Data Protection: Is Someone Stealing Your Gold?

At Elmatica, we see an ever-increasing demand for compliance combined with total transparency, and those who are able to deliver this product will have a strategic advantage. Cybersecurity is practically walking arm in arm with compliance, as it is the essential cornerstone for providing compliance in any industry, whether it is medical, telecommunication, or defense. The questions are simple: Is your data protected? Who has access to your data? And is somebody stealing your intellectual property rights?

Some tend to limit automation and digitalization to robots doing the labor humans used to perform; however, it's so much more. The digital era brings endless opportunities when it comes to manufacturing and purchasing processes. Moving from manual systems and handling to automation all over the PCB production and purchasing chain will affect the business and how we plan, design, purchase, produce, and ship.

Compliance Is King

Digitalization will improve the industry in several fields, and make it harder if not impossible for unprofessional actors who believe in a production strategy not based on documenting everything they do for their customers. Last year, I had the pleasure of attending several courses and seminars in Europe, Florida, Las Vegas, and Washington regarding compliance and cybersecurity. All I can say as the oldest and a trusted broker to all industries, compliance is tightening, and cybersecurity is king. **PCB007**

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1. D. Dörner and D. Edelman, "What 'Digital' Really Means," McKinsey & Company, July 2015.

2. A. Annacone, "The 4 Types of Digital Transformation," June 19, 2019.

3. Business Wire, "Global Printed Circuit Board (PCB) Market Report 2018: Trends, Forecast, and Competitive Analysis 2012-2017 & 2018-2023–ResearchAndMarkets.com," November 12, 2018.

Didrik Bech is the CEO of Elmatica. To read past columns or contact The PCB Norsemen, click here.

Michael Ford

One-year ROI: Smart Factory Implementations

Feature Interview by Dan Beaulieu

At IPC APEX EXPO 2020, Dan Beaulieu spoke with Michael Ford, senior director of emerging industry strategy at Aegis Software, about machines talking to machines using IPC-CFX, as well as strategies to turn any factory with old or new equipment into a smart factory.

Dan Beaulieu: Michael, you're with Aegis Software, which is one of the foremost-thinking companies in our industry, taking us into the future of smart manufacturing and smart factories. Can you expand on that?

Michael Ford: It's a really exciting time because we have been talking about smart factories and Industry 4.0 for quite a while now, and companies have been exploring how to get started. Companies discuss how many connections they think they're going to need, how many machines to talk to each other, and then they find out the cost and say, "Game over. That's it. Stop. I'm not interested anymore." It's millions and millions of dollars of investment. That kind of proprietary interface is making Industry 4.0 a non-starter, but now we have a combination of technologies that makes smart manufacturing available for free.

It sounds too good to be true, but it is because it's kind of three layers. Step one is you start at the base layer with IPC-CFX (connected factory exchange). Instead of paying $30,000 per machine connection, for example, with IPC-CFX you get the data natively from the machine vendor for free—fully featured and documented with all the details you need.

Step two is you introduce the IIOT-based MES platform. This is going to build a context for all of that information. Of course, our software is not free—there will be a price tag—but all of the functions that we create within that MES environment brings a net return on investment (ROI) within the year.

Beaulieu: A one-year ROI?

Ford: Exactly. Now, start to compare any other model of smart manufacturing technology within that year, and that's impossible. Instead of companies seeing a price tag of millions and millions of dollars, that they have to carry on the balance sheet for many years, we say, "By the time you get to the end of the year, you're in profit." That is revolutionary because it means that companies can now seriously start

to introduce Industry 4.0, smart manufacturing, or whatever you want to call it.

Beaulieu: Can you retrofit this, or does everything have to be new to set up?

Ford: It is able to be retrofit in a couple of different ways. Obviously, the 400 machine vendors that are part of the IPC-CFX committee right now and their machines will be expected to have IPC-CFX. The software development kit (SDK), which is available from IPC, is completely free of charge. That can be slotted into existing machines, even end-customer machines; they can use it themselves in their own systems.

Then, there are the really old machines. The equipment manufacturers have been making machines that are too good (laughs). The machines just keep going, and they're adding value, so why replace them? Why do you need to invest money in new machines? There are two ways of doing it.

The equipment manufacturers have been making machines that are too good (laughs). The machines just keep going, and they're adding value, so why replace them?

One way is that from our software, we already have hundreds of legacy machine interfaces that can coexist seamlessly with IPC-CFX. In that case, there's no barrier to doing it. For other solutions, there are little interface boxes, where the machine has genuinely no communication capability whatsoever. Further, there are third parties who are making a little box with the Raspberry Pi computer inside for less than $30.

Next, you have an IO board, which is another $30. You put that in a box and buy it commercially. Seika is one company selling this right now, or you could just do it yourself. It's really simple, and then you have a little bit of firmware inside there. Especially since the software from IPC is completely free of charge, you are then upgrading that machine into the digital factory.

Beaulieu: If I'm the operator at a 20-year-old PCB manufacturer with both new and old equipment, and am interested in this, what's the process?

Ford: The first step is understanding what you want from smart manufacturing because everybody has a different story. It depends on what they have read and who they have talked to, but let's focus on the business principles—the profit and the benefit that we want. Then, you can understand how to get there and what kind of functions you need. For instance, do you need to make faster decisions, reduce the material inventory, or make the lines more flexible by changing over quicker?

Also, what are the key requirements? To achieve that, we have people in manufacturing with the brains that they know what to do, and we augment their decisions by providing information. We identify the precise sources of that information. Then, we go to IPC-CFX and our own repository of interfaces and start to build a structure of the solution that's going to deliver that opportunity. Then you have a plan.

IPC is there to help. They provide accreditation for machine vendors to provide IPC-CFX off the shelf without any issues. We simply "plug and play" those machines into our software. Within a very short time we have the deployment of a fully-featured, IOT-driven MES system.

Beaulieu: How did you get to this point?

Ford: It has been a challenge because the demand for value from the utilization of this data has been there for quite a long time, but the way to get it for all players in the industry, not just us, has been extremely difficult. We spend about half of our total R&D budget on

just making that connection with the machine; that is a barrier to entry for a lot of people.

We pride ourselves on having created all of these interfaces, but the critical thing that's happening now, because the expectation of the industry is we all want to be smart, is not sustainable. That's why Aegis has been one of the leaders to create IPC-CFX so that we can have this availability of information for all.

Beaulieu: Are you getting some interest?

Ford: Yes, it's unbelievable. We cannot stop. People had been afraid of taking that first step. Until now, people had read and talked, but not done anything. This year, they are taking action. We are expecting a fair number of success stories coming very soon, which I will be really happy to share.

Beaulieu: Very good. As we wrap up, where can people learn more?

Ford: People can always visit cfx.ipc.org to learn more about IPC-CFX and become part of the solution.

Beaulieu: Perfect. Thank you for talking to me, Michael.

Ford: It was great to talk to you. Thanks. **PCB007**

To watch this Real Time with... video interview from IPC APEX EXPO 2020, click here.

Electra: The Benefits of Inkjet Printing

Dick Crowe speaks with Shaun Tibbals, sales and marketing director at Electra, about inkjet printing as opposed to conventional approaches, such as curtain coating and/or screen printing. Benefits involve the economical use of materials and zero VOCs. **Click the image to view video.**

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IT-170GRA1 Value Proposition

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- Best in class CAF performance
- Very attractive price to performance ratio
- Pass MRT-6 requirements
  - -CAF > 1000 hours
  - -0.65mm pitch equivalent, no thermal issue
- Available with RTF and 2μ copper which provides additional performance on a very solid platform
- Df = 0.0075 @10GHz

Intel Purley Mid-Loss Solution – IT-170GRA1

Futures

Halogen free mid loss, Df < 0.01
Tg 180ºC by DSC, low CTE

Applications

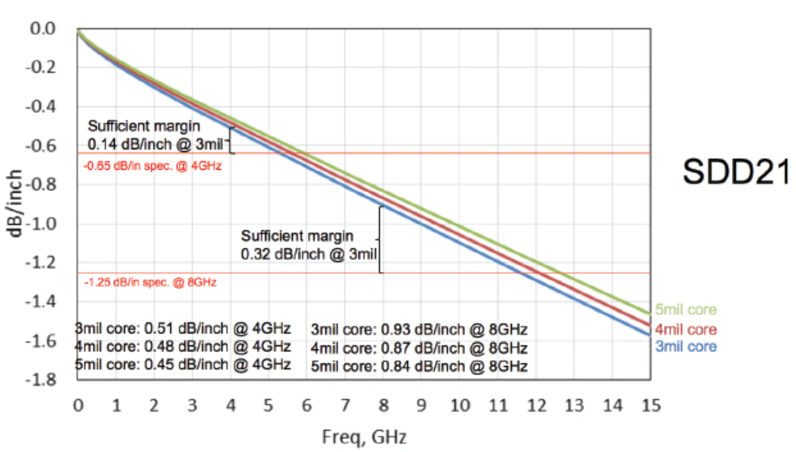
Server/Storage/Switch (10G, 40G)
Backplane, Telecom
Base station

Feature *Purley Platform Mid-Loss Solution – Hi Tg*

General Properties

Items	Methods	IT-170GRA1
Tg (℃)	DSC	180
T-288 (w/ 1 Oz Cu, min)	TMA	60+
Td-5%(℃)	TGA 5% loss	380
CTE (%), 50-260℃	TMA	2.4
Peel strength (lb/inch)	1 oz	7.0
Water absorption	D-24/23	0.1
Dk: 2-10 GHz	Bereskin	3.96 – 3.99
Df: 2-10 GHz	Bereskin	0.0073 - 0.0075

IT-170GRA1 Insertion Loss



ITEQ

MilAero007 Highlights

Zentech Manufacturing Acquires Trilogy Circuits ▶

Zentech accelerates effort and strategy to build leading electronics manufacturing services (EMS) providers for defense, aerospace, medical, and other high-reliability industries.

Dynetics' X-61A Gremlins Air Vehicle Performs Its Maiden Flight ▶

Dynetics, the performer for the Defense Advanced Research Projects Agency (DARPA) Gremlins program, successfully flew its X-61A Gremlins Air Vehicle (GAV) for the first time in November 2019.

Absolute EMS Inc. Passes AS9100 Rev D Audit with Zero Findings ▶

Absolute EMS Inc., a leading provider of turnkey and consignment manufacturing services, is pleased to announce that it successfully completed its 2020 surveillance audit for the AS9100 Rev D SAE International Aerospace Standard with zero findings.

3D Imaging System Innovator GelSight Raises $10M in Series B Funding Round ▶

GelSight, the developer of industrial 3D imaging solutions for the aerospace, automotive, and other electronics industries, announced that it raised $10 million in new funding.

Bell Boeing CMV-2B Osprey Successfully Completes First Flight ▶

The first CMV-22B Osprey, built by Bell Textron Inc., a Textron Inc. company, and Boeing, completed first flight operations at Bell's Amarillo Assembly Center. The CMV-22B is the latest variant of the tiltrotor fleet, joining the MV-22 and CV-22 used by the U.S. Marine Corps and U.S. Air Force.

Dr. Jennie S. Hwang Appointed to the Board on Army RDT&E, Systems Acquisition, and Logistics, U.S. Department of Defense ▶

Dr. Jennie S. Hwang was appointed to the Board on Army RDT&E, Systems Acquisition, and Logistics (BARSL), which has recently been established to advise the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA[ALT]), the U.S. Department of Defense, on national security, engineering, technological, operational, management, and logistical issues.

DOD Innovation Units Join Forces to Engage Small Business ▶

In the collaborative nature of innovation efforts in the Department of Defense, five agencies came together to present the first-ever Joint Small Business Innovation Research Open Topic for the first application period of 2020.

NASA, SpaceX Complete Final Major Flight Test of Crew Spacecraft ▶

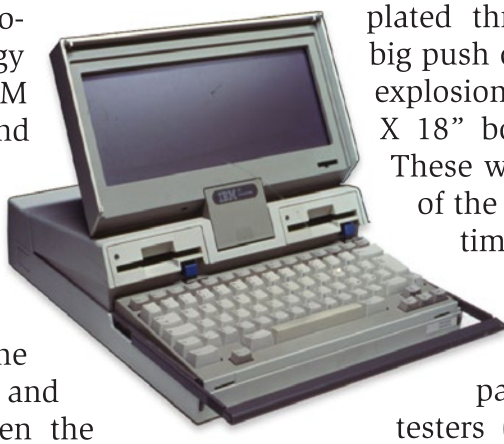
NASA and SpaceX completed a launch escape demonstration of the company's Crew Dragon spacecraft and Falcon 9 rocket. This was the final major flight test of the spacecraft before it begins carrying astronauts to the International Space Station under NASA's Commercial Crew Program.

BAE Systems Awarded a Prime Position on Five-Year IDIQ Contract ▶

BAE Systems will provide C5ISR, technical support, and life cycle sustainment to the U.S. Navy to improve the situational awareness of military operators and decision-makers.

Looking at Digital With 1111100100 Vision

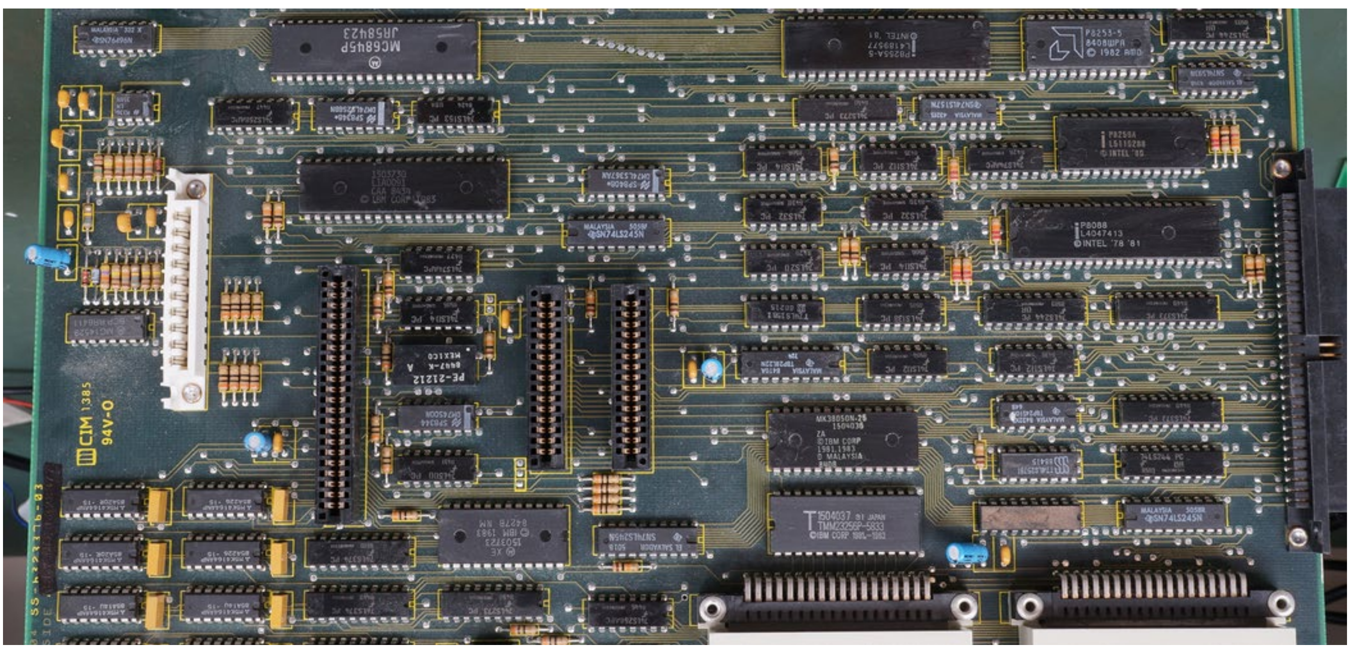
Testing Todd
Feature Column by Todd Kolmodin, GARDIEN SERVICES USA



Sitting down to my first exposure to the modern technology of the era was an original IBM PC (4.77 MHz.) If you could find the 5¼ inch floppy disk with DOS version 0.92 (which I still have for nostalgia), you were up and running. Insert that disk into drive "A," flip the big red power switch on the side, and after some "whirring and buzzing," you would be given the date/time prompt. It works! Now what? I'm staring at an A> on the screen with a flashing cursor. That's what it was just a mere 34 years ago.

Circuit boards of the time were mostly double-sided, with some larger manufacturers delving into the 4, 6, 8, and 10 layers. All were plated through-hole only (PTH). The big push of the time with the computer explosion was the motherboards (18" X 18" boards with all drilled holes). These were the PCs and workstations of the time. The electrical test of the time was extremely easy compared to now. CAD systems were laying out the boards on 100 mil grids for the DIP packages of time. Universal grid testers (fixture testers) were all 100-mil grid as well. There was no such thing as "Netlist" testing.

Back then, it was all self-learn and compare. Creating the test fixtures was a process of manually digitizing the outer layer film. There were no electronic drill files. Remember that we are playing with 360K DSDD floppy disks. Once



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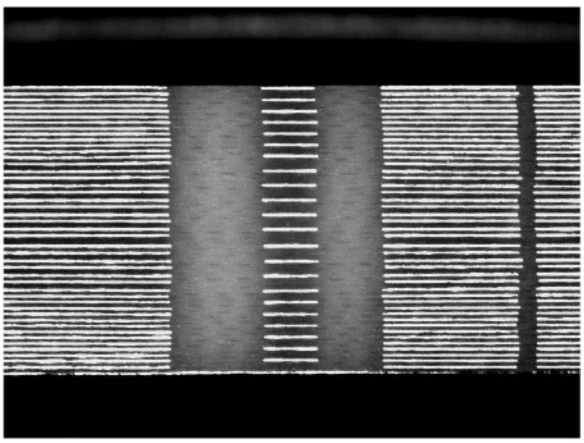

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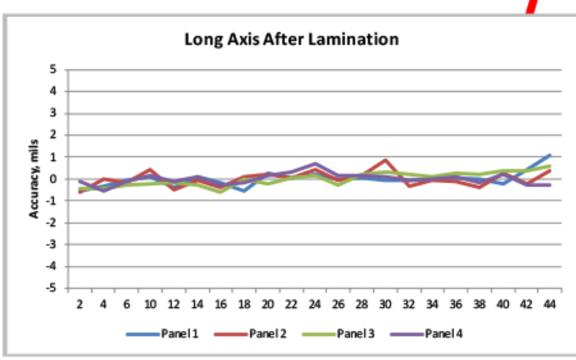

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digitized, the result would be plotted on white paper/mylar and then overlaid on the outer layer film to check for accuracy and/or missing holes. When approved, the drill file would be punched to tape. It would then be read into the drill machine, and the plate would be drilled. These fixtures were typically 1" tall and had a reusable 100 mil base plate.

Once drilled, the plate would again be checked for accuracy, and along with standoffs, it would be assembled. Once complete, the fixture would be placed on the fixture tester. A single board from the lot would be "learned" by the machine. Once learned, subsequent boards would be tested against the learn. If the majority of the lot "passed," the learn would be considered "gold" and could be saved for future lots.

Back then, it was all self-learn and compare.

However, as one would expect, there would be times when a faulty board was learned, and the subsequent boards would all have what appeared to be the same "open" or "short" as compared to the learn. In these cases, the learn would have to be scrapped and a new board selected from the lot to be learned as the new master. This was known as the "learn-comparison or self-learn" methodology. The risk was apparent. All one could certify was that all boards compared the same. It did not mean they were correct. If all boards had the same repeating defect from manufacturing, the self-learn test would not capture the defect. Expensive returns due to electrical defects were not uncommon during this era.

Technology began to advance relatively quickly in the late '80s to the turn of the decade. All of a sudden, we had this thing called "Windows," which, before then, was just something to look out from. The floppy disk was now being replaced by hard drives. This was great! You could purchase a 20 megabyte MFM hard drive for about $1,000 and store hundreds of files.

Now, since we could save files without drawers of floppy disks, we could move them electronically. Well, not so fast. There wasn't much yet regarding networks. Novell had a LAN topography working at the time, but this required add-on network interface cards (NICs). CAT5 didn't exist yet, so computers were linked by coaxial cables. It was cumbersome and expensive.

One nice thing to come along is that we didn't have to "sneaker net" files from the customer any longer. Modems became the new thing, and we could use the phone lines to transfer data. You were really in the know when you had your 1200 baud modem online and automated software running as a 24-hour data service. The 2400, 9600, 14400, and 19200 modems came later, which made life easier.

Time warp to 2020, ask anyone of a younger generation, and they will give you a blank stare regarding any of the technology I just mentioned. Today, we can do pretty much anything from the comfort of our couch, I mean, office chair. To put it in perspective, remember the IBM PC? It had a 4.77-MHz processor and 64K of RAM if you were lucky. You were smoking if you had 128K or the unbelievable 512K. The Apollo 13 mission utilized many computers at mission control. These took up full rooms. Did you know that the computing power of the Apple 4S iPhone could have managed the entire Apollo 13 mission? That's mind-blowing indeed.

Today, you have to go to eBay to find retro floppy disks for your antique if, like me, you have a place in your heart for these old machines. We are in the mainstream of the digital age. "Plugged in" is just the way of life. We are plugged in at home and work, and even while playing. Due to the digital age, we have automation that was just unheard of 30 years ago.

From 1986 to the present day, electrical testing has made momentous advances. From the self-learn of the '80s to today's automated flying probe and fixture testers, the escape risks have gone to basically zero. These advances include the ability to perform buried passive testing and precision 4-wire Kelvin measuring. High-speed data connections, cloud-based computing, and virtually infinite storage make manufacturing and testing almost effortless as compared to the early times. We move gigabytes and terabytes of data effortlessly, while we copied data to a 360K floppy disk 30 years ago and prayed a sector didn't go bad so that the data could be retrieved tomorrow. With industry specifications requiring data/record retention, it is only due to the advances in the digital age that this is possible. Otherwise, we would be renting warehouses to store boxes of paper for 7–10 years.

The advances I've seen in my time are pretty staggering. I, for one, look forward to the continuing advances yet to come. Going digital was inevitable as technology has advanced. For us, that has grown through the digital age, and it has been quite a ride. Now, it's a challenge to be "unplugged" rather than the challenge to "plug in" just 30 years ago.

By the way, in the time it took you to read this column today, you just finished uploading 5 megabytes of data to your customer or manufacturer on a 1200 baud modem in 1988. Also, had it been 1988, I would need two floppy disks just to save this column to disk. Oh, and the word processor I used didn't exist yet, so I guess I wouldn't have been able to write it.

Embrace the digital age, but take time to unplug daily. Information overload is hard on the biological hard drive—you. **PCB007**

Todd Kolmodin is VP of quality for Gardien Services USA and an expert in electrical test and reliability issues. To read past columns or contact Kolmodin, click here.

Developments in Specialized Metallic Finishes

Pete Starkey and Richard DePoto, from Uyemura USA, discuss the market acceptance of the RAIG heavy gold process, the demand for and the benefits of the ENEPIG process.
Click the image to view video.

Alex Stepinski: GreenSource Fabrication Update

Feature Interview by Barry Matties
I-CONNECT007

Alex Stepinski gives an update on GreenSource, their acquisition of AWP, and their move to full production after some delays. Barry Matties and Alex also discuss automation and the difficulties in hiring in the U.S. and announces the decision to go to market with their recycling equipment in 2020.

Barry Matties: It's nice to see you at productronica, Alex. Let's start with an update on GreenSource Fabrication.

Alex Stepinski: We experienced some significant delays in the past year from the equipment supply perspective. It was mostly associated with non-direct process equipment. We have all of our core processes in place with the automation from AWP and a couple of other suppliers. To mitigate this, we recently purchased AWP. We reorganized and got our equipment out of there, as well as finished up machines from other suppliers that were struggling. Everything is going to be on-site within one month. In Q1, we believe we're going to be in full production.

Matties: The story on the street, as you're building this factory, is that it's a hands-off operation from start to finish.

Stepinski: Nobody has to touch anything. We have all different types of automation and applications. We have buffers that reprioritize the work for single-piece flow in a very compact space. We have vertical and horizontal loaders and unloaders and robots that load and unload special machines. The integration of automation into the factory is the key to our being successful.

To continue reading this article which appeared in the January 2020 *PCB007 Magazine,* click here.

Via Hole Filling and Plugging, Part 3

Trouble in Your Tank

by Michael Carano, RBP CHEMICAL TECHNOLOGY

In Part 1 and Part 2, I presented several options with which to accomplish blind and through-hole via filling. In this edition of "Trouble in Your Tank," I will address filling blind and through-holes with polymeric pastes.

Via Fill Paste

Often the term "plugging paste" is used to describe the method and material for completely filling blind vias and through-holes. In general, paste-filling material selection is at the request of the end-user and is indicated for a number of reasons. It has been my experience that major OEMs are driving the industry to migrate to the high Tg/low CTE plugging paste formulations for high-density applications. In addition, these formulations are of a non-conductive nature that provides a high-quality plugged via and is also cost-effective (Figure 1). Limitations abound, depending on PCB thickness, via diameter, and paste properties.

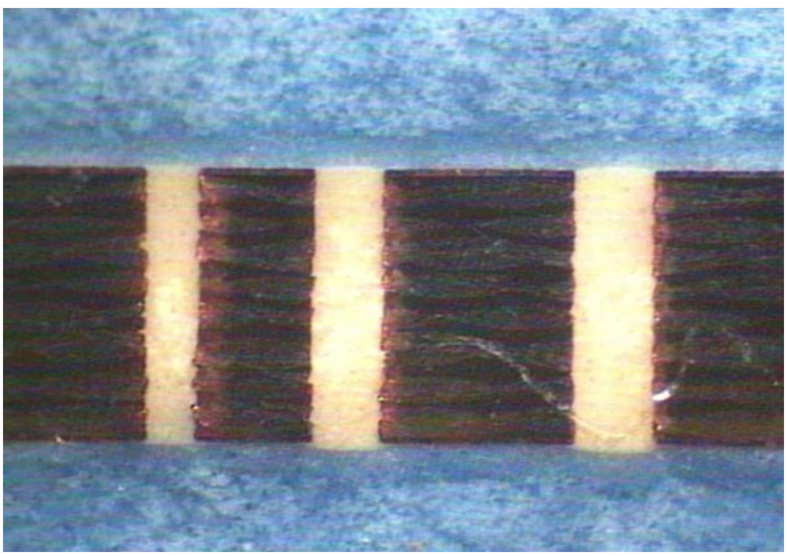

Figure 1: Example of a paste filled through-hole.

Properties of Via Fill Materials

What attributes are needed for a high-performance via fill material? There are specific requirements for the plugging paste material.

- Good adhesion between copper and paste, even under temperature influences
- Good adhesion of copper, dielectrics, or photoresist
- Solvent-free, one-pack system
- No air inclusions in the paste
- Tg > 140°C
- CTE < 40 ppm (below Tg)
- No shrinkage during curing
- Easily planarized

Additionally, the plugging paste material must maintain a reasonable shelf life at room temperatures. Keep in mind that these materials are thermally reactive.

It is highly recommended that the fabricator use a 100% solids content of the paste material with the thermally cross-linkable epoxy resin and specially designed ceramic fillers. The ceramic filling material restricts Z-axis expansion when the filled vias are subjected to a thermal load. Interestingly, the coefficient of thermal expansion must remain in the 40–60 ppm range to ensure that via cracks do not occur in the filled via. In addi-

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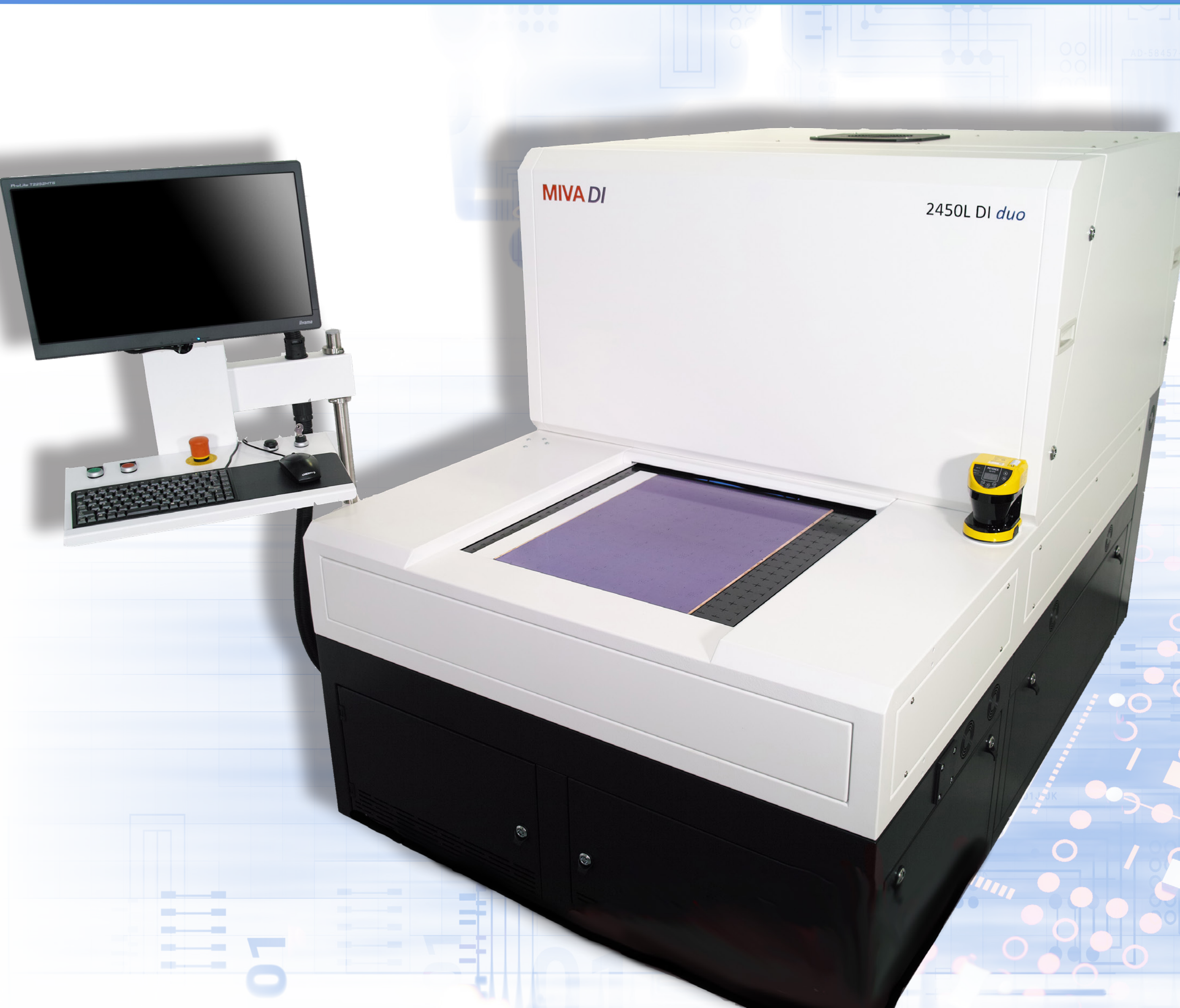

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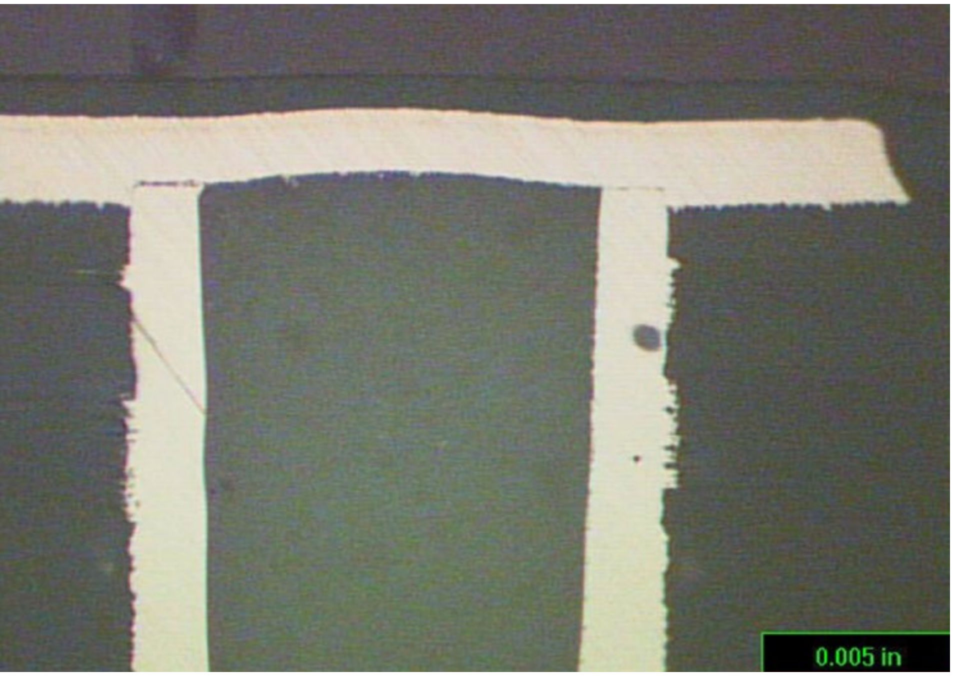

Figure 2: Plated copper separating from filled via due to excessive Z-axis expansion.

tion, it is critical that Z-axis expansion is minimized to prevent the plated cap from lifting (Figure 2).

As noted previously, a properly formulated plugging paste for via fill must maintain a low CTE at and above 140°C. The ceramic particles that are formulated in the resin system function to restrain Z-axis expansion under thermal loading.

The ceramic fillers can be seen in Figure 3 under high magnification of the fully cured polymeric paste.

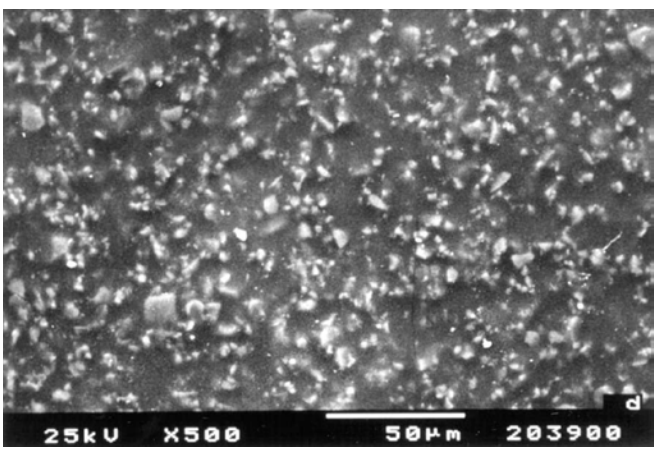

Figure 3: Top view of filled via with plugging paste. Ceramic particles embedded in the matrix clearly visible.

There is no disputing the fact that the vias must be filled void-free and maintain integrity through-out various thermal excursions. Z-axis expansion notwithstanding, the second critical thermal characteristic is the glass transition temperature of the cured paste material. Typically a Tg of 140°C is ideal. However, the Tg can be increased by prolonging the final curing time and increasing curing temperature from 140°C to approximately 175–180°C. It is desired to have the highest possible Tg without impacting the flow and metallization properties [1].

With increased densification leading to higher I/Os, smaller components, higher assembly temperatures, and smaller vias, the CTE gains increased importance. Thus, the CTE values of the paste must be minimized to relieve stress that will cause the plug to over-expand, allowing the overmetalized copper deposit to lift [2]. It is critical that to attain long-term stability within the filled via under load conditions, load amplitudes must be minimized as much as possible. This means that the CTE must be as low as possible over the temperature ranges [2].

Regardless of the method of via filling chosen, this is a process that is here to stay. Via filing technology is a critical aspect of HDI PCB fabrication and the never-ending quest for miniaturization. **PCB007**

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1. Karsten Andra, "Hole Plugging Technology for Multilayers and HDI Packages," EPC PCB Convention, 1999.
2. Internal communication with Lackwerke Peters.

Michael Carano is VP of technology and business development for RBP Chemical Technology. To read past columns or contact Carano, click here.

Figure 1: XRF helps you conform to IPC specifications.

XRF: An Essential Tool to Help PCB Manufacturers Meet IPC Specifications

Article by Matt Kreiner
HITACHI HIGH-TECH

One of the main challenges in PCB manufacturing is to create a stable, long-term coating of the copper surface to perform critical functions throughout the expected lifetime of the part. The surface coating is there to do two things: prevent the copper from oxidizing by coming in contact with the air, and form a reliable contact for a soldered joint or wire-bonded connector. Following IPC specifications IPC-4552A, IPC-4553A, IPC-4554, and IPC-4556 will improve reliability and longevity. X-ray fluorescence (XRF) is a proven method—and, for this reason, has been written into these four specifications—to control processes for plating thickness of substrates to address oxidation and solderability.

IPC and ENIG Specification: IPC-4552A

The electroless nickel/immersion gold (ENIG) deposit is one of the most widespread surface finishes used in printed board manufacturing today. IPC released its first specification for ENIG in 2002, followed by revision A in August 2017. ENIG is an excellent surface finish for reliable solder joints and aluminum wire bonds and has a relatively long shelf-life; however, its high performance depends on the quality of nickel and gold layers. The thin outer layer of immersion gold is very stable and prevents oxidation of the underlying nickel for the life of a component.

The 2017 revision helps manufacturers to create a more reproducible and reliable ENIG surface finish and outlines printed board performance requirements, including the J-STD-003 solderability specification. The revision focuses

on the thickness of the gold layer; the minimum allowable thickness has been reduced, and a new parameter for the maximum gold thickness was introduced. If the gold thickness is too low, the deposit may not remain intact once in use. This would result in corrosion and cause weak solder joints and board failure. With the critical nature of the gold thickness, the specification focuses on three factors in order to:

1. Control the ENIG plating to produce a normal and reliable distribution of thickness for both nickel and gold deposits.
2. Determine the accuracy of the instrument used to measure deposit thickness.
3. Reliably yield consistent and uniform deposit characteristics.

In addition, the IPC-4552A gives details on corrosion identification, with measurements required for pass and fail criteria. The update to the specification required extensive testing by the IPC and associated organizations, and the specification now yields a high-quality finish. However, the stringent measurement controls imposed can be difficult to meet in a production environment without the use of an XRF instrument to precisely control thickness.

IPC-4552A also refers to XRF calibration methods required to meet the statistical requirement of the specification. To use XRF, the instrument must meet specified performance requirements, including stringent criteria to measure the gold thickness. There are two major classes of XRF detectors suitable for plating analysis: proportional counters and high-resolution semiconductor detectors, such as a silicon drift detector (SDD). Both may be used to conform to IPC-4552A. It is incumbent on the production facility to evaluate their existing equipment, and decide which detector technology is most appropriate for their process, as this will have an impact on analysis time and control tolerance. High-resolution detectors are best because they can differentiate gold peaks from copper and bromine.

Avoid Oxidization on Your PCBs With the Immersion Silver Standard: IPC-4553A

Immersion silver's main function focuses on RoHS compliant finishes which protect the underlying copper from oxidation over its lifetime. This thin deposit's main function is to serve as a solderability preservative, by dissipating into the solder to leave a clean copper surface for soldering.

The IPC-4553A specification details the parameters for the immersion silver surface finish in a production environment that results in a reproducible and stable solder joint. The first immersion silver specification, IPC-4553, was issued in 2005 and transitioned to an update in 2009 where the supply of the thin deposit was reduced. The thick version became the industry norm as captured in IPC-4553A.

The revised specification outlines an upper and lower limit to the immersion silver thickness deposit to improve quality control and field reliability of the component. The regulation is designed to provide a reliable surface finish for a shelf life of 12 months per IPC J-STD-003. It focuses on preventing a thickness that is too

Figure 2: Loading boards into XRF for plating thickness measurement.

low, so that the copper will not oxidize during the soldering process, causing the joint to fail in production. If the deposit is too thick, the solder joint may eventually weaken and fail in the field.

As well as finish thickness specifications, the IPC-4553A gives parameters for porosity, adhesion, cleanliness, electrolytic corrosion, chemical resistance, and high-frequency signal loss. Because silver is an active substance and tarnishes when combined with sulfur, packaging and storage guidelines are given to minimize contact of the silver surface with the environment.

The IPC-4553A specification gives maximum and minimum silver layer thicknesses for a specific pad size (60 x 60 mils). This is important because the thickness of the deposit varies with the coated area. Measurement of the layer thickness is carried out with XRF equipment. However, it's extremely important that the equipment is set up correctly for immersion silver thickness measurements. The specification gives detailed guidelines on how to do this; however, regular and rigorous calibration of the XRF equipment is important. Manufacturers must use a calibration standard of silver over copper with a deposited thickness and pad size of an order of magnitude of the actual production values.

Ensure a Long Shelf Life of Immersion Tin Surface Finishes With IPC-4554 Using XRF

The 2007 IPC specification IPC-4554 is applicable to the production of immersion tin as a surface finish for printed circuit boards. It relates specifically to the solderability of the finish for reliability and reproducibility and tackles the difficulty in extending shelf life for over six months for this surface finish type.

The immersion tin finish is a single layer of tin that is deposited directly over the copper surface of the printed board. The function of the layer is twofold: to provide a protective surface to prevent oxidation of the copper and create a reliable solderable surface. Tin may also be used for press-fit connections, and also as the interface for zero insertion force (ZIF) edge connectors. However, the specification from IPC focuses solely on tin as a surface for soldered joints.

Because copper and tin have a strong affinity for each other over time, the two metal layers will diffuse across the copper-tin boundary. Eventually, this will compromise the integrity of the tin over the copper, and the oxidation of the underlying surface will occur, having a negative effect on solderability and shelf-life. Delaying this inevitable diffusion is key to extending the shelf life of the component.

Fundamentally, the thickness of the tin deposit determines the longevity of the part. Therefore, the aim of IPC-4554 is to provide a standard tin thickness for manufacturers to achieve a reliably solderable finish for all surface-mount and through-hole assembly applications. Adherence to the specification should result in components with a Category 3 durability per J-STD-003 for a shelf life of six months.

While XRF instruments are used to measure the coating thickness, older XRF equipment may struggle to differentiate between the tin and other elements present in the coating, thereby resulting in inaccurate readings. The IPC-4554 specification helps manufacturers to ensure they're carrying out accurate measurements by giving detailed XRF instrumentation calibration instructions, including the use of XRF standards specifically for this type of measurement. A full discussion of the use of foils over polyester (to prevent the impact of the diffusion distorting the results) is given, with recommendations on how to incorporate this into production-scenario XRF calibration.

Conforming to IPC-4556 With XRF

IPC-4556 is the specification for the electroless nickel/electroless palladium/immersion gold (ENEPIG) surface finish for printed circuit boards. Released in January 2013, the specification presents the detailed guidelines for achieving a reliable PCB surface finish for optimal shelf-life, solderability, and wire bonding for gold, copper, and aluminum wire applications.

The specification covers a range of PCB surface finish parameters that have been developed for reliable contact performance, including visual references, adhesion, solderability, cleanliness, and electrolytic corrosion. The focus of the document is on the specific thickness range for the nickel, palladium, and gold layers. It's essential that the palladium layer be thick enough to impede nickel diffusion to the gold surface, helping to prevent hyper-corrosion of the electroless nickel deposit. (Hyper-corrosion results in unreliable solder joints). Yet, if the palladium layer is too thick, the solder joint can become brittle and may eventually fail. The gold layer is required to protect the palladium layer from contamination that may adversely affect wire bonding and soldering and must be above the specified thickness.

Adherence to the specification helps PCB manufacturers deliver products that meet the IPC Category 3 life of at least 12 months.

Measurement of the Layer Thickness

IPC-4556 states that XRF methodology is required to determine the layer thickness. Through extensive testing using XRF in the development of the specification, the IPC has set out a detailed set of measurement criteria, including equipment set-up, measurement protocols, and calibration advice. Those using XRF instruments must be aware of a number of factors affecting the results if they are to assure accurate and reliable thickness measurements. These include the following.

Sample Size

Plating thickness varies with the plating area with smaller features resulting in a thicker plating layer. Therefore, it is essential that the pad size used for measurement is consistent for both calibration and production readings.

Calibration Standards

The IPC recommends the use of nationally traceable calibration standards consistent with thicknesses to those measured on the devices in production. A gauge R&R, or equivalent statistical methodology, should be carried out. Furthermore, calibration standards should be checked frequently.

XRF Instrument Software

Many XRF instruments come with background correction software, which is designed to eliminate background scatter from the substrate that can give incorrect readings. This feature may need activating, and the user will need to determine how to do this, if applicable.

Detector Type

The detector must be capable of measuring tri-level thin coatings. Solid-state detectors (SSD) provide better resolution than proportional counter systems; however, there may be a trade-off in longer measurement times for the SSD, depending on the age and capability of the XRF instrument.

The IPC-4556 guidelines help to ensure good quality and predictable, repeatable shelf life of the ENEPIG surface finish. However, careful consideration and understanding of the XRF instrumentation and associated software, as well as using the right calibration procedure, are all essential to ensure accurate layer thickness measurements with XRF.

Next Steps in Meeting the Outlined IPC Specifications

Hitachi High-Tech Analytical Science is a member of IPC, and we support customers who conform to IPC standards to achieve quality and reliability within PCB manufacturing. We have created a complimentary IPC guide for manufacturers, which can help you to conform to compliance with IPC-4552A, IPC-4553A, IPC-4554, and IPC-4556 specifications which you can find here. PCB007

Matt Kreiner is Hitachi High-Tech analytical science's product business development manager for their coatings analysis product line. In his current role, he focuses globally on the company's coatings customers across numerous industries to find new solutions to the challenges they face in their everyday work environment. He has over 15 years of experience working with XRF technology. Kreiner resides in Chicago and holds a B.S. in chemical engineering from Northwestern University.

Electronics Industry News and Market Highlights

Iotic Wins Telecoms and IoT Award in NTT DATA's International Open Innovation Contest ▶

Digital twin and digital ecosystem enablement specialist Iotic was declared champion of the telecoms and IoT domain at the recent grand finale of the 10th NTT DATA Open Innovation Contest in Tokyo.

New Boeing 777X Completes Successful First Flight ▶

The new Boeing 777X jetliner took to the skies on January 25, 2020, entering the next phase of its rigorous test program.

Samsung Proves It Is the Brand for the New Generation of Homeowners at KBIS 2020 ▶

All of the Samsung home appliances on display offer customers control over their connected devices, including the one at the center of the smart home: the family hub.

Is Autonomy the Future of Aerial Mobility? ▶

Advanced computer vision and machine learning—from sensors to cameras—are rapidly enabling major advances in the development of autonomous technologies in aircraft. In the years to come, autonomy could help the aviation industry to mitigate pilot shortages and safely meet the growing demand in commercial air travel.

WESCO International and Anixter International Announce $4.5 Billion Merger Agreement ▶

WESCO International Inc.—a leading provider of electrical, industrial, and communications MRO and OEM products, construction materials, advanced supply chain management, and logistics services—and Anixter International Inc. (NYSE: AXE) —a leading global distributor of network and security solutions, electrical and electronic solutions, and utility power solutions—announced that their boards of directors have unanimously approved a definitive merger agreement under which WESCO will acquire Anixter in a transaction valued at approximately $4.5 billion.

Bell Textron Teams Up with Sumitomo Corporation and Japan Airlines to Explore Air Mobility ▶

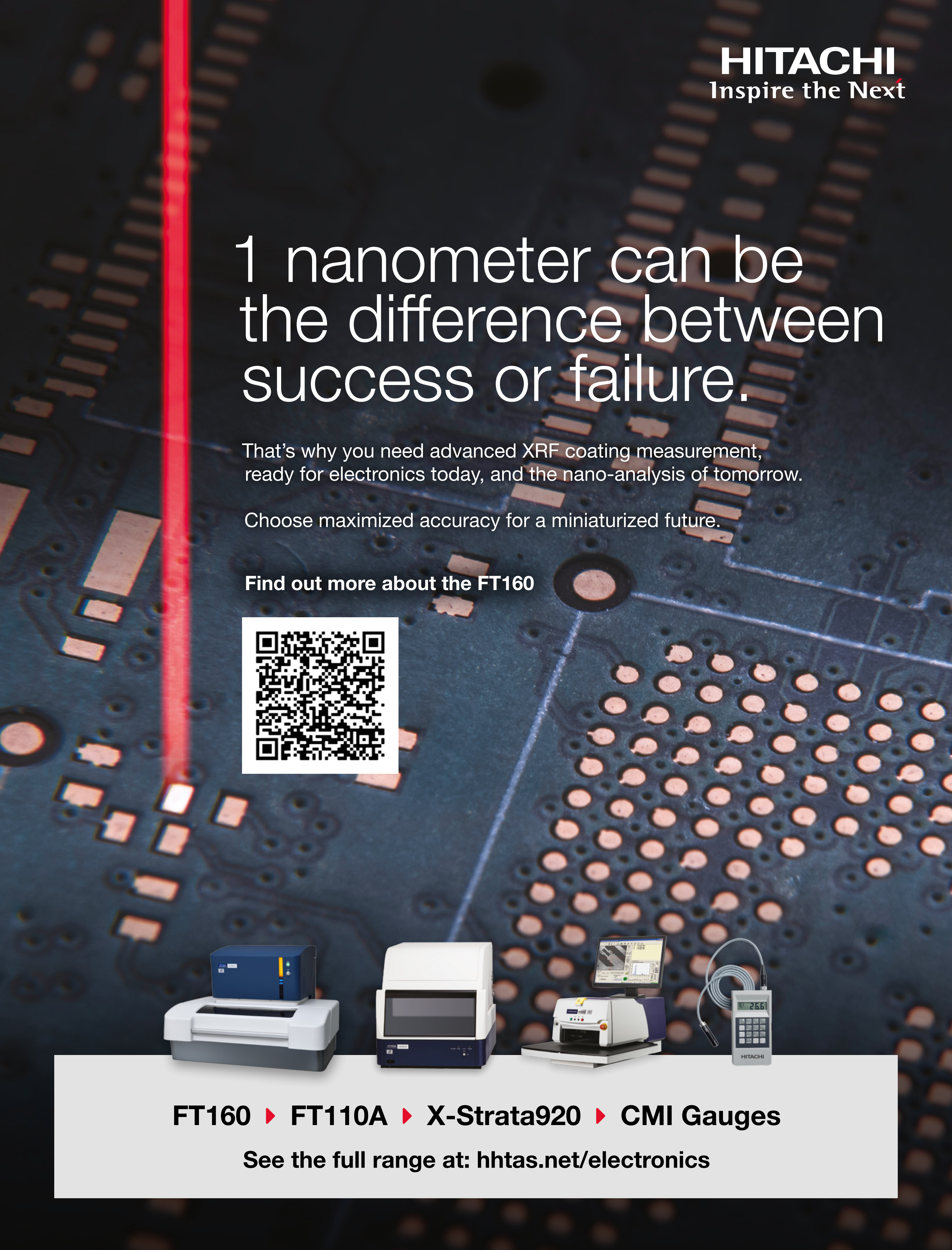
Bell Textron Inc., a Textron Inc. company, announced a signed memorandum of understanding with Sumitomo Corporation and Japan Airlines Co. Ltd., to explore Mobility-as-a-Service (MaaS) and to foster the required infrastructure and regulatory environment.

Ravi Ravichandran Appointed as Chief Technology Officer of BAE Systems' Intelligence and Security Sector ▶

BAE Systems Inc. has named Dr. Ravi Ravichandran as VP and CTO for the company's Intelligence & Security Sector. As CTO, he drives the development, integration, and transition of next-generation solutions that advance the company's current programs and future technology pursuits.

Lockheed Martin and Oriden Team on Flow Battery Technology ▶

Lockheed Martin and Oriden LLC, a Mitsubishi Hitachi Power Systems venture, announced a teaming agreement for future energy storage projects using GridStar® Flow, Lockheed Martin's innovative flow battery technology. This cutting-edge energy storage system is capable of storing six to 12 hours or more of energy and dispatching it as needed.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Lenora Clark

The Direction of MacDermid Alpha's Automotive Initiative

Interview by Nolan Johnson
I-CONNECT007

Nolan Johnson speaks with Lenora Clark about MacDermid Alpha's automotive initiative, where her role fits into the company's focus on supporting carmakers in various business areas, and where the future of automotive is heading.

Nolan Johnson: We did an interview at SMTAi 2019 about your new role as director of autonomous driving and safety technology at MacDermid Alpha Electronics Solutions. Refresh us on that role. How is it going?

Lenora Clark: It is going very well, thank you. I am learning every day, and I enjoy working in the automotive space during this exciting time. My role is to understand the technical and strategic challenges of the automotive market. This is to see how a chemical supplier can make automotive Tier 1s and, ultimately, carmakers successful during a time of change, specifically with respect to advanced safety from a systems level.

Johnson: How did you arrive at this role? Give us a little background on the start of your career.

Clark: I started in this organization fresh out of college with a bachelor's degree in chemistry. My focus was surface finishing, which gave me a lot of exposure to end-users. At the time, we worked closely with all market segments, testing immersion silver. It was a time of transition away from leaded hot-air solder level. Immersion silver was my introduction to alternative surface finishes.

Through this, I learned assembly and the importance of collaboration through a supply chain from a chemical supplier to a PCB fabricator. This included the assembly facility and finally testing and execution of a final product in end-use. This experience in surface finishing laid the perfect foundation for my role today in the automotive initiative.

Johnson: Is the automotive initiative new to MacDermid Alpha?

Clark: MacDermid made the decision 15 years ago to give the automotive industry the next

level of support, particularly with respect to corrosion-resistant and decorative coatings. We hired a group of people who understood the large carmaker organizations. The work they did helped promote further penetration and collaboration on all levels of the supply chain, including electronics. We provide technical support for our products and also help develop their global supply chains.

Around the same time, Alpha was supplying directly to Tier 1s with joining materials for PCBs and semiconductors. After the MacDermid Alpha integration, it was a natural fit to expand upon the success of these individual groups and become an even stronger resource for carmakers, Tier 1s, and additional tiers in the automotive space.

The level of experience we deliver is unrivaled; and is supported by research and development, which delivers innovative materials in the different segments. Ultimately, this achieves even better products for our customers. This is important for our integrated automotive strategy.

Johnson: With so much activity in the automotive sector currently, that must be a busy business unit. How are you approaching the market?

Clark: We are taking a very specific three-fold approach to the market. For the carmaker, we have an account manager as a point person for anything they may need. This account manager not only communicates our capabilities but also gets the account an expert in any of our business segments. We have individuals working globally to support all major carmakers. We do the same thing for the top Tier 1s. They have an account manager who understands their organizations and overall strategic needs and offers solutions.

With the dramatic changes in the space, we also decided it was best to come to the market with a use case perspective, such as understanding the challenges associated with autonomous driving. This is the third leg of our strategy, considered strategic marketing, which I am a member of. My team understands the bigger picture needs for electric vehicles, autonomous driving, and safety as well as integrated electronics.

Johnson: Are you involved in EVs and autonomous vehicle technology?

Clark: I personally focus on autonomous driving and safety technology. EVs will have many ADAS features, but my support is best kept as a focused effort. I have a good understanding of our offerings and strategy for EVs, but should a contact of mine need assistance in this area, it is a simple phone call or email to get them the experts they require. We are dedicated to supporting EV, ADAS, and integrated electronics equally. Each of these business areas has a dedicated technology director. Our materials can make our customers more successful in these areas.

Johnson: What are the immediate technical challenges you're tackling in the team?

Clark: From my perspective, the most influential areas in ADAS are high-density designs, testing for life expectancy, and the reliable mass production of unique materials. We have experience in all of these aspects through work with other markets, such as aerospace and handhelds. Collectively, our technologies applied to these areas enables next level autonomy. This is achieved through design freedom and enhanced reliability.

Johnson: How are industry trends influencing your product roadmap?

Clark: I see technology, design, and materials used in other market segments now being used in automotive, but with a twist. A great example is vision systems for advanced safety. From a PCB design perspective, we see many similarities to a tiny, handheld PCB with multiple layers of stacked microvias. The twist is that the cameras for a car are in continuous use as it is driven, and the required level of reliability is much greater. Placement and alignment of the camera lens are more critical than in a smartphone. Therefore, adhesive materials change, but material suppliers learn from one industry and innovate for the next as required.

For radar designs, we see the adoption of high-frequency, low-loss substrate materials used in the telecommunications market. Now, the automotive PCB fabricators need to become experts in manufacturing these materials. The frequencies are much higher than 5G even, so tolerances are immensely critical.

Johnson: How do these drivers change your product offering?

Clark: I see it in two ways. There are products being used in other markets that will fit well in the new safety system designs. This is a matter of educating the automotive supply chain that these products exist and how to benefit from them. There are other instances where we need to innovate specifically for the enhanced requirements of the automotive industry, but we learn from our historical offerings.

Johnson: Automotive is demanding something like two orders of magnitude more reliability in the field than the industry as a whole currently delivers. While no one step in the PCB fabrication process can deliver all of that reliability, are your products capable of helping with that improvement?

Clark: We continue to test our individual products to automotive reliability criteria, which are ever-changing. We also test the synergies of our materials and how, when paired together, they can offer even greater improvements. This is an advantage we have over current technology within the industry. We touch a broad range of segments in electronic build, including PCB fabrication chemistry, joining materials, and chemical solutions for semiconductors and packages.

Johnson: Are the Tier 1s making the key design decisions, or is that coming from the automotive company design teams? I'm wondering how much visibility into the changing dynamics a board fabrication house, for example, may need and/or be able to access.

Clark: Key decisions are being made at every level now. Tier 1s are currently making most of the decisions about board build and materials for advanced safety. However, we see carmakers keeping some designs to themselves. We even see carmakers sourcing electronics manufacturing services (EMS) for design. PCB fabricators see the advantage of working with many levels of the automotive supply chain. Some players in the industry already have relationships with both the Tier 1s and carmakers.

Key decisions are being made at every level now. Tier 1s are currently making most of the decisions about board build and materials for advanced safety.

Johnson: Who is your ideal customer?

Clark: One who is open with information and willing to collaborate. Without an open exchange of information, it can delay the delivery of project goals. When you engage the resources of two or more companies, it shortens the time to success. This is critical because this market is changing so quickly. Collaboration is crucial.

Johnson: Maybe a bit of devil's advocate here from me, but the Tier 1 automotive supply chain does not exactly have a reputation for being particularly collaborative. Can you set me straight on that?

Clark: I understand the perception, but in my perspective, things are different now. I have been working with Tier 1s and carmakers for over 20 years now. In my experience, people understand that they cannot be experts in everything. The primary reason for this, in automotive electronics, is the increasing complexity in systems such as vision and radar systems.

On new projects, collaboration will get them to a resolution faster and, in many cases, helps to build a better product than originally expected. The automotive industry understands this and is more open with information than in the past. It helps to work with a trusted global partner. That is how MacDermid Alpha differentiates itself.

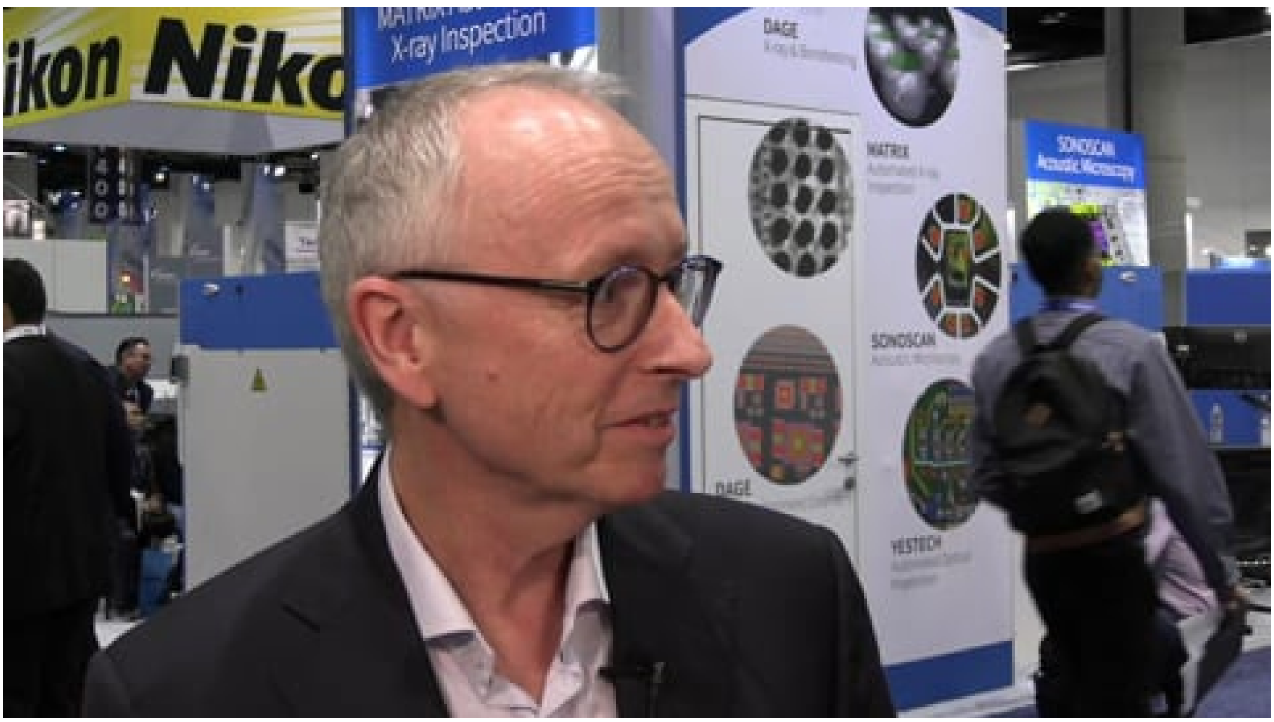
Johnson: This time next year, what should we be talking about as your 2020 accomplishments?

Clark: Today, we are a global, trusted partner in the automotive supply chain. For me, future success would be that we are a trusted partner, specifically to Tier 1s in autonomous driving and safety.

Johnson: Thank you for your time, Lenora.

Clark: Thanks for this opportunity. I understand that many in the automotive industry are concerned about success, especially in the fast-paced ADAS landscape. We are here to support them. We're already on it. **PCB007**

Developments With IPC-6012 and IPC-2581



IPC Task Group Chair Jan Pedersen comments on successes in the development of the IPC-6012 automotive addendum and progress with its medical counterpart. Pete Starkey and Jan also discuss ways in which digital specification information could be abstracted from IPC-2581 in a readable form for quotation and sales office purposes.
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KIC Making Ovens Smarter
KYZEN
MacDermid Alpha ELECTRONICS SOLUTIONS
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Chris Ryder

The Current State of Embedded Active Components

Interview by Nolan Johnson
I-CONNECT007

Chris Ryder of ESI explains the thought process behind an OEM's decision to embed a component and the typical pros and cons that must be considered before trying to adopt this rather tricky process.

Nolan Johnson: Why don't you start by telling us about your company's experience with embedding components.

Chris Ryder: From a laser-drilling perspective, we are responsible for creating that interconnect. There are different ways to do it, but in general, you begin with a component lodged between two copper layers and drill from the copper layer to the component termination, whether it's an end termination or an I/O grid array. Any challenge here is typically linked to the required positional accuracy, via size, and/or material stackup.

Materials within or surrounding the component can be more sensitive to thermal loading. They may include secondary materials, such as polyimide, between the component and the adjacent copper layer. The danger is creating a thermal load during drilling that could potentially lead to overheating the material, creating a potential for later delamination.

Ideally, we would limit such thermal damage to the component or any sub-layers. It comes down to a finite amount of energy that we can manage with our via drilling system's capabilities. Being able to define exactly how much energy is displaced over time to create that via is key to the success of the entire construct, and product yield is crucial, considering how expensive boards become when you embed a component. ESI's systems support the power control and accuracy needed to meet these demands. I see some great opportunities for ESI in this growing market, especially for our new Geode system.

Johnson: For board assemblies with active parts embedded, the assemblies are required to be stable and long-lasting in production. They're going to do this for applications only

where it is important; this is not a "try it out" strategy. They only embed because it's needed.

Ryder: From an OEM perspective, the decision-making process to lead you to an embedded component board or package is going to be extremely well thought out. It's a big decision to embed a component. There has to be a lot at stake for this to happen, which is a testament to how young the technology still is, despite decades of activity. Active components, in particular, bring in a whole new cost and yield barrier that has to be met to make that product feasible.

Active components, in particular, bring in a whole new cost and yield barrier that has to be met to make that product feasible.

I would argue that the use of embedded components is predominantly driven by miniaturization, reliability, or performance. In terms of miniaturization, the key benefit is newly won real estate for the PCB or substrate surface. Reliability may improve in some cases, as the component is not directly exposed to outer assembly stress, and the component's connectivity is not limited to the success of a solder joint. Regarding potential performance improvements, one may benefit from inner layer shielding effects, short trace/wire routing, and electrical signal benefits that you get by having a package directly connect with memory, for example, versus having to be redistributed throughout the substrate layers.

Johnson: The criteria that would force you to embed actives and get serious about this technique, with everything else we talked about so far, screams smartphones and handheld devices that are going to be manufactured in very large quantities and with relatively short, useful lives. Cellphones don't work the way the military expects them to work, which seems to be a very natural fit.

Ryder: Mobile communications is a very competitive market. One of the major hurdles getting embedded components, and especially active components, into a smartphone is the potential new cost paradigm. As long as there's still room to breathe in terms of performance and real estate within the PCB, substrate, and package design, more inexpensive options will be preferred. Hence, for proper embedded actives, the cost is largely inhibitive for widespread adoption as yet.

To my knowledge, however, there are various efforts ongoing to embed particular ASICs and MEMS, usually in the form of a packaged module. We're not talking about CPUs here, as such components can be immensely difficult to embed, due to, for example, a high level of registration and accuracy required for a high I/O count and potential thermal management issues stemming from the lack of heat channeling away from the chip.

Johnson: In what applications are active embedded components being used?

Ryder: It's not to say cellphones don't make use of it. Again, there are likely package modules in cellphones that contain embedded components.

Johnson: It's at the point where design teams start to build up the subsystems.

Ryder: Correct. I'd say that's where things are right now. From a packaging perspective, technology development is rather conservative. To move crucial functionality to a fully embedded system would require a lot. That doesn't mean it's not happening. The development is there, and some of it is more mature than others, but the degree to which we see embedded actives in the market is fairly low compared to passives.

Eight or nine years ago, the prognoses showed a broadband ramp-up by 2020; we'd see X million embedded actives in the market

ESI's new Geode system machine.

with X revenue generated. But this has been consistently pushed back, and while growth is certainly not stagnant, the lessons are still being learned on how to design, manufacture, and integrate the technology for cost-effective solutions. It's definitely going in the right direction.

The supply chain has been one of the hurdles in ramping up products as well. Relevant applications typically require specifically designed components for an embedded application. They've been thinned. Some have unique passivation layers on them, and others require different termination metallization, etc. There is a supply chain ecosystem that has to be there first before this becomes commercially viable, and building this up takes time.

Johnson: For those who end up using embedded actives, you'll know you need it when your design constraints tell you that you need it.

Ryder: As a PCB or substrate manufacturer who's engaged in that kind of manufacturing and marketing of embedded technologies, ideally, you want your customer to quickly recognize the benefits you envision for them. Any top-tier manufacturer's roadmap is well ahead of their customer's current dilemmas. You must say, "Imagine what you could do with X real estate and a given performance enhancement if you were to embed this." The reality is they will likely first explore solutions using the tools that they already have in favor of time-to-market or economy. However, the larger and more established the embedded component supply chain ecosystem becomes, the more we'll see commonplace use of this technology shelf.

Johnson: At ESI, would your customers generally be on that part of the supply chain?

Ryder: That's correct.

Johnson: What sort of challenges do your customers face through all this?

Ryder: Assuming that a PCB supplier or substrate manufacturer has done their R&D homework and gone through the initial process of finding and evaluating embedded solutions, our challenge is to supply laser drilling systems that support high-yield, cost-effective volume manufacturing. One of the hurdles is that companies often have their own IP around the technology, so it's hard to generalize any solution. Add to that the plethora of components and component requirements for thermal and structural integrity, and things can get tricky quickly. Having a very flexible tool for processing such a potentially large range becomes crucial. ESI's technology delivers the necessary power control, accuracy, and beam steering needed to enable a reliable interconnect and ensure the customer's product functionality.

Johnson: What if an embedded component doesn't work? PCB fabricators are not accustomed to being a test house.

Ryder: I hesitate to believe that many PCB or substrate suppliers would make themselves the component tester. Embedded resistors would be conceivably easy to test, even within a test circuit. However, if you had 150 embedded capacitors, how would you test for capacitance within the total embedded structure? And if it's an RF sender, a transmitter, Bluetooth, or some sort of processing component, you're not testing a simple digital response; you're testing a full functionality. This would be too risky being outside of core competency. In addition, active component testing is often subject to a chip manufacturer's own IP and test methods.

Johnson: Maybe we exposed an assumption I didn't know I had. For the manufacturers involved in active component embedding, how far does a typical PCB fabricator go?

Ryder: Essentially, the end-product should be a final substrate or a PCB, ready for surface mount.

Johnson: Who does the fabricated board test?

Ryder: When it comes down to a full final functional test, this would have to take place post-SMT.

Johnson: They're taking a flying leap on that.

Ryder: That is the risk,

Johnson: Which takes us all the way back to the beginning of this conversation.

Ryder: That is part of the decision-making process on whether to embed an active component or not. This demonstrates one aspect of what limits the technology from becoming more extensive than it is right now.

Johnson: That's why it's not a widely accepted approach that shows up in your typical prototype process.

Ryder: A single function module would be a good way to start. Some of these modules can be included in a SiP or even on the motherboard. To me, that seems more where the technology is right now. For large, high I/O embedded actives for complex processing, we're a little ways out before widespread implementation.

Johnson: What do you think needs to happen to create that hockey stick in the forecast that keeps moving out? You've already alluded to infrastructure.

Ryder: First and foremost, there needs to be a killer application that justifies the investment from an end-product perspective. If it means X performance improvement or Y dimensional improvement that differentiates your product and drives margin, the stakeholders will make it happen. There are players in the market that know how to execute, and they will drive demand down the supply chain and make it possible. It's getting there. I see a lot of movement and development in the market, but most of the movement is sort of early technological adoption in late R&D project phases. But that's not to say that there is no volume manufacturing. But the scope of applications is still somewhat limited.

Johnson: What you're saying seems to match up with what we've been talking about the past couple weeks. Happy Holden said that embedded actives have been used in high-volume products for quite some time in the right applications. The design gets stabilized, and then they're going to keep the board assembly unchanged for a long time.

Ryder: There are so many things to contend with, including design, manufacturing, thermal management, warpage, etc. Consider you have fundamentally different CTEs of components versus the PCB or substrate you're embedding it into; there's also the interconnect integrity, reliability, testing, etc. This is likely the reason such technologies remain on the shelf of most manufacturers before becoming a volume product. Happy is absolutely correct.

Johnson: Let's talk a little bit about thermal management once you have embedded that active. How do they do that?

Ryder: That's a very good question. There are experimental ways and given ways. The most common and directly addressable way would be to use your surrounding copper planes for conductivity. You can do that by having thermal vias. In other words, stacked vias that lead down to a copper plane that help to fan out and distribute some of the thermal energy caused by the component's operation. Then, you have a host of special dielectrics that claim to be highly thermally conductive. There are some very promising materials for such a task, such as graphene, which is highly thermally conductive but also brings new manufacturing risks.

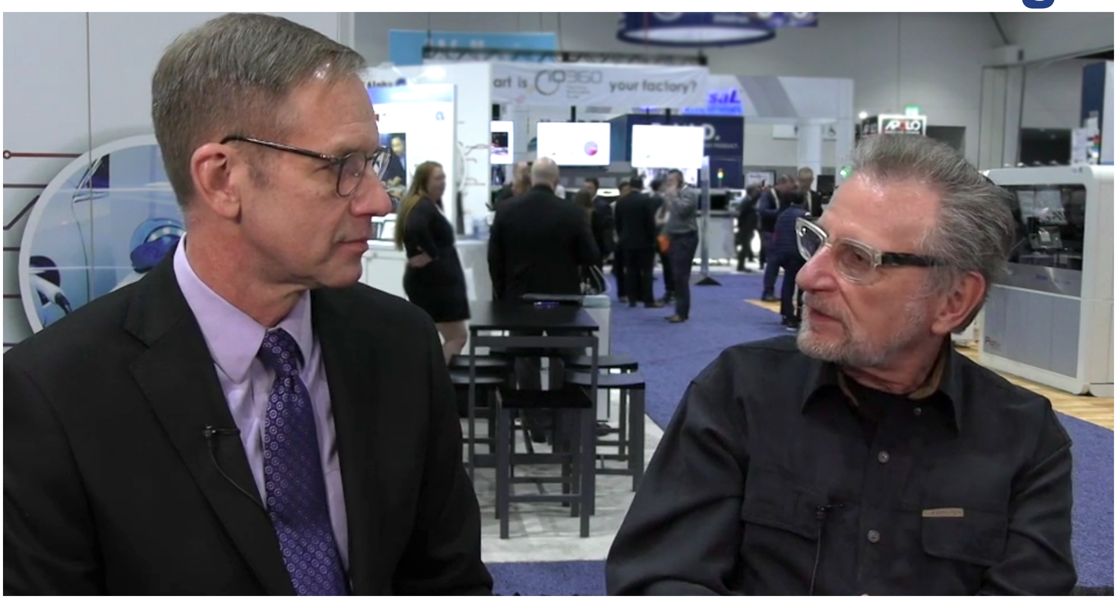
Johnson: Graphene has promise for a lot of things, so that becomes very situationally dependent.

Ryder: It does. Such considerations would go into your decision-making process when you're modeling that final product. You can calculate what the thermal load is going to be for a given component during activity, and you can calculate that thermal distribution within a PCB stackup. All these things can be modeled and simulated, which would be an important part of that process.

Johnson: This has been great. Thank you very much, Chris.

Ryder: It's my pleasure. **PCB007**

IPC APEX EXPO 2020 and IPC Design



Dan Feinberg and Dr. John Mitchell, IPC president and CEO, discuss IPC APEX EXPO 2020, how the show is evolving to be a mini CES—including ideas and prototypes—new IPC initiatives, and IPC Design. **Click the image to view video.**

Supplier Highlights

Aismalibar North America to Exhibit at Strategies in Light ▶

Aismalibar announced the company will exhibit at this year's Strategies in Light trade show in San Diego, Calif., on February 11-13, 2020. Strategies in Light is the leading LED and lighting event in North America and has been for more than 15 years.

Ventec's High-Speed/Low-Loss/ High-Frequency Material Technology Takes Center Stage at U.S. Expos ▶

Ventec International Group Co., Ltd., a world leader in the production of polyimide & high reliability epoxy laminates and prepregs and specialist provider of thermal management and IMS solutions, will feature its brand new and enhanced set of high-performance, high-reliability high-speed/low-loss/high-frequency materials at the upcoming DesignCon and IPC APEX EXPO shows.

Insulectro Focuses on New Design and Education Services During DesignCon

Insulectro, the largest distributor of materials for use in printed circuits boards and printed electronics manufacturing, will exhibit at the 2020 DesignCon technical conference at the Santa Clara Convention Center, Wednesday, January 29 and Thursday, January 30.

Averatek Announces A-SAP License Agreement With Calumet Electronics ▶

Averatek Incorporated has announced Calumet Electronics as its first A-SAP™ licensee. A-SAP™ is an advanced PCB manufacturing technology that enables feature sizes of 25 microns and below, effectively providing PCB designers with new opportunities to address the challenges of next-generation electronics.

DuPont and SCHMID Announce Partnership for New PCB Plating Applications ▶

DuPont Electronics & Imaging and SCHMID Group have announced that they have entered into a nonexclusive joint development agreement to explore new PCB plating applications to bring advanced innovations to their global customers.

Not All Plating Lines Are Created Equal

Barry Matties and Happy Holden met with CEO Michael Ludy and CMO Sarah Großmann from Ludy, a company specializing in galvanic plating equipment for PCBs.

Isola Courts Engineers With High-Reliability Laminates at DesignCon ▶

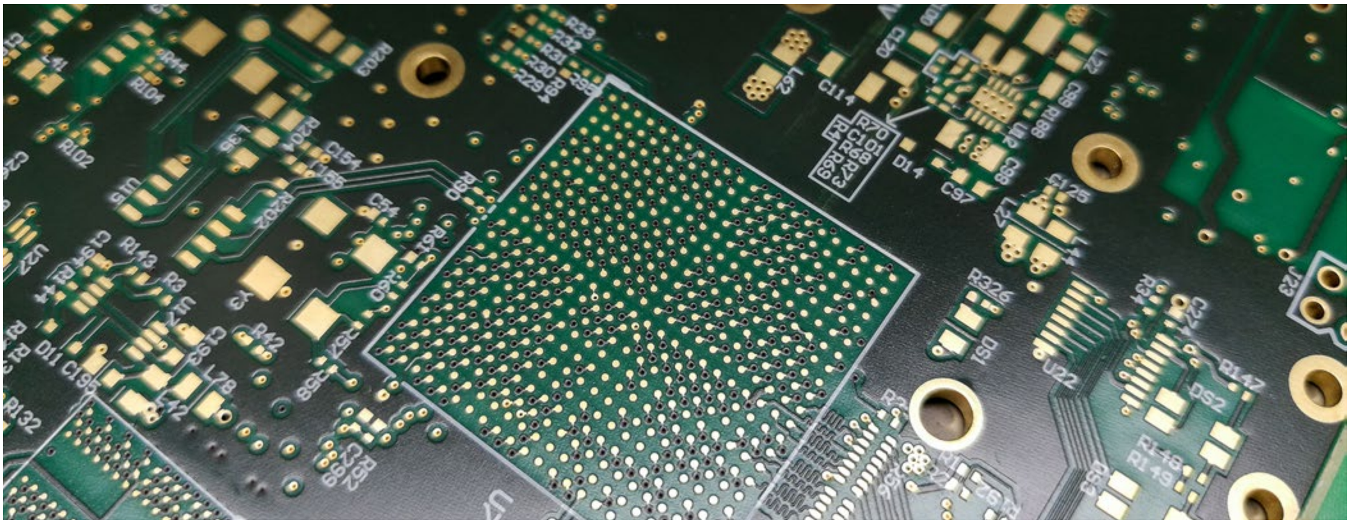
Isola Group, the leading global and local manufacturer of copper-clad laminates and dielectric prepregs for use in the manufacture of PCB boards announced it will exhibit at DesignCon in Santa Clara, CA, in January.

Rogers Corporation to Highlight Next Generation Innovative Materials at IPC APEX EXPO 2020 ▶

Rogers Corporation announced it will exhibit at IPC APEX EXPO in San Diego, CA Feb. 4th-6th, highlighting some of its next generation high performance circuit materials.

Kurt Palmer Takes on New Role as Burkle America President

Barry Matties chatted with Kurt Palmer about his new role as president of Burkle America, the work they do with Schmoll Maschinen, and why customers in North America must continue to invest to keep up with the technology and be profitable.



PCB Surface Preparation Before Solder Mask on Non-copper Finishes

Article by Nikolaus Schubkegel

A circuit board is made of copper. Usually, final finishes are applied after the solder mask process. In some cases, for special applications, the final finish may be applied before solder mask. In this case, we have solder mask on ENIG or galvanic nickel-gold. It is also possible to have tin or tin-lead under solder mask; this was an old technology that no longer plays a role today.

The methods for surface preparation of PCBs with copper are very well known. All these methods of pretreatment, chemically or mechanically, increase the surface roughness and ensure good solder mask adhesion. Many technical papers provide details on this topic. Yet, there is almost no literature available on the topic of surface preparation of ENIG or galvanic nickel-gold.

The main criterion for copper preparation is to achieve the desired level of surface roughness. But the gold surface is even, glossy, and very thin. I don't recommend increasing the surface roughness of the gold, as the gold surface itself will be destroyed. As a consequence, mechanical methods—such as brushing, pumicing, or jet scrubbing—are not applicable to gold.

In addition, chemical microetches, such as mixtures of acids with oxidants, are not recommended. The gold surface generally resists these blends, but due to the fact that the gold thickness is just 0.03–0.07 µm after ENIG, the result is that the gold surface is porous. Acids and oxidants can attack the less noble metals beneath the gold with a negative impact on solderability and reliability. Even after galvanic gold plating with a higher thickness, the surface is porous. In addition, the edges of the tracks are generally not plated, allowing another point of entry for the oxidants.

Nickel-gold Surface (ENIG, ENIIPIG, ENIPIG, Galvanic Ni-Au)

PCBs with a nickel-gold finish can be processed directly over solder mask coating. But to do so, the rinse process following the nickel-gold plating step is good. The rinse water should not exceed 10 µS conductivity. The hold time between ENIG plating and solder mask coating must be held to less than one hour, as well.

In this case, there is no need for pretreatment. Nevertheless, it is always recommended to perform a pretreatment prior to solder mask coating. In this case, developing as a pretreat-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ment can be a good process step. Keep in mind that the boards will need to be completely dried after developing.

With constant production at higher outputs, the use of developing as the only pretreatment process will disturb the normal solder mask process. The developer is key equipment in the solder mask process. It can be used for developing or pretreatment, but not for both at the same time. Additionally, pretreatment must be carried out at a lower transportation speed; otherwise, the PCBs will not be dry.

If the ENIG process is performed at a subcontractor facility, hold time might be longer. Sometimes optical inspection is performed before solder mask coating; other times, electrical testing is performed before coating with solder mask. In all these cases, the gold surface may be contaminated with fingerprints, dust, saliva, and/or grease, so an additional cleaning process prior to solder mask coating is necessary. Figure 1 shows a dirty gold surface next to a cleaned gold surface.

For cleaning gold surfaces, an alkaline-based cleaning process is recommended. The alkaline cleaning agents deliver the best cleaning results when compared to neutral or acid cleaning agents. The disadvantage of alkaline cleaning agents, however, is a tendency toward strong foaming. If surface contamination is minimal, then cleaning in a neutral or slightly acidic medium is possible.

Although there are strong acid cleaning agents available, I do not recommend a strong acid cleaning process for a nickel-gold surface. At the microscopic level, three or more metals come in contact (gold, nickel, copper). I am concerned that, in a strong acid medium, a galvanic element is created with accelerated corrosion of the less noble metal, despite the use of inhibitors.

Alkaline Cleaners

There are several types of alkaline cleaners commercially available. These cleaners also have the advantage of removing fingerprints leftover from inattentive handling of the panels. It must be stressed that you need to follow the technical datasheets, as concentrations and operating temperatures vary. After cleaning with alkaline, rinsing with demineralized water is necessary.

These cleaners are also suitable for cleaning gold surface finish PCBs before shipment. This last cleaning step will reduce ionic contamination and significantly improve the solderability and bondability of the boards.

Neutral or Slightly Acid Cleaners

There are also a number of slightly acid or neutral cleaners available. This class of cleaning agents provide reduced foaming while providing a good cleaning capacity. The products can be applied by spraying or dipping. Again, concentration and temperature may vary by supplier.

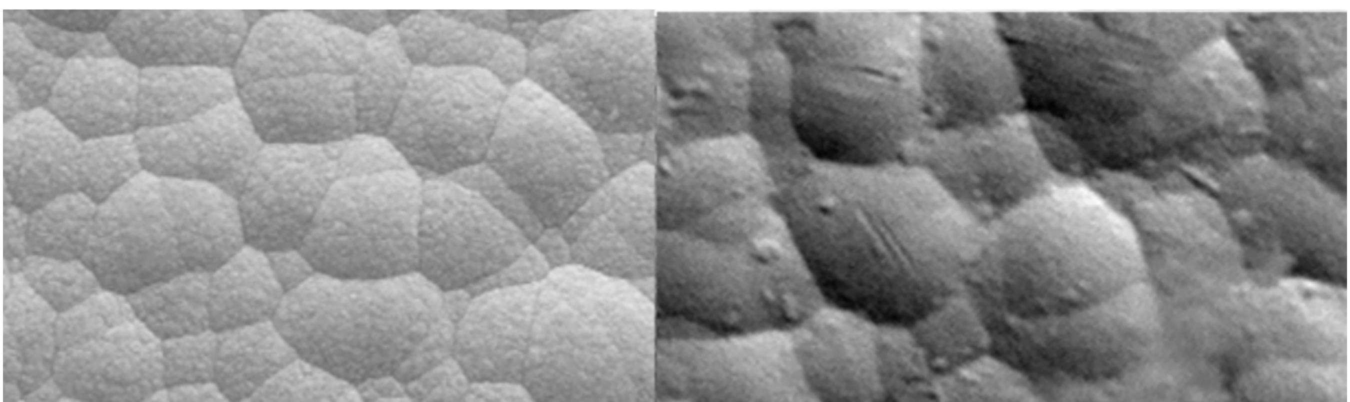

Figure 1: SEM picture of ENIG surface (L) and ENIG surface with visible contaminants (R), both at 1000X magnification.

Strong Acid Cleaners

There are also strong acid cleaners available. The cleaning effect is quite good, and some companies use this method. However, I do not recommend strong acid cleaners for an ENIG surface.

Conclusion

Before implementing a new cleaning product or process, compatibility and feasibility tests must be performed. Failure method and effect analysis (FMEA) needs to be carried out. FMEA is a systematic, proactive method for evaluating a process to identify where and how it might fail and assessing the relative impact of different failures. The intent is to identify the parts of the process that are most in need of change. When introducing new technology, such as a new cleaning process, you have to estimate the effect on wastewater treatment, solder mask adhesion, assembling, reliability, etc.; a few examples will often suffice. In addition, the supplier must be contacted. TDS and MSDS need to be observed.

On the environmental side, the impact on wastewater treatment needs to be checked; some of these cleaners may contain complexing agents with repercussions on waste treatment. Furthermore, interactions with other parts of the PCB stackup or substrate need to be evaluated. For example, a strong alkaline cleaner is suitable for a nickel-gold surface, but not for tin-lead, reflowed tin-lead, or a PCB on an aluminum carrier. Finally, the behavior of copper and immersion silver when subjected to the new cleaning agent also needs to be checked. **PCB007**

Nikolaus Schubkegel retired in February 2019. For the past 12 years, Schubkegel worked at Umicore Galvanotechnik GmbH in Germany as a technical service engineer for Taiyo products. Before that, he worked as a process engineer in the solder mask department at the former IBM-PCB plant (later STP) in Albstadt, Germany. Schubkegel obtained an M.Sc. degree in chemical engineering from the Polytechnic Institute in Timisoara.

Rogers' Materials and Business Updates

Judy Warner and Tony Mattingly, senior product manager at Rogers Corporation, discuss the state of materials at the company, as well as a general business update.
Click the image to view video.

The Founding Fathers of Quality: Ishikawa and Shewhart

The Right Approach

by Steve Williams, THE RIGHT APPROACH CONSULTING

This column continues the series of installments, each highlighting one of the seven founding fathers of quality (as selected by the author). It is important to understand and acknowledge their revolutionary contributions that still form the foundation of modern quality practices.

Dr. Kaoru Ishikawa (1915-1989)

Dr. Ishikawa was revolutionary in that he wanted to change the way people think about work. His vision was one of company-wide, total quality management, and argued that an over-reliance on the quality professional would limit the potential for improvement. Ishikawa believed that by empowering all personnel with quality, responsibility would result in a synergy not possible with the typical silo approach to quality. He urged management to resist becoming content with simply improving product quality, teaching that quality improvement can always go one step further by using statistics to drive process improvement.

Dr. Ishikawa is perhaps best known for his cause and effect diagram, also known as a fishbone or Ishikawa diagram. Ishikawa's vision with this tool was not to merely address the symptoms, but to drive issues to root cause by pinpointing problems from the bottom up. Ishikawa also started the quality circles movement, which is still used today by many companies in the form of quality improvement teams. Dr. Ishikawa was the first quality pioneer to emphasize what he termed the "seven basic quality tools" as a foundation for any quality system (Figure 1). My favorite Ishikawa quote is, "Quality control which cannot show results is not quality control. Let us

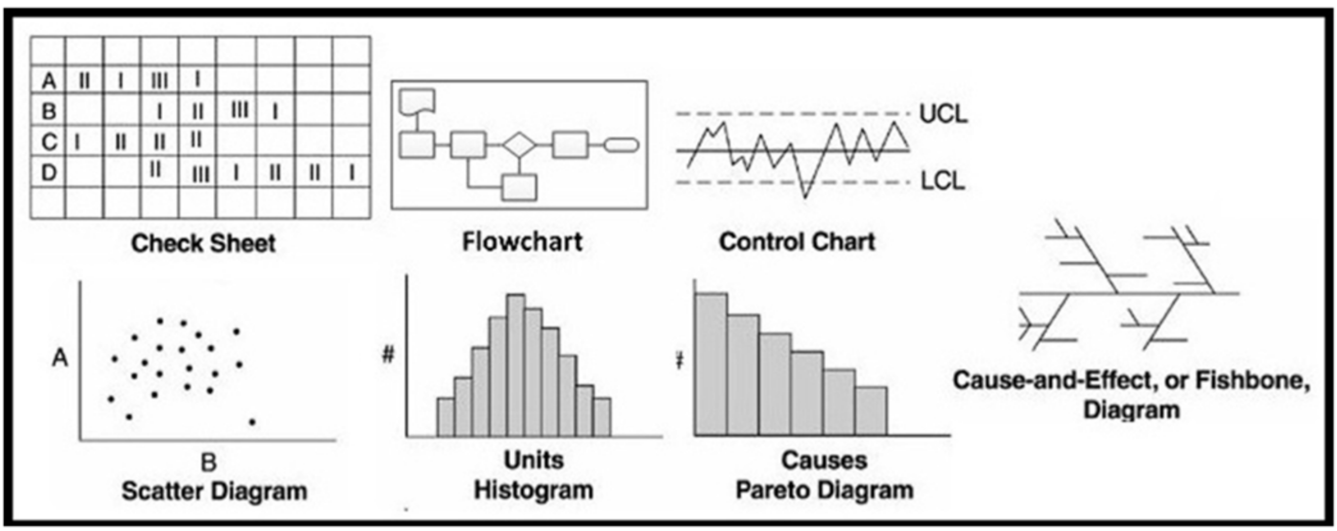

Figure 1: Seven basic quality tools.

engage in QC which makes so much money for the company that we do not know what to do with it."

Core Attributes of the Ishikawa Philosophy

Here are Ishikawa's seven basic quality tools.

1. Cause and effect diagram: Identifies root cause by brainstorming many possible causes for a problem, and then sorts the causes into categories.
2. Pareto chart: Bar graph representation of a histogram sorted by descending frequency used to prioritize data based on the Pareto principle (80/20 rule), where 80% of a problem comes from 20% of the causes.
3. Flowchart: A visual representation (picture) of a process.
4. Check sheet: A customized form for collecting and analyzing data.
5. Scatter diagram: Graphs pairs of numerical data, one variable on each axis, to look for trends, patterns, or relationships in the data.
6. Control charts: Graphs used to study how a process changes over time.
7. Histogram: A graph for showing frequency distributions and how often each different value in a set of data occurs and determining whether a process has a normal or bell-shaped distribution.

Walter A. Shewhart (1891-1967)

Dr. Walter A. Shewhart was one of W. Edwards Deming's early mentors, promoting the utilization of his own groundbreaking creation: the SPC control chart. Shewhart believed that management did not have sufficient access to the real-time data needed to effectively manage and control processes in a manufacturing environment. To this end, Shewhart developed a set of statistical process control methods that focus on reducing process variation to improve quality.

He was also the creator of the Shewhart cycle, better known as the plan–do–check–act (PDCA) cycle, which seeks continuous improvement by combining constant evaluation of management policy and procedures with statistical analysis. It is not hard to appreciate Shewhart's passion for statistics when considering his most recognizable quote: "The long-range contribution of statistics depends not so much upon getting a lot of highly trained statisticians into industry as it does in creating a statistically minded generation of physicists, chemists, engineers, and others who will in any way have a hand in developing and directing the production processes of tomorrow."

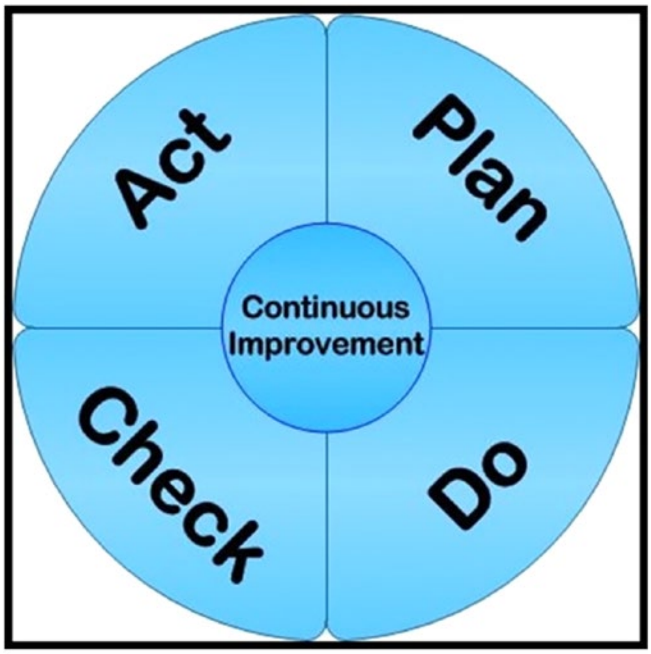

Figure 2: The Shewhart cycle.

Core Attributes of the Shewhart Philosophy

The Shewhart cycle (Figure 2) is a basic model for continuous improvement that can be used in a variety of situations, such as beginning improvement projects; developing a new or improved process, product, or service; defining a repetitive work process; performing root-cause analysis; or implementing any change. The Shewhart cycle was later improved on by Dr. Deming.

PDCA Cycle

Plan the activity that is going to take place. In this step, a gap analysis is done, looking at the

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Professional development courses are a great way to delve deeper into the challenges facing the electronics industry. Instructors of these courses reach a wide swath of attendees focused on learning. This is also a great way to pass on knowledge based on years of experience and leave a legacy.

Technical Conference

Provide an abstract of approximately 300 words that summarizes technical work, covering case histories, research and discoveries. Authors of papers selected for the conference will each receive a detailed speaker manual to assist them with numerous items, including the formatting of their papers and presentation slides. Speakers receive a complimentary technical conference pass for the day they present and special pricing for additional conference options.

Conference Paper Timeline

Abstracts due **June 20, 2020**

Professional Development Courses

Course proposals are solicited from individuals interested in teaching half-day (three-hour) professional development courses on design, manufacturing processes, materials, supply chain and reliability.

Honorariums are offered to professional development instructors to cover travel expenses.

Professional Development Timeline

Proposals due **June 8, 2020**

For more information on TOPICS, SPEAKER BENEFITS and SPEAKER RECOGNITION AWARDS, please visit www.ipcapexexpo.org/cfp.

Any questions or special requests, contact **BrookSandy@ipc.org**.

current state and desired future state and planning for how to close the gap. Identification of potential solutions occurs during the "plan" stage.

Do test the various potential solutions.

Check results to see if any of the potential solutions tested had the desired effect and assess the effectiveness of successful solutions.

Act on what you have learned, implementing the best of the potential solutions. If you have accomplished your objective, put controls into place so that the issue never comes back again. If you have not accomplished your objective, go through the cycle again, starting with the plan step.

Conclusion

It is interesting how long it took the American industry to adopt Dr. Ishikawa's philosophy of empowering all personnel with quality responsibility. Not until the latest 2015 revision of ISO 9001 did the international standard require that all employees, starting with top management, be responsible for the QMS. His seven basic quality tools are still prevalent in most quality management systems to this day. Shewhart's PDCA improvement tool is now a requirement in ISO 9001:2015, which validates the relevance of Shewhart's work from over 70 years ago. It is hard to find an organization today that is not running their processes using some form of SPC or statistical methods. These facts demonstrate just how far ahead of its time these founding fathers were. **PCB007**

Steve Williams is the president of The Right Approach Consulting. To read past columns or contact Williams, click here.

Strategies for Handling Big Data

Joe Fjelstad catches up with Marc Benowitz, CEO of iNEMI, as he provides an overview of his background at the company as well as strategies for handling big data. **Click the image to view video.**


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Editor Picks from PCB007

1 DuPont Introduces New Pyralux and Riston Products ▶

DuPont Interconnect Solutions has announced that it is introducing several new products across its DuPont™ Pyralux® and Riston® product families to address a diverse set of needs for both the manufacturing and performance of advanced electronics devices.

2 Residual/Free TBBPA in FR-4 ▶

Sergei Levchik describes how testing has shown that FR-4 PCBs do not contain free or residual tetrabromobisohenol-A (TBBPA).


Sergei Levchik

3 Punching Out! Preparing for Life Post-transaction ▶

Congratulations! You have punched out! Now what? Tom Kastner details how being prepared for life after a transaction is a good idea not only to help set up a smooth sale but also to give you the motivation to get through the deal process.


Tom Kastner

4 Fresh Thinking on the Logistics of Laminate Distribution ▶

Mark Goodwin, COO of Europe and the Americas for Ventec International Group, sits down with Barry Matties to explain his approach to supply chain management, efficient distribution, and maintaining definitive product identity at every stage.


Mark Goodwin

5 One World, One Industry: IPC APEX EXPO 2020— A Special Anniversary Year ▶


John Mitchell

This year marks the 20th anniversary of IPC APEX EXPO, and IPC is thrilled to celebrate this event milestone with attendees, exhibitors, and presenters. Dr. John Mitchell shares other accomplishments of the show, what's new in 2020, and other highlights.

6 AT&S: Working With Designers on a Global Level ▶


Gerald Weis

Barry Matties recently took a tour of AT&S's Austrian factory, which is developing new circuit design strategies surrounding embedded and active components. Gerald Weis discusses the company's focus on serving and educating PCB designers around the world, as well as their plans to embrace the latest technology and Industry 4.0 processes going forward.

7 Flexible Thinking: Additive Manufacturing of PCBs ▶


Joe Fjelstad

The future is very difficult to predict, but certain things can be intuited with a modicum of logic and a bit of wild-eyed speculation. Joe Fjelstad explores the increasing interest in additive manufacturing techniques as well as some history on additive's origins and his suggestions to embrace change.

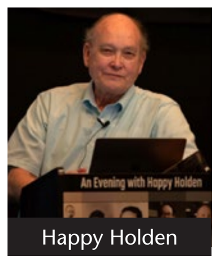
8 CES: The Main Halls ▶

CES 2020 is now over, and the next round of shows is underway. CES displayed electronics related to gaming, monitors, computers, smartwatches, TVs, vehicles, cellphones, etc. However, the effect on the industry and the way we live will be felt until the next CES. Dan Feinberg brings you the highlights.

9 TTM Technologies Inc. to Sell Four China Manufacturing Plants Comprising Its Mobility Business Unit ▶

TTM Technologies Inc. announced the execution of a definitive agreement under which TTM has agreed to divest its four China manufacturing plants comprising substantially all of the assets of its Mobility Business Unit as a separate enterprise for $550 million in cash consideration.

10 'A Night of Happy-ness' and 2020 Good for the Industry Awards ▶



Happy Holden

The Horton Grand Hotel in San Diego was the site of "A Night of Happy-ness" on the evening of February 3, 2020. I-Connect007 transformed the Regal Ballroom into a cozy lecture hall with two key objectives: to award the I-Connect007 Good for the Industry awards and celebrate the life, achievements, and personality that is industry pioneer Happy Holden.

Career Opportunities

Looking for the purrrrfect applicant?

Find industry-experienced candidates at I-Connect007.

For just $750, your 200-word, full-column ad will appear in the "career opportunities" section of all three of our monthly magazines, reaching circuit board designers, fabricators, assemblers, OEMs, and suppliers.

In addition, your ad will be featured in at least one of our newsletters, and your posting will appear on our **jobConnect007.com** board, which is also promoted in every newsletter.

Potential candidates can click on your ad and submit a resume directly to the email address you provide. If you wish to continue beyond the first month, the price is the same per month.

No contract required. We even include your logo in the ad, which is great branding!

Don't delay, contact us right *meow!*

To get your ad into the next issue, contact:
Barb Hockaday at barb@iconnect007.com or +1.916.608.0660 (-8 GMT)

I-Connect007
GOOD FOR THE INDUSTRY

Career Opportunities

Employment Opportunities

National Technology, Inc., a manufacturer of high-quality printed circuit boards, is currently looking for candidates for the following positions in our Rolling Meadows Illinois Facility:

Quality Control Manager

- Manage QMS in accordance with the ISO 9001:2015 system.
- Manage inspection departments, including final inspection, pre-mask inspection, AOI inspection and all associated quality inspections.
- Maintain continuous improvement initiatives.
- Generate and maintain monthly quality reporting.
- Manage internal and external corrective and preventive action.
- Responsible for maintaining the ISO status, including audits, training, procedures, etc.
- Maintenance and scheduling of calibrations.
- Be a liaison to our facility in India regarding customer related issues.
- Customer contact with RMA and corrective action.

Process/Quality Engineer

- Develop and document new processes and technologies.
- Review existing processes for improvement opportunities.
- Assist in identifying and addressing manufacturing issues.
- ISO internal auditing and process related audits.
- Set-up and monitor process controls through manufacturing.
- Maintain regulator compliances.

Candidates for these positions should have a solid background in printed circuit board fabrication. An in-depth knowledge of applicable IPC standards as well as ISO 9001 standard will be required.

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I-Connect007

GOOD FOR THE INDUSTRY

News Editor – Full Time Position

I-Connect007 seeks a positive, independent self-starter to manage news gathering process and work closely with editorial team. Qualified candidates will demonstrate strong organizational and communication skills and be able to work full-time remotely.

New hire will start with a portion of this work and ramp up with demonstrated mastery of the processes.

Aptitudes

- Organized
- Time aware
- Team oriented
- Planning skills
- Meeting deadlines
- Good record keeping
- Problem solving skills
- Attention to details
- Strong follow-through skills
- Grammar and editing skills
- Knowledge of basic photo editing
- Knowledge of HTML a plus

Attitude

- Ability to work remotely, often with only "virtual" supervision.
- Discipline to keep regular hours, communicate with team and deliver on deadline.
- Curious, investigative nature and interest in technology.

Objective: Submit editorial proof for the newsletter daily. This task includes news gathering, posting, categorization and simple editing functions.

- Gather news items from pre-planned primary sources for publication.
- Review and post all news items to the news manager prior to deadline.

Interested candidates please submit resume by clicking below.

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Career Opportunities

Talent for Hire

Have a position to fill? D.B.Management has the people you're looking for. Candidates currently available include:

- **Director of Operations, PCB and CEM**
  Grew previous operations to over $100 Million.

- **Technical Field Applications Engineer**
  Over 15 years of experience working in the U.S. with offshore companies.

- **Two Highly Experienced Front End Engineers**
  Over 25 years of experience. Will work remotely.

- **Four Experienced Sales Professionals for Both PCB Fabrication and Assembly**
  All four exhibit successful growth records.

Let D.B. Management help you with your staffing needs. Contact us now by calling Dan Beaulieu at:

207-649-0879

or emailing him at:

danbbeaulieu@aol.com

more details

Sr. PCB Designer–Allegro

Freedom CAD is a premier PCB design service bureau with a talented team of 30+ dedicated designers providing complex layouts for our enviable list of high-tech customers. Tired of the commute? This is a work-from-home, full-time position with an opportunity for overtime at time and a half.

Key Qualifications

- EXPERT knowledge of Allegro 16.6/17.2
- Passionate about your PCB design career
- Skilled at HDI technology
- Extensive experience with high-speed digital, RF and flex and rigid-flex designs
- Experienced with signal integrity design constraints encompassing differential pairs, impedance control, high speed, EMI, and ESD
- Experience using SKILL script automation such as dalTools
- Excellent team player that can lead projects and mentor others
- Self-motivated, with ability to work from home with minimal supervision
- Strong communication, interpersonal, analytical, and problem solving skills
- Other design tool knowledge is considered a plus (Altium, PADS, Xpedition)

Primary Responsibilities

- Design project leader
- Lead highly complex layouts while ensuring quality, efficiency and manufacturability
- Handle multiple tasks and provide work leadership to other designers through the distribution, coordination, and management of the assigned work load
- Ability to create from engineering inputs: board mechanical profiles, board fabrication stack-ups, detailed board fabrication drawings and packages, assembly drawings, assembly notes, etc.

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Career Opportunities

CAM Engineer

Eagle Electronics is seeking a CAM engineer specific to the printed circuit board manufacturing industry. The candidate should have a minimum of five years of CAM experience and a minimum of two years of experience in Frontline InCAM software. The candidate should also be fluent in PCB and CAM language pertaining to customer and IPC requirements. The ideal candidate has experience with scripting Frontline InCAM software.

This is a first-shift position at our Schaumburg, Illinois, facility; this is not a remote/off-site position. Any offer would include relocation costs to the Schaumburg, Illinois, area along with competitive salary and benefits.

If interested, please submit your resume to HR@eagle-elec.com and include "CAM Engineer" in the subject line.

About Eagle—Since 1979, Eagle Electronics has provided customers with the highest quality printed circuit boards at fair and competitive prices. From providing customers with short standard lead times to very low premiums on quick turns, Eagle strives to provide the best total value in high technology rapid turn-around PCBs in the industry.

apply now

West Software Application Engineer

This position reports directly to the Orbotech West software support manager and works with customers to support Orbotech's pre-production software products. Acts as a focal point for technical issues, manages product implementation projects, provides customer training, and supports the sales process. Advanced knowledge of Frontline PCB products, including InCam, InPlan, InStack, InSight, Genesis, and Genflex. Ability to travel and manage time to maximize results. Requires both written and oral technical communication skills. Skilled in the use of scripting languages, including C-Shell, Perl, or Python. Knowledge of relational databases and HTML/XML highly desirable. Knowledge of PCB manufacturing processes. Familiar with the processes used in front-end engineering departments at PCB fabrication sites. Requires use of project management skills to organize and complete projects that involve the implementation of sophisticated software tools used in printed circuit fabrication facilities.

An expected average of 35%+ travel. College degree or equivalent technical education, in addition to a minimum of five-plus years of related experience. Experience supporting sales and sales activities is a plus. U.S. citizen with the ability to work and travel within the U.S., Canada, and internationally.

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Career Opportunities

ventec
INTERNATIONAL GROUP
騰輝電子

OEM Sales Manager

Chicago/Home-Office-Based

Want to advance your career by joining a globally successful and growing world-class CCL manufacturer and help drive that success? We are seeking to hire an OEM sales manager to grow and manage key customer accounts with OEM's and Tier 1 manufacturers in the USA, focusing on Ventec's core market segments: mil/aero, automotive, and medical, offering a full range of high-reliability materials, including polyimide, IMS, and thermal management products.

Skills and abilities required for the role:
- Non-negotiable: Drive and tenacity!

Required:
- 7 to 10 years' experience in the PCB industry in engineering and/or manufacturing
- Detail-oriented approach to tasks
- Ability to manage tasks and set goals independently as well as part of a team
- Knowledge of MS office products

Full product training will be provided.

This is a fantastic opportunity to become part of a successful brand and leading team with excellent benefits.

Please forward your resume to jpattie@ventec-usa.com and mention "Technical Sales Engineer—Chicago" in the subject line.

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FREEDOM
CAD SERVICES

Sr. PCB Designer—Mentor Xpedition

Freedom CAD is a premier PCB design service bureau with a talented team of 30+ dedicated designers providing complex layouts for our enviable list of high-tech customers. Tired of the commute? This is a work-from-home, full-time position with an opportunity for additional compensation for overtime work at time and a half.

Key Qualifications
- EXPERT knowledge of Xpedition VX 2.x
- Passionate about your PCB design career
- Skilled at HDI technology
- Extensive experience with high-speed digital, RF, and flex and rigid-flex designs
- Experienced with signal integrity design constraints encompassing differential pairs, impedance control, high speed, EMI, and ESD
- Excellent team player who can lead projects and mentor others
- Self-motivated with the ability to work from home with minimal supervision
- Strong communication, interpersonal, analytical, and problem-solving skills
- Other design tool knowledge is considered a plus (Altium, Allegro, PADS)

Primary Responsibilities
- Design project leader
- Lead highly complex layouts while ensuring quality, efficiency, and manufacturability
- Handle multiple tasks and provide work leadership to other designers through the distribution, coordination, and management of the assigned workload
- Ability to create from engineering inputs, board mechanical profiles, board fabrication stackups, detailed board fabrication drawings and packages, assembly drawings, assembly notes, etc.

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Career Opportunities

ROGERS CORPORATION

Advanced Connectivity Solutions

Senior Development Engineer

Rogers Corporation is seeking a senior development engineer accountable for the development of more complex products and processes, the establishment of sound technical bases for these developments, and effective interaction with technology, process, and platform innovation; operations; sales and marketing; and process engineering personnel to commercialize these developments.

Essential Functions:

- Design and conduct experiments and interpret the results
- Report on projects in both written and verbal formats at all levels of the organization
- Perform technical troubleshooting of new products and processes; act as new product/concept incubator for new technologies and platforms, identifying opportunities for improvement and incorporation design for manufacturing requirements resulting in a viable, scalable product
- Provide ongoing process and manufacturing support to newly launched products as applicable
- Provide support in terms of analytical equipment maintenance, methods development, material analysis, and documentation of new process or products
- Manage capital projects for the purchase and installation of new process or support equipment; train employees in new processes

Required Education and Experience:

Ph.D., Ch.E., M.E., or material science, or B.S. or higher in a technical discipline with accomplishment in product development and project management.

Rogers Corporation provides equal employment opportunities to minorities, females, veterans, and disabled individuals as well as other protected groups.

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GO Gardien

Gardien Is Hiring!

The Gardien Group, a leading solutions provider in the PCB industry, is looking to fill multiple openings in their China, Japan, Taiwan, and United States service centers.

We are looking for electrical engineers, operations managers, machine operators, and sales executives. Prior experience in the PCB industry is beneficial but not essential. Training will be provided along with excellent growth opportunities, a benefits package, and periodic bonuses.

Our global teams are from diverse cultures and work cohesively as a tight-knit unit. With performance and initiative, there are plenty of opportunities for professional growth.

Gardien is an equal opportunity employer. Employment decisions are made without any regard to race, color, religion, national or ethnic origin, gender, sexual orientation, age, disability, or other characteristics.

Interested candidates, please contact us with your resume and a cover letter. Kindly note that only shortlisted candidate will be contacted.

Apply at careers@gardien.com.

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Career Opportunities

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TRAIN. WORK SMARTER. SUCCEED.

Become a Certified IPC Master Instructor

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

Qualifications and skills

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

Benefits

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

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INSULECTRO

Technical Account Manager Chicago/Minneapolis

Insulectro, the largest national distributor of printed circuit board materials, is seeking a talented sales superstar for a Technical Account Manager role based out of either our Chicago or Minneapolis office. This role will focus on maintaining the existing customer base and developing new business within the assigned territory in both the printed circuit board and printed electronics industries. We are looking for the perfect fit of education, experience, and attitude that matches our company culture and enhances the service level to our customers.

Qualifications:

- A self-motivated business professional who is driven to succeed with a minimum of 3 years outside sales experience in the PCB or PE industry
- Proven sales/business development record
- Excellent communication and interpersonal skills
- OEM and electronic assembly experience is a plus

We offer:

- Competitive salary and commission plan with a comprehensive benefits package
- A fun, high-energy company with an entrepreneurial spirit
- A great group of people to work with!

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Career Opportunities

APCT, Printed Circuit Board Solutions: Opportunities Await

APCT, a leading manufacturer of printed circuit boards, has experienced rapid growth over the past year and has multiple opportunities for highly skilled individuals looking to join a progressive and growing company. APCT is always eager to speak with professionals who understand the value of hard work, quality craftsmanship, and being part of a culture that not only serves the customer but one another.

APCT currently has opportunities in Santa Clara, CA; Orange County, CA; Anaheim, CA; Wallingford, CT; and Austin, TX. Positions available range from manufacturing to quality control, sales, and finance.

We invite you to read about APCT at APCT.com and encourage you to understand our core values of passion, commitment, and trust. If you can embrace these principles and what they entail, then you may be a great match to join our team! Peruse the opportunities by clicking the link below.

Thank you, and we look forward to hearing from you soon.

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Development Chemist
Carson City, NV

Develop new products and modify existing products as identified by the sales staff and company management. Conduct laboratory evaluations and tests of the industry's products and processes. Prepare detailed written reports regarding chemical characteristics. The development chemist will also have supervisory responsibility for R&D technicians.

Essential Duties:

- Prepare design of experiments (DOE) to aid in the development of new products related to the solar energy industry, printed electronics, inkjet technologies, specialty coatings and additives, and nanotechnologies and applications
- Compile feasibility studies for bringing new products and emerging technologies through manufacturing to the marketplace
- Provide product and manufacturing support
- Provide product quality control and support
- Must comply with all OSHA and company workplace safety requirements at all times
- Participate in multifunctional teams

Required Education/Experience:

- Minimum 4-year college degree in engineering or chemistry
- Preferred: 5-10 years of work experience in designing 3D and inkjet materials, radiation cured chemical technologies, and polymer science
- Knowledge of advanced materials and emerging technologies, including nanotechnologies

Working Conditions:

- Chemical laboratory environment
- Occasional weekend or overtime work
- Travel may be required

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Career Opportunities

INDIUM CORPORATION®

Multiple Positions Available

The Indium Corporation believes that materials science changes the world. As leaders in the electronics assembly industry we are seeking thought leaders that are well-qualified to join our dynamic global team.

Indium Corporation offers a diverse range of career opportunities, including:

- Maintenance and skilled trades
- Engineering
- Marketing and sales
- Finance and accounting
- Machine operators and production
- Research and development
- Operations

For full job description and other immediate openings in a number of departments:

www.indium.com/jobs

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Manncorp™

SMT Field Technician
Huntingdon Valley, PA

Manncorp, a leader in the electronics assembly industry, is looking for an additional SMT Field Technician to join our existing East Coast team and install and support our wide array of SMT equipment.

Duties and Responsibilities:

- Manage on-site equipment installation and customer training
- Provide post-installation service and support, including troubleshooting and diagnosing technical problems by phone, email, or on-site visit
- Assist with demonstrations of equipment to potential customers
- Build and maintain positive relationships with customers
- Participate in the ongoing development and improvement of both our machines and the customer experience we offer

Requirements and Qualifications:

- Prior experience with SMT equipment, or equivalent technical degree
- Proven strong mechanical and electrical troubleshooting skills
- Proficiency in reading and verifying electrical, pneumatic, and mechanical schematics/drawings
- Travel and overnight stays
- Ability to arrange and schedule service trips

We Offer:

- Health and dental insurance
- Retirement fund matching
- Continuing training as the industry develops

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Career Opportunities

Career Opportunities

BLACKFOX

Premier Training & Certification

IPC Master Instructor

This position is responsible for IPC and skill-based instruction and certification at the training center as well as training events as assigned by company's sales/operations VP. This position may be part-time, full-time, and/or an independent contractor, depending upon the demand and the individual's situation. Must have the ability to work with little or no supervision and make appropriate and professional decisions. Candidate must have the ability to collaborate with the client managers to continually enhance the training program. Position is responsible for validating the program value and its overall success. Candidate will be trained/certified and recognized by IPC as a Master Instructor. Position requires the input and management of the training records. Will require some travel to client's facilities and other training centers.

For more information, click below.

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YOUR JOB AD HERE

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

I-Connect007
GOOD FOR THE INDUSTRY

Events Calendar

CPCA Show 2020
Postponed–**NEW DATE: June 22–24**
Shanghai, China

Electronica & Productronica China
Postponed—Date TBA
Shanghai, China

LOPEC Exhibition and Conference (Driving the Future of Printed Electronics)
March 24–26, 2020
Munich, Germany

KPCA and KIEP Show
April 22–24, 2020
Kintex, Korea

IMAPS High Temperature Electronics HiTEC
April 22–24, 2020
Albuquerque, New Mexico, USA

IMAPS CICMT Ceramic Interconnect
April 22–24, 2020
Albuqerque, New Mexico, USA

JPCA Show
May 27–29, 2020
Tokyo Big Sight, Japan

Productronica India
September 23–25, 2020
Bengaluru, India

Additional Event Calendars

IPC

SMTA Surface Mount Technology Association

iNEMI

pcb007

Coming Soon to *PCB007 Magazine:*

MARCH 2020: Driving Out Waste
Reducing manufacturing waste and improving profits: just how connected are they?

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