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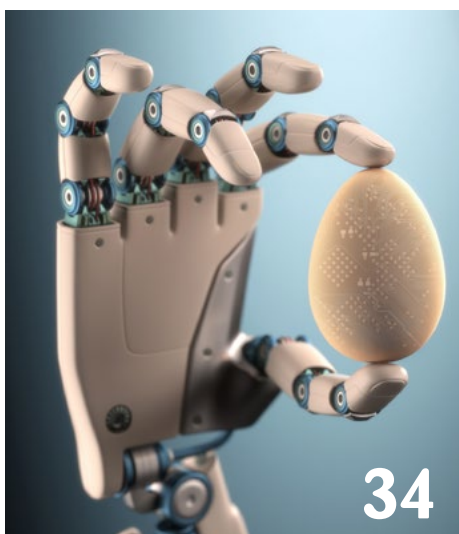
May 2016

Featured Content



Strategies to Reduce Handling Errors

Handling and people-related mistakes and defects are always a concern in manufacturing. What's the answer? Is it automation? Is it more training? A little of both? This month, our experts weigh in on the who, what, when, where and how of reducing handling errors.



12 Automate to Innovate in Flex Processing
by Mark Wegner and Patrick Riechel

20 Quick & Easy 6S to Reduce Handling Issues
by Steve Williams

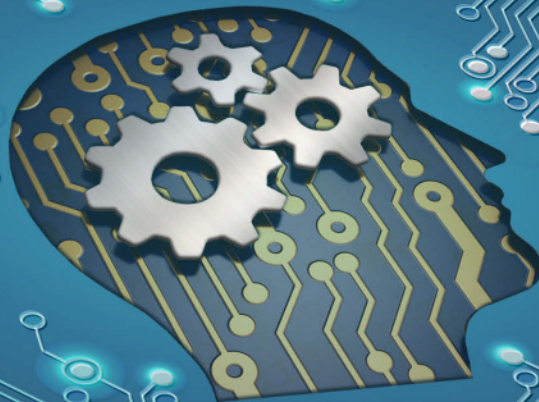
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Chris Ryder, ESI

The Quiet Mainstreaming of HDI Manufacturing

by Chris Ryder, ESI | Feb. 2016, I-Connect007

Although design engineers have driven the evolution of the current class of mobile devices, primarily through addressing market demand for new form factor innovation, the push to meet the associated manufacturing challenges has been responsible for a revolution in PCB manufacturing.

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Getting a Handle on Handling Errors

by Patty Goldman

I-CONNECT007

When gathering info for this month's topic on handling strategies, I knew there was much happening in the automation end of things and all that it can do for handling. But I also knew it was not something that is easy for the "little guy" to do—automation is expensive, in general, and it is not always conducive to the high mix of small lot sizes typical of the many prototype-plus facilities in North America and Europe.

I talked with upper management at a few of these shops, to get their thoughts on handling errors and automation, and they agreed:

It is difficult to automate when you are running prototypes and small lots. For example, Yash Sutariya of Saturn Flex told me that some years ago they had abandoned a type of auto unloader at the end of a line because it actually caused defects. The solution was a totally different type that worked much better. More on that in Yash's short feature this month.

In conversations with IMI Inc.'s Peter Bigelow and Nilesh Naik of Eagle Circuits, while at IMPACT Washington, D.C. (another story, another time), they both agreed that handling and people-related mistakes and defects are always a concern, mainly because of the frequently changing requirements from one quick-turn proto job to the next. Their answer was training, training, and more training, reducing as many opportunities for error as possible and requiring everyone, from bottom to top, to constantly question and be aware of every step in the entire manufacturing process. It's not perfect, but perhaps it is what works best when capital funds are limited and every job is non-standard.

All this being said, let's not forget that the standard DES (develop-etch-strip) line is an automated process, as is that plating line with the automated hoist, as is the drill machine that is programmed to pick up and dispose of drills automatically. So you probably have already eliminated some handling issues. Read on for more pointers on how to further reduce handling and errors in your facility.

First up this month we have an interesting article on roll-to-roll processing of flex by Mark Wegner of Northfield Automation and Patrick Riechel from ESI. As flex applications grow and as technology forces ever finer and thinner circuits and materials, automated web handling may prove to be the most sensible and cost effective solution—even for small facilities.

Next, Steve Williams of The Right Approach Consulting provides a clear and easy to understand discussion of 6S methodology. He shows



Figure 1: Improved unloader at Saturn Electronics.

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how following this almost-no-capital-involved approach can significantly reduce handling issues while increasing efficiency. Immediately following is a short case study by Yash Sutariya of Saturn Electronics/Saturn Flex Systems that provides a real life example of this in action.

Happy Holden also weighs in with a case for automation as a means to reduce handling errors. Happy thoroughly explains the six classes of automation, ranging from a totally manual operation through 100% automated (recall our [article](#) on Whelen Engineering in October's issue). He also details some inexpensive ways to automate or reduce handling.

Taking a different approach, Dave Becker of All Flex Flexible Circuits discusses the importance of a clean operation to preventing defects. He details the requirements for a cleanroom—ever more important as feature sizes decrease. Is a defect caused by a human hair considered a handling defect?

Moving on, we have a series of interview excerpts by our own Pete Starkey from the recent CPCA show in China. Three diverse people offer their thoughts on automation, mainly in China. It's important to read if only to learn what the thinking is on the other side of the world.

Regular columnist Mike Carano of RBP Chemical is on hand to provide us with an excellent primer on imaging for pattern plating. And Todd Kolmodin with Gardien Services USA explains why you need to get individuals (“the hidden ‘I’ in team”) to buy into your quality process in order for it to be successful.

We have included a special report on a collaborative research project (MACFEST) on advanced formulations for final immersion gold and palladium finishes for future electronic systems. It is authored by Dr. Andrew Ballantyne and Professor Karl Ryder, both with the University of Leicester in the UK.

Wrapping up this issue we have our most venerated columnist Karl Dietz, with a discussion on the levels of electronic packaging along with the material and processing requirements detailed for each level. As usual, clear and concise and just the basic info we need, when we need it.

In our June issue, we delve into fine features, as in the ever finer lines, spaces, pads and tolerances that we are all faced with in the continuing race towards...what, exactly? Yes, these ever-finer features are still manufacturable. Tune in next month to learn more. **PCB**



Patricia Goldman is a 30+ year veteran of the PCB industry, with experience in a variety of areas, including R&D of imaging technologies, wet process engineering, and sales and marketing of PWB chemistry. Active with IPC since 1981, Goldman has chaired numerous committees and served as TAEC chairman, and is also the co-author of numerous technical papers. To contact Goldman, [click here](#).

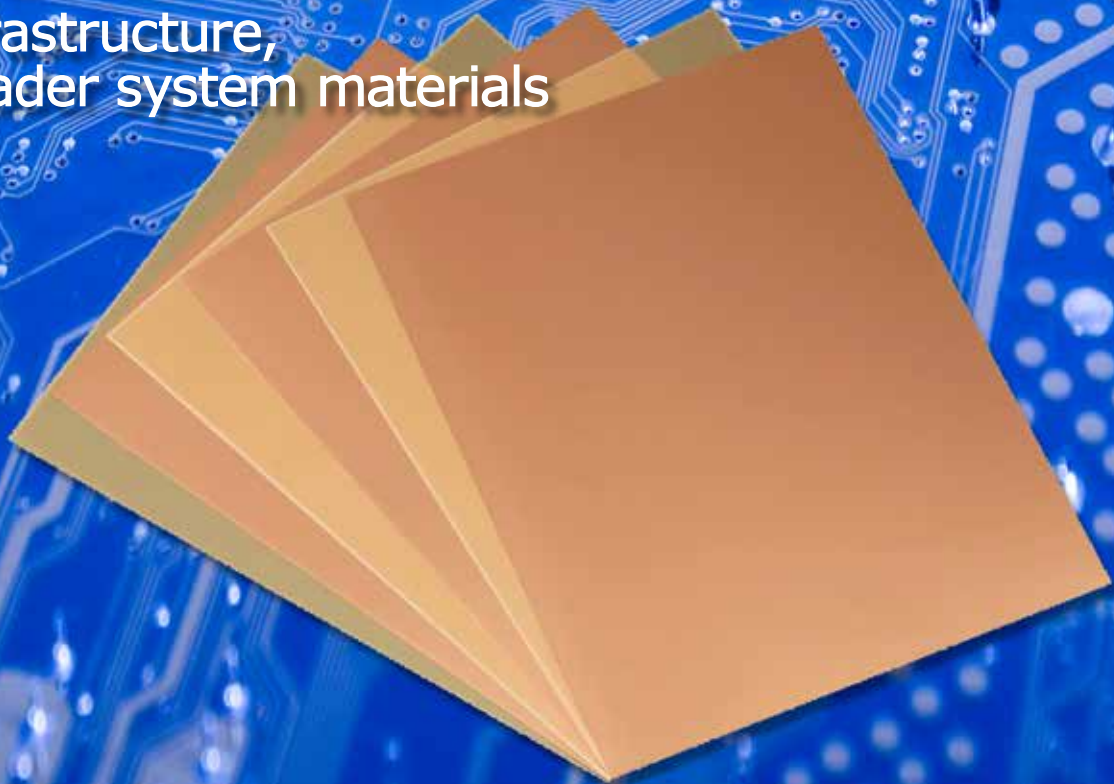
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Automate to INNOVATE in FLEX Processing

by **Mark Wegner**, NORTHFIELD AUTOMATION SYSTEMS and **Patrick Riechel**, ESI

Introduction

The growing market demand for mobile devices, wearables and Internet of Things (IoT) devices continues to create new challenges for suppliers and manufacturers in the electronics value chain. Along with this market demand comes a challenging set of market requirements for the underlying circuits and components that drive such devices. These requirements are primarily related to functional attributes such as speed and functionality, and to form factor constraints such as size, build quality and durability. At the same time, the big brands—the manufacturers' customers—are not only battling to differentiate themselves among myriad alternatives, but are also striving to be the first to address new and broader markets with a wider range of devices.

Effectively responding to these new requirements—and doing so profitably—requires

that manufacturers continually innovate, but with a focus on maintaining processing quality without sacrificing throughput or increasing costs. They must adopt new processes, new techniques and new technologies, and be willing to creatively adapt their production capabilities to match the changing needs of their customers.

In their drive to aggressively cut costs out of their business, manufacturers are looking for more creative ways to optimize production, increase efficiency and improve yields. All factors that affect a lower cost of ownership for capital equipment.

One of the ways flexible printed circuit (FPC) manufacturers have been effective in staying ahead of the throughput/cost curve is through the deployment of appropriate automation. Yet, although automation may be one of the low-hanging fruits for flex PCB processors, its application should be viewed in the context of a production flow that may already include other innovations.

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The Need for Automation

Demand trends for virtually all electronic products point to the need for manufacturers to dramatically improve their accuracy in the fabrication of high-volume electronics. Especially as it relates to their proficiency at processing extremely thin films, flexible glass and other fragile substrate materials. To stay ahead and successfully compete in global markets they must produce precision-quality electronics that incorporate novel materials and nanotechnology-level accuracy. In this environment, automation isn't a luxury; it's a requirement.

Automation can mean different things to people in different manufacturing environments, and numerous material handling technologies are available that address myriad production challenges. In this article, however, we will focus primarily on automation in the context of flex PCB and interconnect material handling.

Roll-to-Roll Web Handling Automation

The good news in this discussion of production challenges is that, given the flexible nature of FPCs, the vast majority of flex processing can be performed in roll formats using web han-

dling automation technologies. There are numerous advantages to keeping roll-to-roll materials in this format through as much of the manufacturing process as possible.

These advantages include:

- Large-volume rolls of material are easily and safely transported between process machines
- Much shorter panel-to-panel move times as compared to swapping individually-cut panels manually or with robotic stack handlers
- Material moves between process machines with constant tension and automated precision positioning, both of which can be critical to meeting requirements for fine-line accuracy
- Tension and position control for step-and-repeat processes such as laser drilling, testing, blanking, printing, photo lithography, etc.
- Tension, positioning, and speed control for continuous processes such as wet process develop, etch, strip, plating, printing, coating, lamination and so on

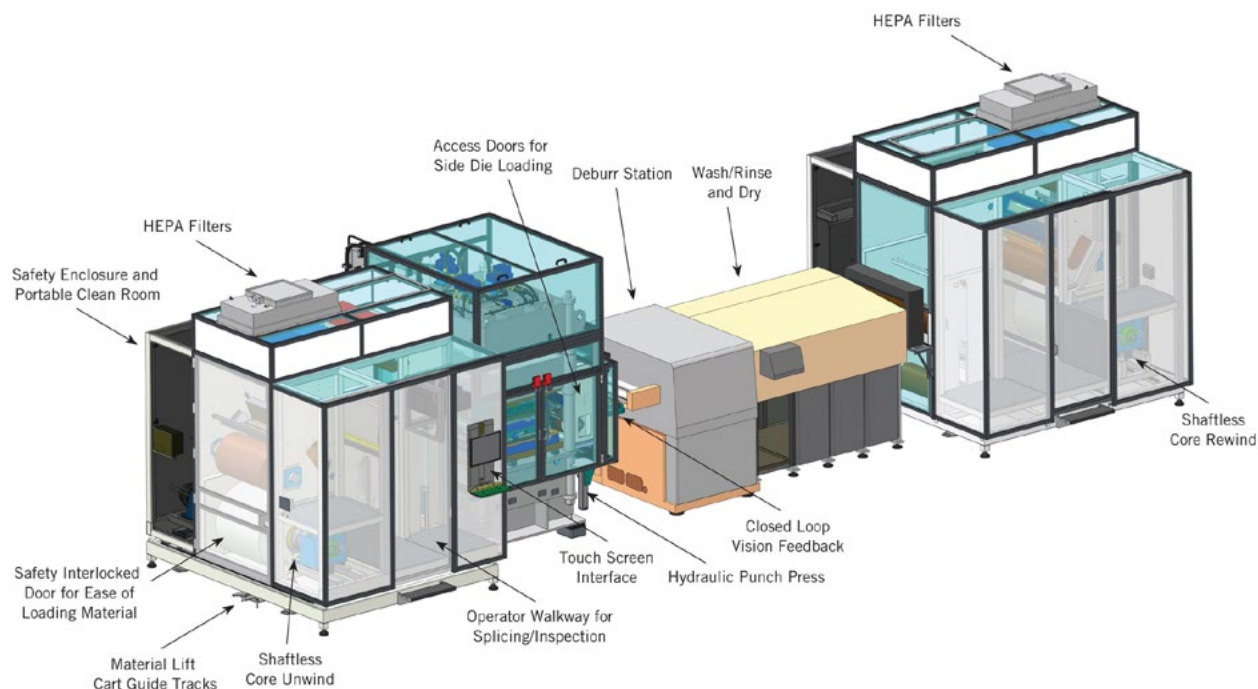


Figure 1: Example of turnkey web integration of multiple processes.
(Courtesy of Northfield Automation Systems Technology)

For the remaining process steps or for products that must be individually handled in panel formats such as multilayer FPCs, coverlay, or rigid-flex circuits, robotic stack handler systems can be used to increase the level of automation. Standardized and custom solutions cover almost all segments of the processing flow, thus making it possible to accommodate a wide range of product-specific requirements and sizes.

When does it make sense to automate?

Many factors can spur FPC manufacturers to consider automating parts or all of a production line.

Key considerations include:

- Yield loss due to operator material handling, material contamination, and operator errors
- Low equipment efficiency due to high levels of operator interaction, variability, standby, and non-scheduled equipment time
- Continuously-shifting bottlenecks in a production line due to cycle time variability
- High operator labor costs that could be alleviated through handler automation

In general, low-mix, high-volume manufacturers tend to get the most value from automation with the least amount of investment. For such manufacturers, investments in web handling automation can often provide sufficient increases in throughput, uptime and yield on existing process machines to obviate the need for additional investment in capacity.

However, even high-mix, low-volume manufacturers are finding that the cost-benefit analysis is beginning to favor automation technology as wages rise globally, materials become more susceptible to damage from manual handling, and accuracy and quality requirements become more stringent. And, as noted above, the macro trends in wearables, medical devices and other electronics devices point to greater use of thinner, more fragile materials, which can only be processed cost-effectively with automated web handling solutions.

Automation: The Low-Hanging Fruit?

The move to automated web handling systems, while not trivial, often proves to be relatively easy to implement for many of the processing tools used in most FPC manufacturing operations around the world. This is especially true for tools such as laser-based processing systems that incorporate communications interfaces capable of supporting integrated handlers. In such cases, the resulting gains in yield, throughput, and efficiency lead to rapid returns on capital equipment investments. Of course, the ideal scenario for rapid ROI is a turnkey automated process solution, such as when setting up a new or expanded process.

As materials become thinner and more sensitive, it becomes more and more difficult to prevent material damage from occurring during the normal course of manual material handling operations. As damage problems and risks mount, significant yield improvements can be realized from the use of web handlers with automated positioning and automated tensioning control that virtually eliminate damage and wear to flex materials during the manufacturing process.

Let's take a look at some of the problems with manual panel-based processes with modern flex materials.

Panel Damage

Moving the panels is a challenge since the slightest bend or uneven tension applied to materials can result in permanently bent edges and wrinkled substrates.

Operator Handling

Even the slightest physical contact with the material surface can cause scratches or surface contamination, as all too frequently occurs during the course of manual panel handling by operators.

Machine Calibration

Manual operator material handling requires significant user-machine interaction. Each interaction presents an opportunity for errors to be introduced. With web automation, closed-loop feedback can assure that error tolerances are not accumulated through the processing of even a large roll of production material.

Material Contamination

In roll-to-roll processes, contamination problems are almost completely avoided. Rolls of material can be wrapped for protection when moving between processes and portable clean room enclosures can be used to enable machine tools to process the exposed web in a clean environment. By limiting user interactions to a single, automated lot of rolled material, yield loss due to operator errors are minimized as well.

Rapid equipment efficiency benefits can also be achieved through greater automation. Tool load and unload time are greatly reduced when moving from panel handling to web handling. Processing equipment typically requires safety doors to avoid harm to operators. Web handling equipment is designed so the flex materials can travel through very narrow slits that are inaccessible to operators. As a result, no time is lost due to the need to continually open and close safety doors.

Example: Replacing an operator-panel-loaded process with a web handling unwind and rewind:

- Prior to automation, panel removal, placement and readiness required an average of 12 seconds per panel between process machine cycles

- With the unwind and rewind systems installed on that same process machine, the panel removal, placement and readiness within the web was reduced to two seconds between machine cycles

- The increased 10 seconds of machine up-time per panel raised that machine's throughput enough to deliver a web handling unwind and rewind ROI of six months

Another process advantage is that material webs have effectively near-zero distance between the edges of one panel to the next. Movement time is reduced given these shorter distances for the material to travel. Efficiency is further improved by reducing the amount of inefficient operator interaction, reducing system standby time due to absent or busy operators, and reducing non-scheduled equipment time due to unworked shifts. For certain applications and processes, it is possible to start a job at the end of a day shift and have it finish overnight in time for the beginning of the next day shift. Also, some process machines can support two webs running through in parallel, giving twice the throughput with the same investment of one process machine.

Planning can often also be simplified by reducing cycle time variability caused by differences in operator-tool interactions. If this variability is causing continuously-shifting bottlenecks in a production line, it may be due to the difficulty of accurately planning material movement and product delivery schedules. Handling automation improves cycle time consistency and eases production planning.

Labor costs can often be reduced through the use of handling automation. These labor costs show up in various forms. Obviously, when automation reduces the amount of operator-equipment interaction, fewer operators can do the same amount of work. One operator can support multiple roll-to-roll manufacturing lines. Less obvious benefits include higher operator satisfaction that results in less employee turnover as well as fewer operator injuries. Both of these benefits can be achieved due to the less-repetitive work that is generally further distanced from the dangerous parts of process machinery.

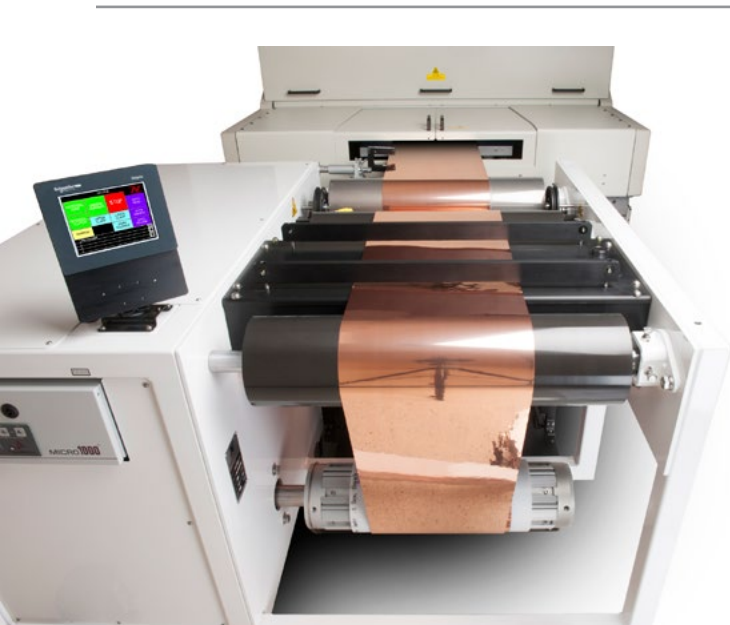


Figure 2: Roll-to-roll automation of flex material.

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Example: Minimizing operator handling and related defects

Prior to automation:

- 30 seconds required to load and unload each thin panel into a rigid frame for processing through wet process
- Required three operators (frame, load and unload)

After moving to roll-to-roll format: Operator handling removed from the process

- Requires less than one minute to load a 1,000 foot roll—1000 panel equivalent
- A single operator supports up to three roll-to-roll process lines
- Yield improved from 84% to 99% for material handling related defects
- The throughput, yield improvement and labor reduction combined to deliver an ROI of only three months

Selecting an Automation Supplier

Regardless of production needs and scenarios, it's important to work with an automation supplier who has the process experience necessary to design and manufacture a turn-key solution that will ensure product quality, maximize efficient throughput, deliver meaningful data outputs, and is user-friendly for operators.

Going a step further, the supplier should be able to demonstrate the expertise necessary to enable the seamless movement of materials across the entire manufacturing process. Additionally, suppliers should demonstrate a willingness to partner with FPC manufacturers to both maximize efficiency and maximize quality.

In cases where manufacturers are adding new processes and tools, it's often advantageous to consider solutions that already have the right processing platform paired with the right high volume production-oriented automation. One



Figure 3: Roll-to-roll automation integrated with a PCB laser processing system.

such example, as shown in Figure 3, is the recently introduced pairing of the RollMaster thin material web handling system with the ESI 5335 flex PCB laser processing system.

An Incremental Automation Step that Pays Big Efficiency Dividends

Although the implementation of web handling automation is a great way to gain efficiencies in FPC manufacturing, it doesn't require drastic changes to one's processing technology roadmap. As an incremental technology change to the process flow, most of the existing flow is maintained, with the only change being the automation of the web handling component. It is also possible to incrementally convert process steps to roll-to-roll processes using standalone web-to-panel process tools as the overall process flow is converted. The web-to-panel tool moves further down the process flow as the conversions are made downstream. Also, the use of wider web widths can still be maintained in the upstream processes for further production efficiency. In such cases, the wide web is slit into narrower widths using a web splitter, in order to support production webs in the downstream processes.

In this sense, web handling automation can be seen as an incremental step, but a step that delivers major gains in efficiency and yield without adding significant systems management overhead. The resulting increase in total processing up time also helps maximize investments in the laser processing tool.

A strong case can be made for adding web handling automation, but it needs to be viewed in the context of the overall process flow. As part of a broader automation roadmap, the minimal disruption, ease of implementation and the resulting operating efficiencies gained through roll-to-roll automation make it worth considering. The increase in capacity with less capital and labor expense not only benefits the bottom



Figure 4: Web splitter. (Courtesy of Northfield Automation)

line, but also positions FPC manufacturers for long-term success. **PCB**



Mark Wegner is president and co-founder of Northfield Automation Systems.



Patrick Riechel is flex laser processing product manager with ESI.

Quick & Easy 6S to Reduce Handling Issues

by Steve Williams

THE RIGHT APPROACH CONSULTING LLC.

Introduction

Handling is often the source of many pain points for PCB fabricators, resulting in rework, scrap and customer returns. Quick & Easy 6S is a fantastic tool to minimize handling risk by reducing product travel and improving shop cleanliness.

6S Methodology

6S (Figure 1) is literally five Japanese words beginning with the letter S, plus Safety, which together form a systematic process for organizing a workplace. While this may seem to be a minor tool in the war on waste, the benefits include quality and safety improvements, lead-time reduction, reducing hidden waste, and of course, increased profits. Below we will explore what the six Ss are and why they are important.

Sort (Seiri): Ensuring each item in a workplace is in its proper place or identified as unnecessary and then removed; it's simply getting rid of unnecessary stuff.

Questions to ask:

- ✓ Can this task be simplified?
- ✓ Do we label items properly and dispose of waste frequently?

Set in Order (Seiton): Arrange materials and equipment so that they are easy to find and use. Prepare and label storage areas using paint, tape, outlines, or color-codes. Shadow boards are a great way to identify the type and location of tools (Figure 2).

Questions to ask:

- ✓ How much time is spent looking for things and putting things away?
- ✓ Can we improve the ergonomics of this task?

Shine (Seiso): Repair, clean and shine work area; in other words, "everyone is a janitor" (this is a concept that U.S. workers have a difficult time embracing!). Aside from any safety or health risks, employees honestly perform



Figure 1: Flowchart of 6S.

The standard for the Internet of Manufacturing (IoM) has arrived!



The Open Manufacturing Language (OML) is a real-time communication standard for PCBA manufacturing that defines the interconnectivity of assembly production processes and enterprise IT systems.

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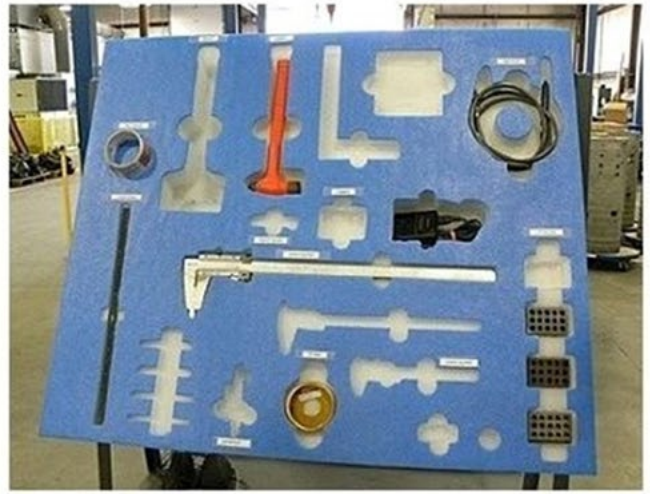
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Shadow Board



Cutout Shadow Board

Figure 2: Examples of shadow boards.

better in a neat and clean environment. Figure 3 illustrates how one advanced printed circuit board manufacturer, TTM Technologies, whose majority of processes are chemical-related, has successfully applied this concept.

Questions to ask:

- ✓ *Do we have a schedule for cleaning, sweeping, and wiping off for each department?*
- ✓ *Do we have cleaning inspection checklists?*
- ✓ *Are we seeing the workspace through our customers' eyes?*

Standardize (Seiketsu): Formalize procedures and practices to create consistency and ensure that all steps are performed correctly.

Questions to ask:

- ✓ *Does everyone know what they are responsible for doing?*
- ✓ *Is there a documented process that describes when and how to do it?*

Sustain (Shitsuke): Perhaps the most critical of the six Ss is keeping the prior four processes going through training, communication, and organizational structure.

Questions to ask:

- ✓ *Does our senior management support this*

initiative by allocating the appropriate time and resources?

- ✓ *Do we create awareness by publicizing and rewarding successes?*

Safety is the foundation for the prior five Ss and underscores the importance of keeping the workplace environment safe for employees and product.

Questions to ask:

- ✓ *Is there a safety impact of every single 6S activity we are proposing?*
- ✓ *Is there an opportunity to remove safety risk by implementing 6S?*

6S and Handling

The three keys to reducing handling issues are fundamentally simple:

1. Minimize product touch time
2. Reduce product transit time/distance
3. Maintain a clean and uncluttered work environment

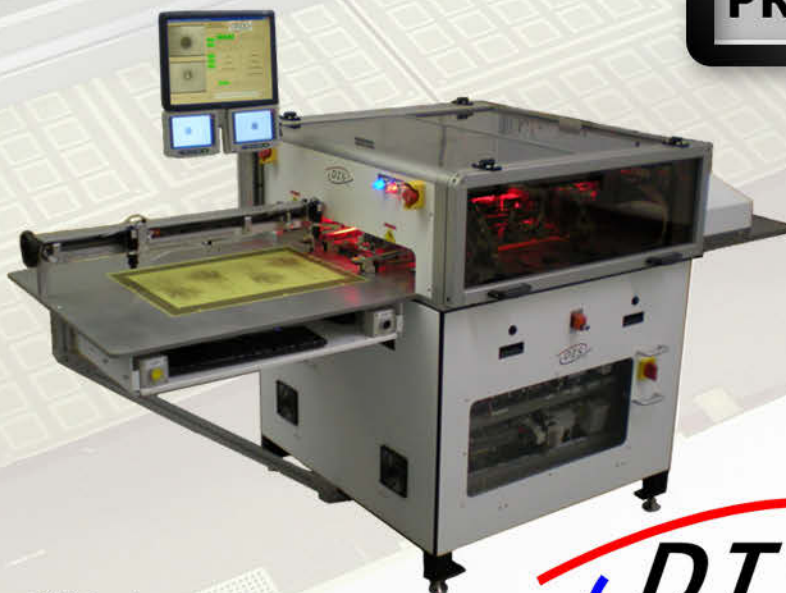
A sloppy workspace is ripe for opportunities to inadvertently scratch, dent or otherwise damage the product. I have witnessed countless examples of certified cleanroom environments that are so cluttered that artwork, resist

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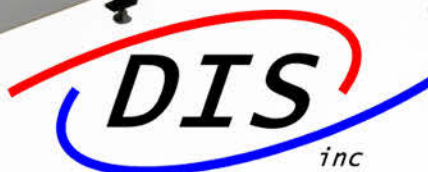
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Figure 3: Before and after a PCB 6S project.

and panels are easily damaged just from moving them from a rack to the operation. Material handling rack design is also a major contributor and should be evaluated with the same 6S eye as the workspace to design out any extra features that could cause product damage.

The shop environment is also a 6S opportunity, as airborne particulate and chemical vapors and residue can redeposit on WIP product. Cleanliness is a state of mind and needs to be ingrained in the daily work life of each and every employee.

All 6S projects also need to be visual and placed in plain sight of all workers so everyone can understand the status of the system at a glance. Visualizing projects also supports the Shitsuke process of publicizing and rewarding successes. Digital imaging has made documentation of “before and after” improvement easy to incorporate into the documents, posters and reports that make up a good visual management system.

Penny Wise and Dollar Foolish

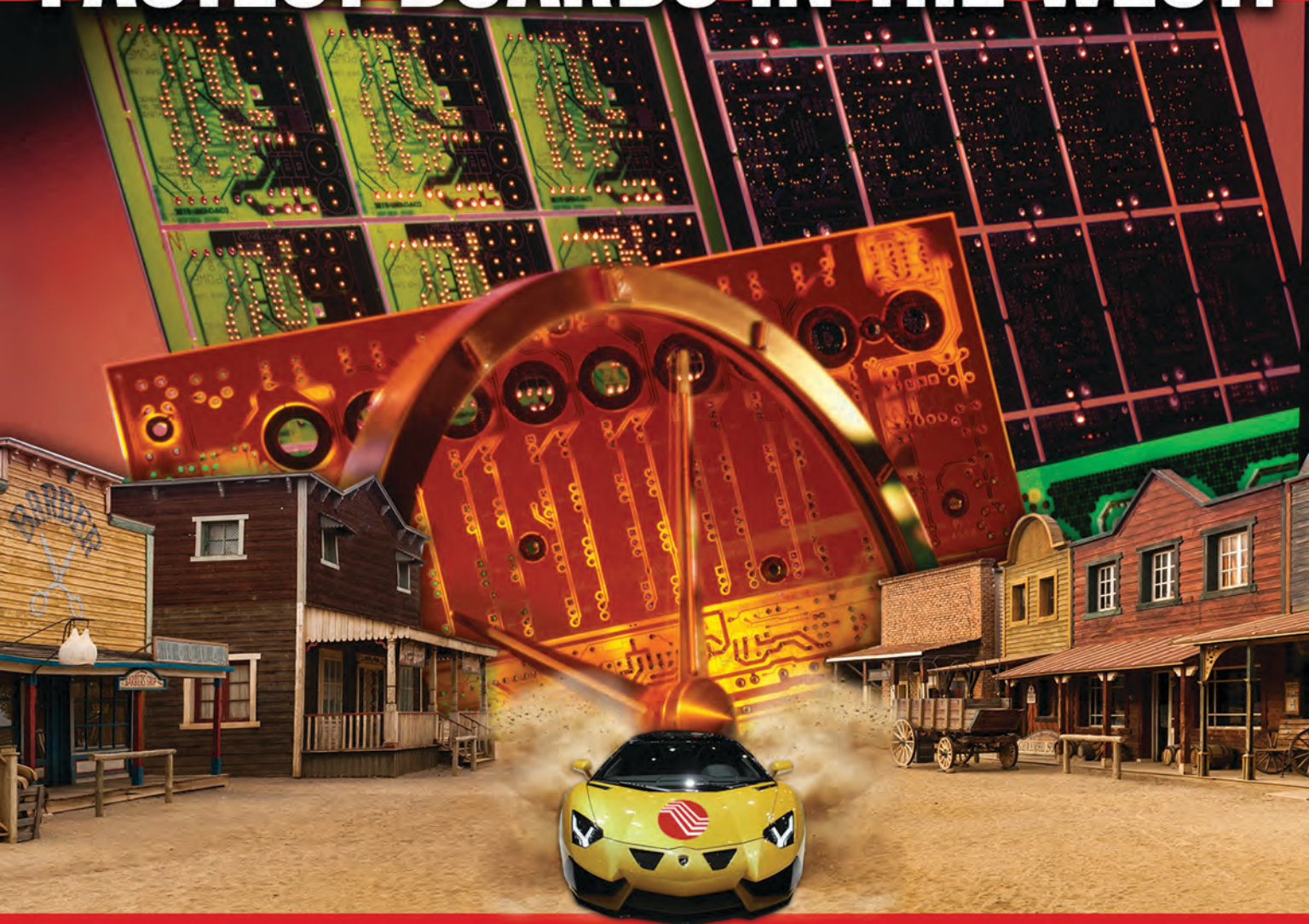
One roadblock to achieving the true benefits of Lean tools like 6S is that traditional improvement efforts have always focused on reducing the time of value-added steps; in other words, reducing the amount of time it takes to do something to a product.

Let's take a look at a discrete machining op-

eration for example, where the run time of this operation is 19.5 minutes per part. Much effort is placed on fixturing, training, spindle feed and speed, etc., to reduce the 19.5 minute run time. While this is obviously an important activity, we fail to attack the greatest opportunity for improvement: eliminating waste from the process. For example, zero effort has been expended to reduce the average two days of queue time this product waits before it can be machined, the 25 minutes of transportation time to move this large unit to the next department located at the opposite end of the building, the two weeks added to the product's lead-time waiting for raw material to arrive, or the four days of various inspections throughout the process due to inferior quality and/or process control.

Contrast this to Figure 4, which graphically represents the results of a recent Lean project done by Calumet Electronics Corporation, a company that really gets it. Calumet is a printed circuit manufacturer that could have literally 100 process steps, so travel and motion is a big deal. By focusing on motion waste, this company was able to reduce one department's functional motion by 45%, thereby taking it from 162 feet down to 88 feet. Saving seconds at the expense of minutes, hours, days or even weeks is saving a penny where you could be saving a dollar, and as I have said before, it's always about the dollars.


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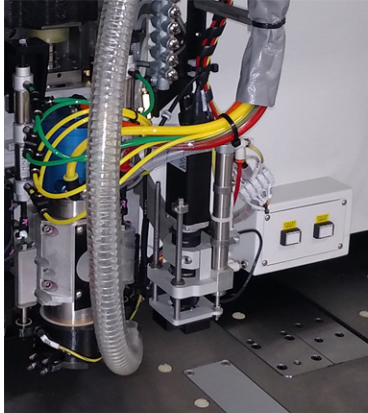
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CASE STUDY: REDUCING DEFECTS CAUSED BY EXCESS HANDLING AND MISHANDLING

by Yash Sutariya

SATURN ELECTRONICS/SATURN FLEX SYSTEMS

Most folks associate quality improvement initiatives with upfront expenses and ongoing cost increases. Fortunately, when done efficiently and with enough forethought and planning, quality improvement programs can pay for themselves in the form of increased throughput, reduced labor steps, and reduction in materials consumption. Increased yield improvements are then a pure bonus. The following project, centered on Saturn's LPI solder mask operation, was implemented about 13 years ago and details just such an example. It was one part of a comprehensive review of our processes prompted by customer complaints of scratches on their incoming PCBs. The results, including a customer award, galvanized us to our current continuous improvement modus operandi.

Cleanroom Fixes

Following LPI solder mask application, panels were partially cured in a tunnel oven and then scheduled for LPI imaging. A number of

cosmetic defects were found to be related to mishandling and air cleanliness of the imaging area. To reduce mishandling, a new transportation cart system was implemented. To reduce opens due to dust, the entire area was enclosed with clean room curtains and station HEPA filters with particle counting machines.



Figure 1: Cleanroom with curtains and HEPA filters in place (odd points of light are reflections).

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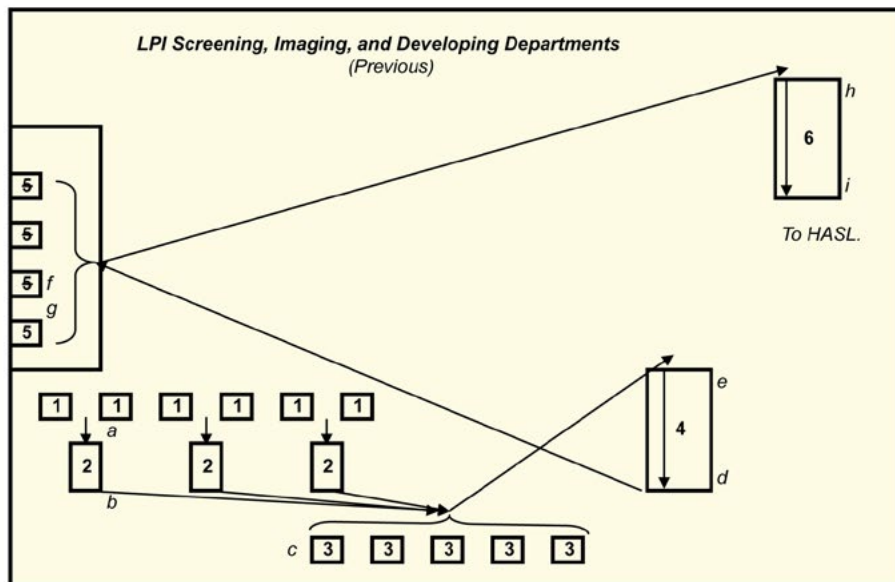
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Figure 2: a) Previous transportation system; b) New transportation system.



LPI Imaging to Cleaning processes.

- 1 Automated LPI applying machines.
- 2 Bassi tunnel curing ovens.
- 3 Exposure units.
- 4 LPI Developer.
- 5 Manual ovens for final baking.
- 6 Cleaning line.

Developing Manual Handling

- a Load freshly soldermasked panel into rack.
- b Unload rack into old cart.
- c Unload rack from cart to exposure.
- d Load on developer.
- e Unload from developer.
- f Load into manual oven.
- g Unload from manual oven.
- h Load into cleaning line.
- i Unload from cleaning line.

Figure 3: Original room layout for LPI imaging process; product movement shown with arrows.

Material Handling—LPI to LPI Imaging

To reduce rejection due to mishandling, a new transportation system and automatic loading/unloading system was implemented on every conveyORIZED process.

LPI Developing, Baking and Cleaning

The previous process layout and equipment required six points of manual handling after exposure. In addition, the boards had to be moved to various locations within the building on old

carts, which also increased the opportunities for mishandling, as shown in Figure 3.

Saturn rebuilt and installed equipment to dramatically improve this process. Processes 4, 5 and 6 were conveyORIZED in a single line, thereby eliminating much of the manual handling required.

As can be seen in Figure 4, the new line eliminated five points of handling as well as two vectors of board movement. Additionally, the use of accumulators (#4) at the beginning

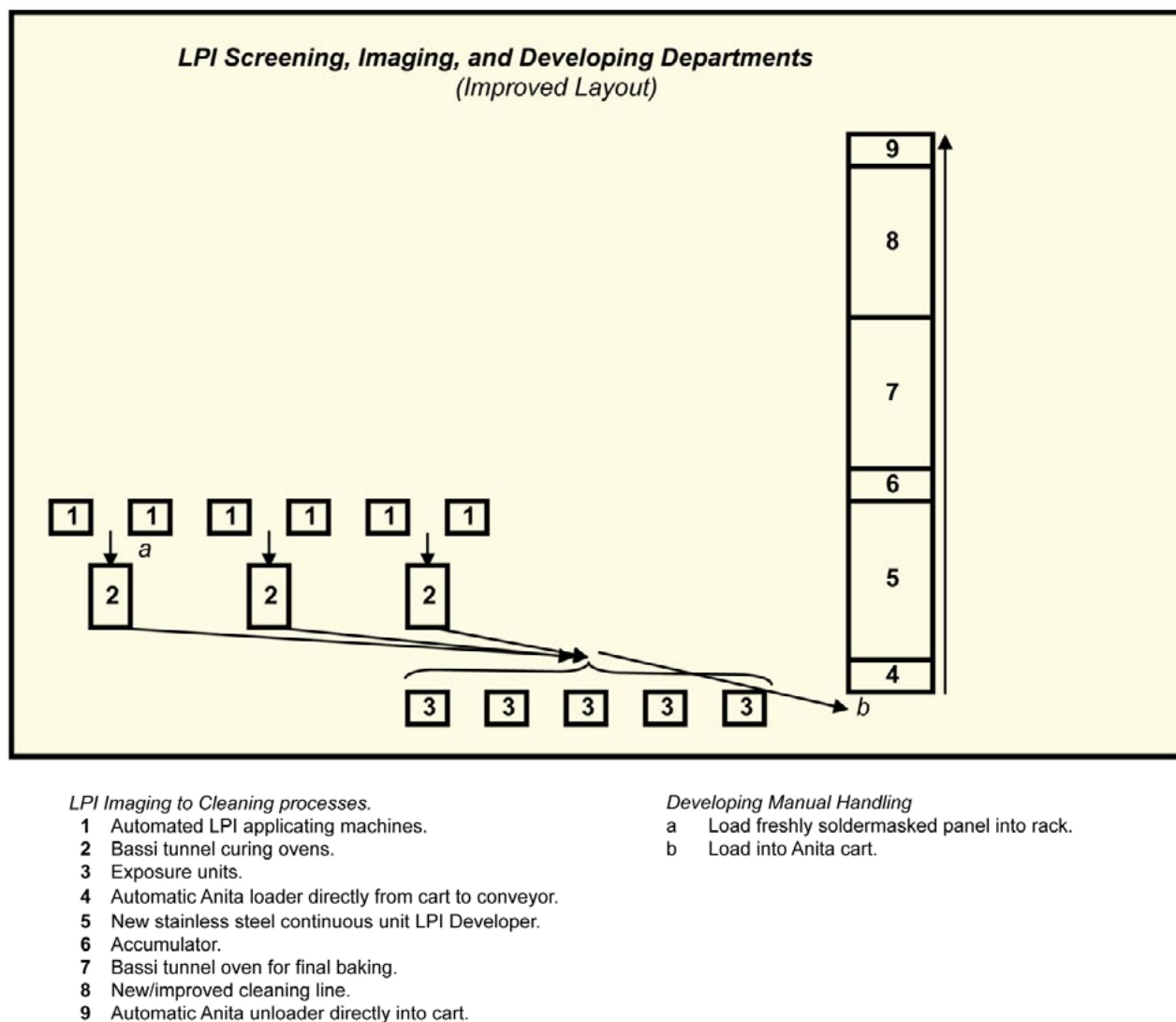


Figure 4: Revised room layout.

of the develop/bake/cleaning line and prior to bake in the Bassi tunnel oven allows for ample time for in-process inspection with minimal handling.

Postscript

The cleanroom curtains and HEPA filters were so effective that a permanent cleanroom was later installed. The resulting quality improvements in this area were instrumental in helping Saturn to achieve a supplier quality award for holding a 17 ppm defect rate on three automotive programs. Over the subsequent 10 years, similar changes, methodologies and improvements helped Saturn to more than triple sales.

Just as importantly, customers appreciated and are attracted to the resulting culture of continuous improvement which helps Saturn to continue to win, hold and grow business. Something that began by implementing some simple, very low-cost improvements. **PCB**



Yash Sutariya holds management positions at Saturn Electronics Corporation and Saturn Flex Systems Inc. To contact the author, [click here](#).

Supply Lines Highlights



Matrix's NEW Hakuto Dry Film Laminator Impresses at IPC

Matrix is delighted with customer reaction at last month's North American IPC unveiling of the new Hakuto Mach 630NP/6630NP Series Dry Film Laminators and is now ready to provide sales and service to North America.

Altium to Release Integrated Documentation Solution for Altium Designer

Altium is scheduled to release a new documentation workflow available exclusively in their flagship PCB design platform, Altium Designer 16.1. Draftsman™, which provides PCB designers with a unified documentation solution with customizable drawing views, documentation templates, and a fully complete design to documentation workflow in Altium Designer 16.1.

Mentor Graphics Releases Newest HyperLynx

Mentor Graphics Corporation has announced its newest HyperLynx release, which integrates signal and power integrity analysis, 3D-electromagnetic solving, and fast rule checking into a single unified environment.

IPC APEX EXPO: New Arlon Materials Address Design and Fab Challenges

Brad Foster, VP and general manager of Arlon, discusses some new laminates and pre-pregs that help designers and fabricators address a variety of challenges. He explains how Arlon works with customers to help them with stack-ups and other issues.

PhiChem Open House a Success!

Delighted to be invited to an exclusive preview of the new PhiChem global headquarters and R&D centre in Shanghai's Baoshan suburb, I joined the VIP group assembled at the PhiChem booth at the CPCA show, made welcome by PhiChem President Dr. Jin Zhang.

Orbotech's Gaby Waisman: 'The Future is Digital'

I sat down with Orbotech President Gaby Waisman at CPCA in Shanghai recently, who offered a

comprehensive explanation of why digitalization is truly the future, especially with regard to increasing throughputs. We also discussed Orbotech's company vision and products, as well as its role in "helping to drive the industry into fully digitalized imaging technology."

Insulectro's Jane Ark Promoted to Product Coordinator

Insulectro, the largest distributor of materials for use in the PCB and printed electronics industries, announces the promotion of associate Jane Ark to product coordinator.

TTM Chippewa Falls Acquires four New Hakuto dry film laminators from Matrix USA

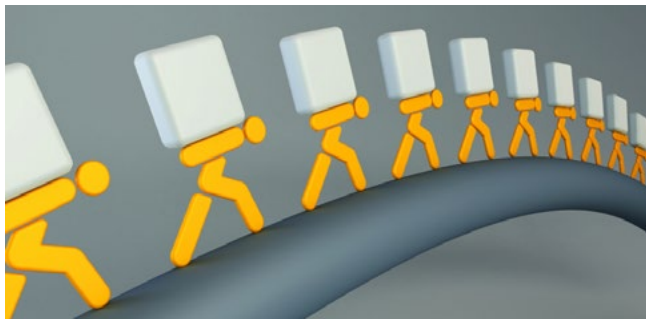
Matrix is delighted to announce the sale of four Hakuto Mach 630NP auto dry film laminators to TTM, following a successful four month trial.

Dow Presents IEC with 50th Anniversary Plaque at IPC APEX EXPO

Dow presented International Electronics Components (IEC) with a commemorative plaque during the 50th Anniversary festivities in Las Vegas at IPC APEX EXPO honouring IEC as their longest serving partner in the PCB industry.

Nano System, Two Years On

Established in July 2014, Nano System Inc. focuses on the design and manufacture of laser drill systems for the PCB industry. I-Connect007's Stephen Las Marias caught up with Nano System President Sam Sekine last month at IPC APEX EXPO to discuss the latest product and business developments at his company.





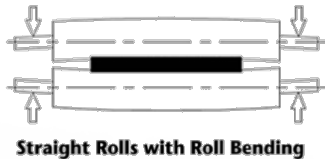
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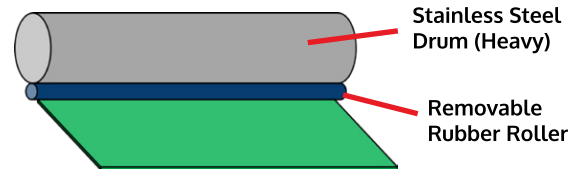
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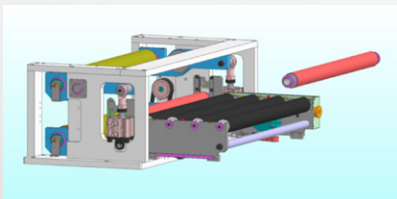
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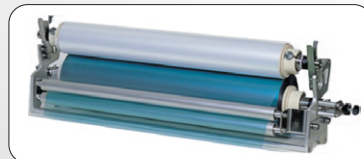
Offline Cassette Loading of Film



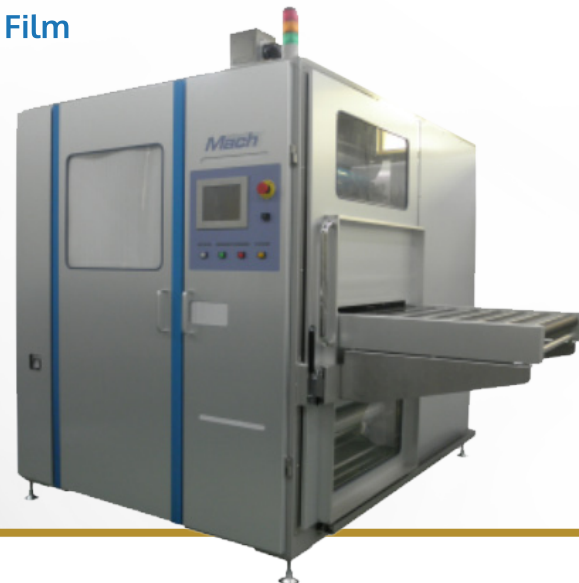
Easy removal of rollers with no tools
(change of durometer rubber now possible)

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Material Handling Innovations: Should You Automate?

by Happy Holden

Materials handling is a huge topic. The automation of materials handling is also a very big industry. For PCB fab and assembly, the problems with materials handling can be significant. Scratches, nicks, dents and abrasions can be serious reject categories for the product, and the indirect materials used to make the PCB can be formidable, as can their disposal. The solutions are varied depending on the size of the operation, the size of normal lots, and the number of different processes the facility runs. For a PCB fabricator, the important aspects of material handling are:

- Minimize damage to products
- Organize the queue for WIP and through-put
- Allow lots to be found in a timely manner
- Minimize labor/maximize safety in transporting materials
- Make distribution, storage and disposal of indirect materials timely, economical and safe

For assembly, the emphasis is on the parts that make up the BOM. But the inspection and test of each assembly is of major concern also—especially fixtures, revision control and product options. For a PCB assembler, the important aspects of materials handling are:

- The right part, in the right quantity, at the right place
- Minimizing damage to products
- Storage and retrieval of components and parts
- Storage and retrieval of test fixture and cables
- Disposition of the correct product to the intended user

Minimizing Damage

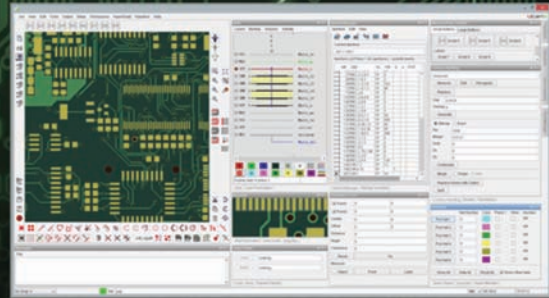
Minimizing damage to a PCB panel while in production starts with these questions: How will you transport the panels between processes? Will the panels just be stacked on carts? Will they go into totes, trays, or bins that offer protection for their edges? Will they go into ‘cassettes’ that may be part of the loader’s or unloader’s mechanization?

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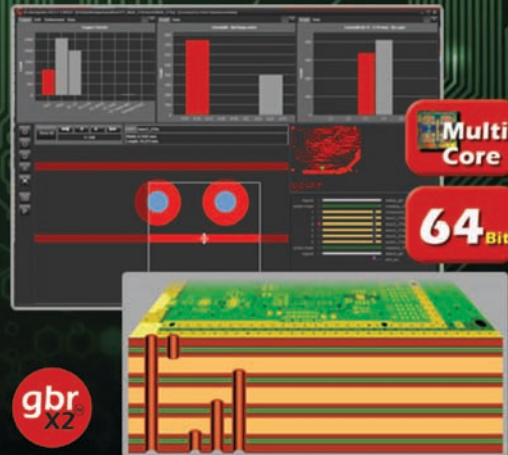
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Figure 1: Typical trays or bins for transporting flat PCB panels (some w/locking covers) and two typical carts for transporting the trays.

The answers depend on how large your lots are and how much mechanization you employ. Figure 1 shows some of the different stacking trays or bins and a few carts.

Material concerns for damage starts at the very beginning with initial receiving and storage of the laminate and prepreg. Whether sheets or cut panels, the laminate has to be secured and stored in a way to keep it clean and free from stress (undue weight or warpage). There are 37 separate workcenters used in making a multilayer. Materials handling should be thought out for the entire process, and hopefully the automation methodology will give you some insight into that thought process.

How Does Automation Fit?

Automation is a strategic tool for controlling, managing, and directing a productive process by automatic means. It usually is comple-

mented by product and technological innovations. The chief ingredients in automation are adequate know-how and common sense.

Automation: a Working Definition

In a working context, automation is more than just automatic machinery. Machinery implies mechanization, while automation also means the system information used to direct and control the people, materials, and machines, or systemization. Automation, then, as seen in Figure 2, is made up of two components, like a vector: the mechanization or material flow, and systemization, or information flow.

Mechanization Classes

Mechanization can be divided into six classes, which indicate the level of sophistication of machines and machine interactions with hu-

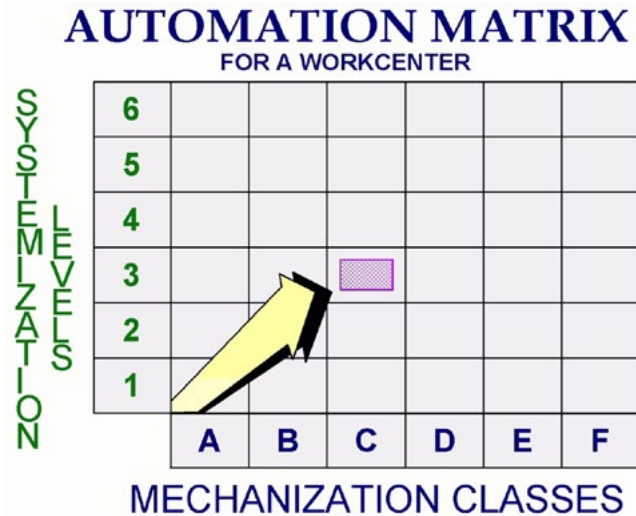


Figure 2: Automation is really a combination of two strategies, mechanization classes and systemization levels. The resulting vector is automation.

A.	Manual	0% done by machine
B.	Semi-manual	10–25%
C.	Machine assisted	25–50%
D.	Human assisted	50–75%
E.	Semi-automatic	75–99%
F.	Fully automatic	100%

Table 1.

mans, rated by percent of the work done by machines (Table 1).

Systemization Levels

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

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

Automation Matrix

When both measures are applied to any activity in the process to tool or build a printed circuit, then an *automation matrix* is created in

1	Manual information collection/distribution	0% done by computer
2.	Batch computer/human collection/distribution	10–25%
3.	On-line computer/human collection/distribution	25–50%
4.	Real-time computer/machine interface	50–75%
5.	Dedicated supervisory control	75–99%
6.	Fully auto gateway/network control	100%

Table 2.

that workcenter. This matrix, as illustrated in Figure 2, allows for the current situation to be appraised (even if it is all manual) as well as future objectives and plans. It is quite common to make automation objectives a number of steps or phases, which allows each step to be stabilized before the next one is taken. The automation matrix lends itself to this step approach.

Automation: Evolves from and Coexists with Manual Techniques

One of the simple truths in automation is, if you can't do it manually, what makes you think you will do it by automation? The corollary, automate for quality, is a myth. The truth is, you must automate for consistency—either consistent quality or consistent scrap. The automated system must share the same heritage as the manual systems. The most suitable manual technique for automation is just-in-time (JIT) or the continuous pull production technique. It focuses on many of these problems in a conventional material flow system:

- Excess inventories
- Queue and safety buffers
- Extensive repair and rework

Automation Methodology

An automation methodology is a formal procedure for planning, designing, and implementing automation. It is particularly important when you start integrating several previously independent production tasks into one or more automated systems. The methodology stems from the previously defined automation matrix. Additional axes are added to the matrix to cover material handling (mechanization) between cells or workcenters and to cover network communication (systemization) between

cells (workcenters). A simplified diagram is illustrated in Figure 3. The actual methodology will take up several drawings and utilize a number of worksheets to analyze and plan the data. Look for a detailed explanation of PCB automation in my regular column, *Happy's Essential Skills*, published on PCB007, later this fall.

Mechanization Alternatives

The definition of mechanization and the material flow handling helps plan how to tackle any issues with material damage. The choices of mechanization for PCB processes can be:

- Manual movement, loading and unloading
- Automatic feeders and stackers
- Connecting conveyORIZED machines with accumulators
- Transport systems

Manual Handling

Class A mechanization is all manual. This may be the condition in small PCB fabs or when the cost of a higher level of mechanization is too high. Justifying additional mechanization will depend on any defect cause by manual transport and the loading and unloading of various machines or conveyors.

Automatic Feeders and Handlers

The vast majority of mechanized systems are in this category, from Class B to Class E. The complexity comes in when the method of transport between workcenters (work-flow Class from A to F) is taken into consideration and the state the panels are known (e.g., just drilled, covered with a resist, wet prints, plated, hot, or some other state). Figure 4 shows some typical loaders and unloaders.

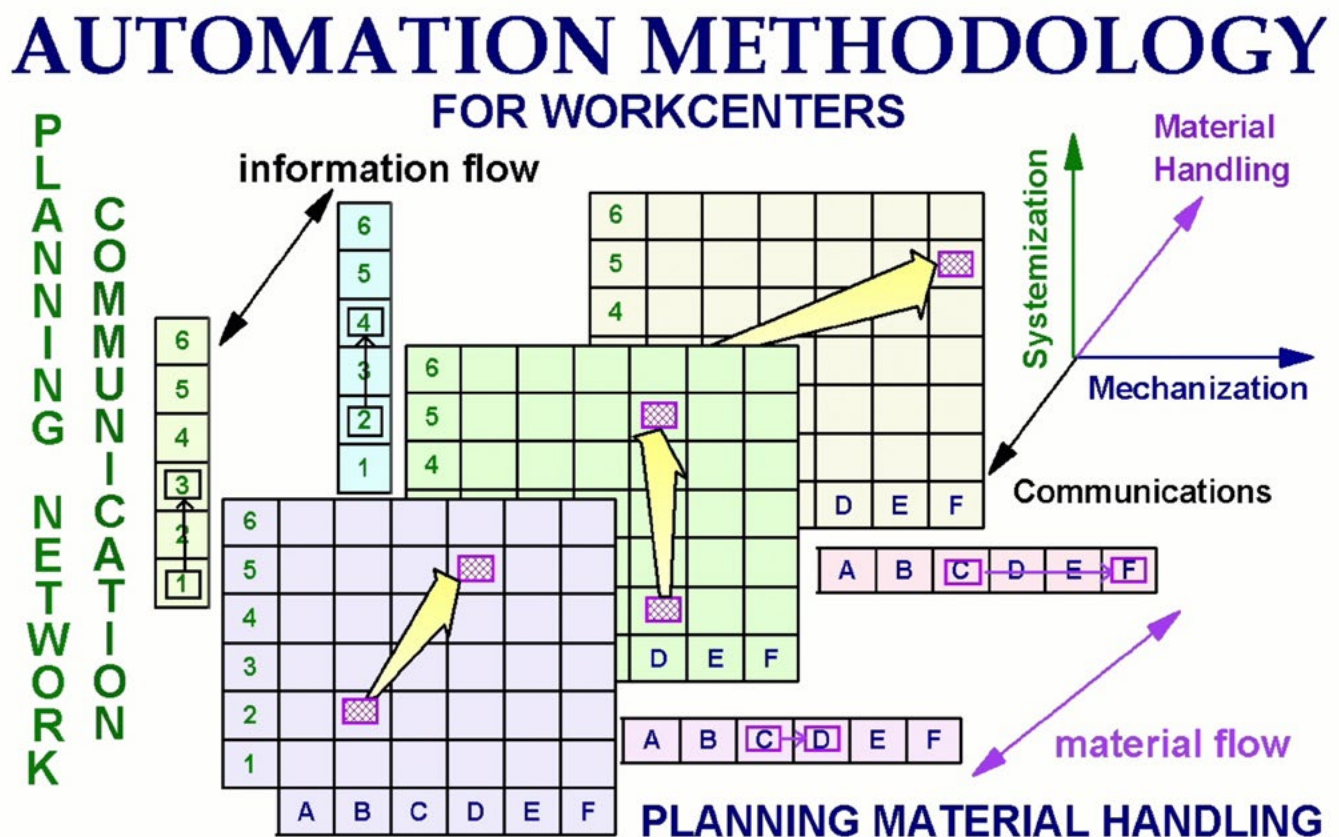


Figure 3: Automation methodology consists of automation plans for each workcenter plus plans for material flow and information flow between workcenters.

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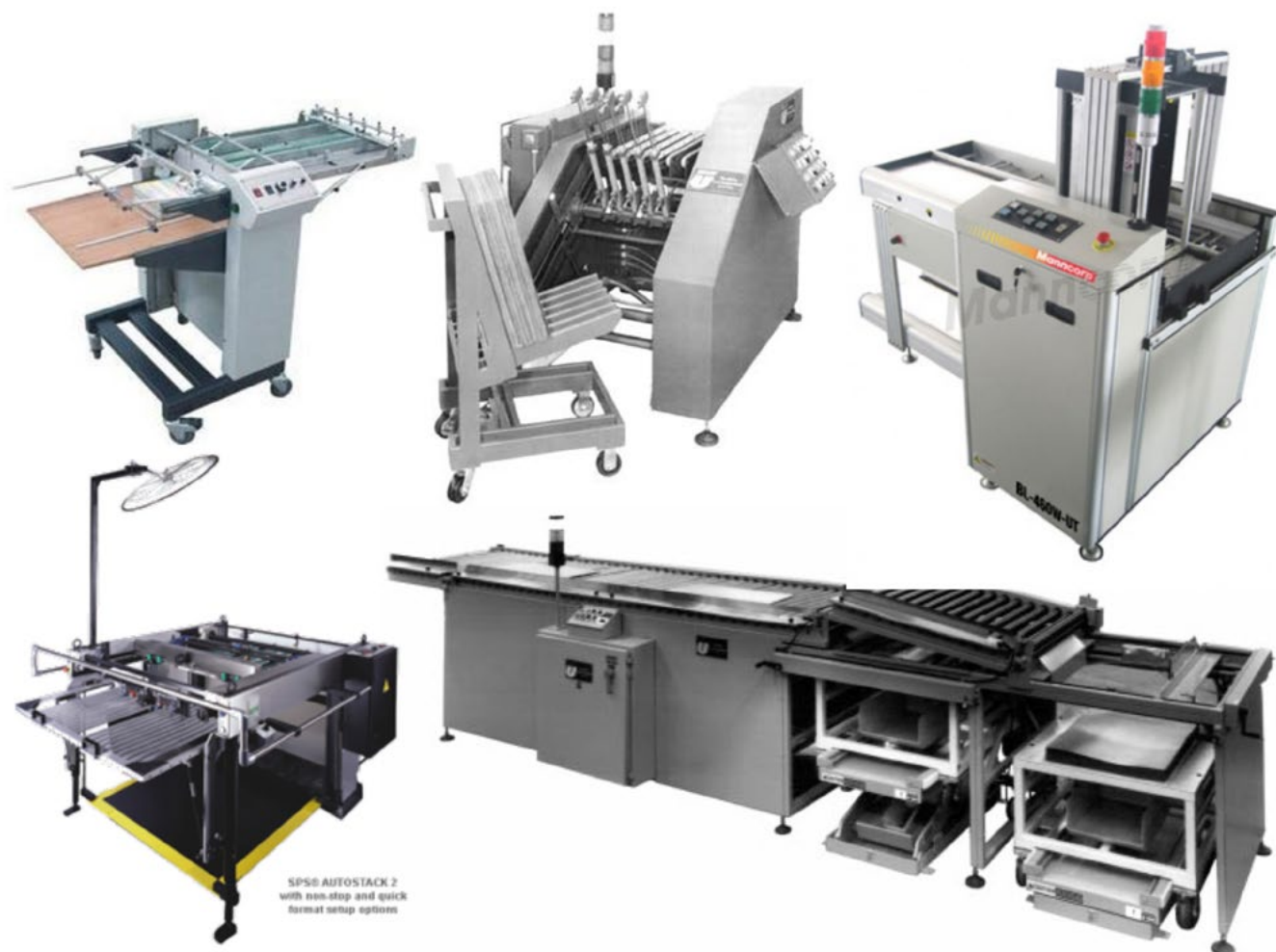


Figure 4: Typical loaders and unloaders for PCB panels sold by various vendors all over the world.

Connecting Conveyors with Accumulators

There are some conveyORIZED processes that can be connected together because their process times are in sync or the latter runs faster than the former. But other times, the proper conveyor settings are just not compatible. In that case, an accumulator (either elevator or rotary) may be the mechanization solution. Figure 5 shows the typical units.

Transport Systems

Of course, the conveyor is a transport system (Class F), but then, so is a hand-pushed cart (Class A). Process hoist and vertical conveyORIZED plating or etching are other Class E mechanizations. In reviewing the higher productivity

Connecting Conveyors & Accumulators



Figure 5: Two typical accumulators for conveyor processes.

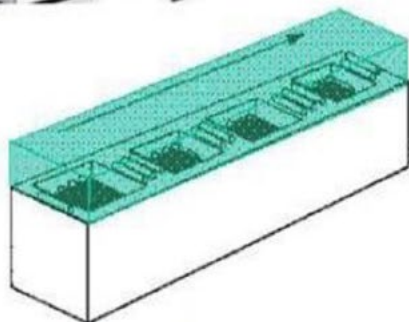
options for PCB processes, the basic material handling choices are:

- Vertical or horizontal conveyORIZED transport (Figure 6a)
- Overhead conveyor or powered roller (Figure 6b)
- Walking beam or I-beam transport (Figure 6c)
- Split-rail pusher or side-arm return type transporters (Figure 6d)
- Cantilevered or overhead (gantry) programmed hoists (Figure 6e)



Vertical conveyor

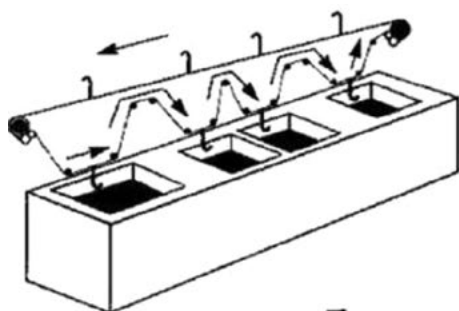
Work is moved horizontally by chain or other conveyORIZATION through a series of spray or immersion cells. I.e. Eichen 9,000, AEL, PAT, PAL, DuPont I-System or COF/TAB plating



Horizontal conveyor w/immersed/sprayed

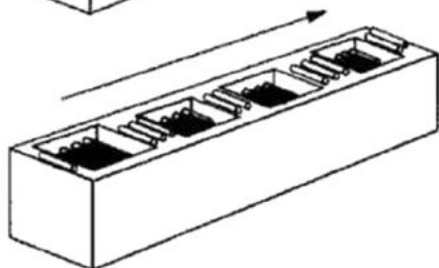
Instead of tanks-level powered rollers move payloads between stations, within a closed environment and the solution is sprayed or immersed. May have handlers for reel-to-reel. I.e. Chemcut, Autotech Hollmeuler, Pill, and Schmid

Figure 6a: Typical conveyORIZED process, vertical and horizontal.



Overhead conveyor

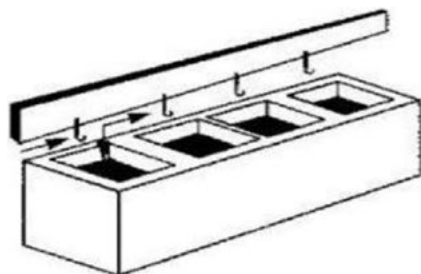
Overhead conveyors incorporate a chain pulley mounted above the centerline of the tanks. Tank lengths are typically exaggerated to accommodate the transition from vertical travel, and there is high risk of contamination associated with moving parts above the payload. Additionally, there is no flexibility in altering processing, and the only variability in throughput involves altering conveyor speed



Powered rollers

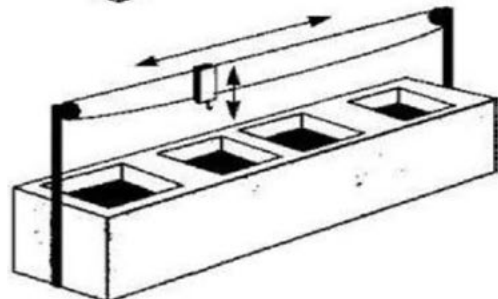
Tank-level powered rollers move payloads between stations, vertical movement occurs via lifts in each tank. Although this approach can be efficient in terms of automation, processing flexibility is limited, tanks are significantly oversized, and may not be appropriate for delicate parts

Figure 6b: Overhead conveyor and/or powered rollers.



Walking beam

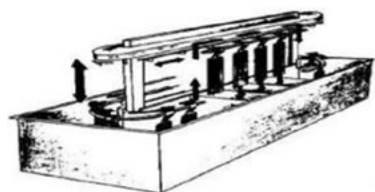
Typically a top-mounted (but can be side mounted) fixture, a walking beam advances payloads simultaneously, one station at a time. The approach can be advantageous in single-recipe, high volume applications. Limitations in flexibility and throughput are comparable to those described before, and contamination potential applies to the top-mounted systems. Additionally, these systems limit tank design in that all stations must be the same distance apart, with identical process times for each



I-beam or cable

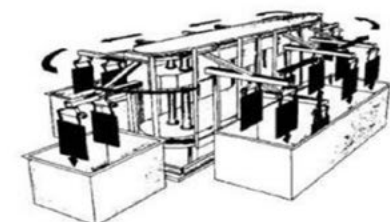
This configuration employs suspended independent head(s) which travel over the centerline of the tanks. The only advantage of these systems is where ceiling clearances are an issue. By design, the moving parts of the head create potential for particulate generation and thus payload contamination

Figure 6c: Walking beam or I-beam transporter.



Split rail pusher

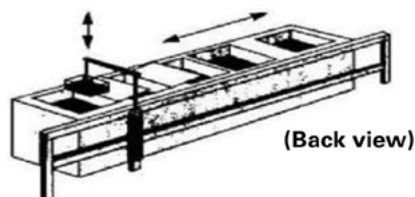
Simplest of the automatics and like a walking-beam, only it has a return. A simple process cycle of “up-forward/slide-down-back/slide” pushing the load and jumping over individual tanks. Extended lower slides allow longer continuous immersions. Any weight or size can be accommodated



Side arm

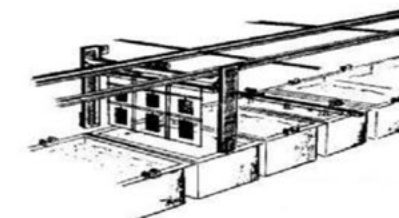
A cantilever-arm design (overhead) makes use of arms for each process tank along each short axis of the tank-line. Using a “lift-slide-drop” cycle each arm visits each process tank. Advantage is the slide mechanism is NOT over the process and optional lift timers can remove the loads earlier. Arms can remain down for extended durations. Any weight or size can be accommodated

Figure 6d: Split-rail and side-arm return type transporter.



Cantilevered

For a cantilever setup, a horizontal frame is mounted behind the tank-line along which one or more heads travel and execute vertical movement. Properly designed, this concept is considered optimal for general applications since it creates the least contamination, uses the smallest footprint, and affords unimpeded operator access to the tank-line. Use of multiple heads which overlap one station can be an efficient way to increase throughput. With the use of a “gang fixture”, any head can lift more than one payload at a time for simple high-throughput applications



Gantry

A gantry design (overhead) makes use of two horizontal frames, one along each long axis of the tank-line. From here the system can essentially be two I-beam setups with associated contamination concerns, or mated cantilevered heads sharing weight distribution of the payload

Figure 6e: Cantilevered or overhead (gantry) programmed hoists.

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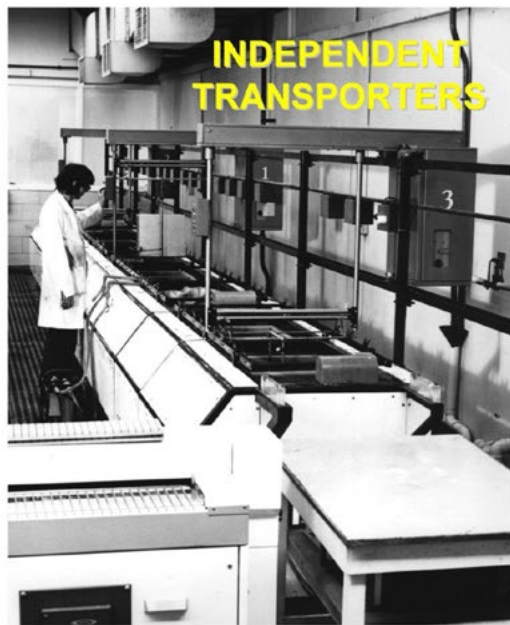
Most manufacturers select horizontal conveyorized machines for etching, developing and stripping, and cantilevered programmed hoists for electroless copper, black oxide, and smear removal, with a multiple overhead programmed hoist for electroplating. Vertical and horizontal conveyorized electroplating machines have become very popular for mass-produced rigid PCBs, high-density interconnects (HDI), panel plating and reel-to-reel (RtR) flex applications^{[1][2]}.

Vertical Conveyorized

Vertical conveyorized mechanization has become increasingly popular, especially for thin materials and HDI. Vertical electroplating

of panels for panel-plate or pattern-plate is also popular. The electrified panels slide continuously next to solution ejectors that supply fresh solution at a high agitation and behind them are the titanium baskets with copper slugs that supply cations to the solution and cell. Alternatively, if insoluble anodes are used, copper oxide or copper sulfate dissolution and makeup tanks can supply the copper.

In 1974, one of HP's nine prototype facilities developed their own low-cost automatic panel transporter. Figure 7a shows the electroless copper processing line built over the manual tanks. This transporter and frame costs only about \$7,000 to manufacture. It is simple enough for any PCB



(a)

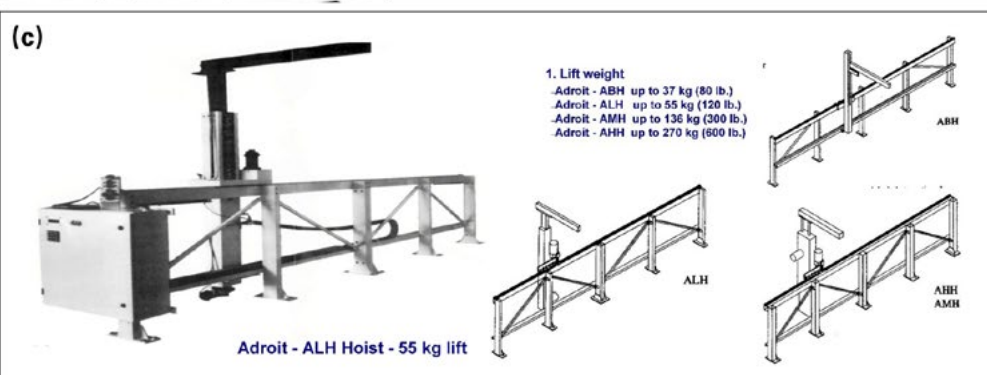
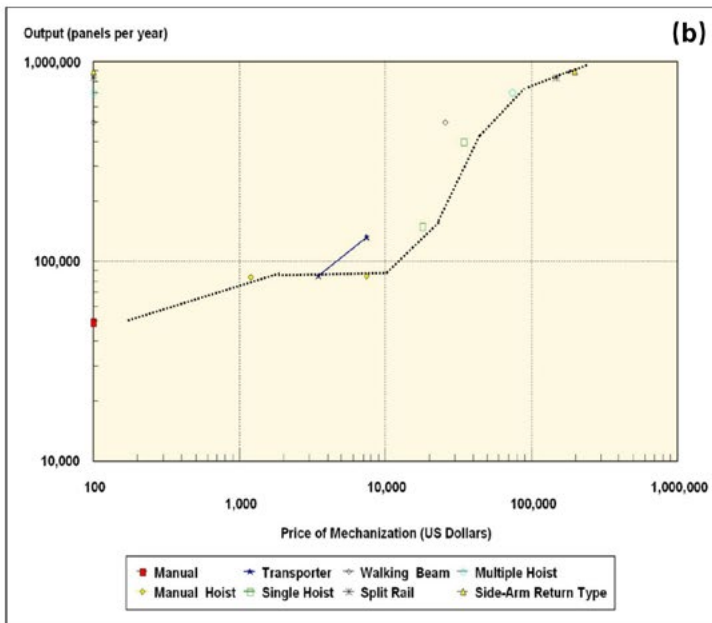
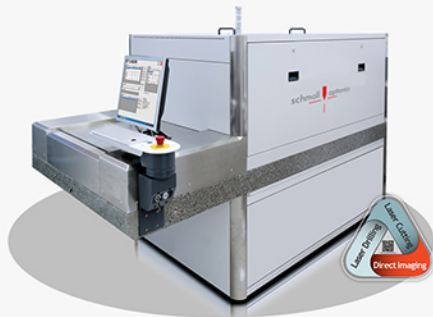


Figure 7: (a) Constructed transporter for manual PCB process line; (b) production output curve of PCB panels as a function of the cost of various transporters (annually); (c) cost-effective commercial programmed hoist system.

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maintenance personal to construct. The frame is 2.0 inch painted tubular steel welded together and the transporter is constructed out of high-strength aluminum tubing that has been painted.

The system in Figure 7a has two additional transporters running on it. Each transporter is battery powered and runs autonomously. The controls for the system are very simple and basically they are electromechanical, so again, any PCB maintenance personal can construct and maintain them. The transporters are controlled by a timer at each process step. Once the transporter arrives on station, it starts the timer for that process, and when the timer times out, the load is lifted and the transporter moves to the next process step. After it is unloaded at the end, the transporter is reversed and moved back to the load station by an operator. The slightly larger electroplating process line transporter was arranged in an oval, with the load adjacent to the unload.

The blueprints and plans for these battery-powered transporters are available in the HDI Handbook, 2nd Edition, to be published by I-Connect007 this fall. If you're not up to building the hoist system, you can purchase a system for as little as \$75,000 from firms like Adroit Automation (Figure 7c). Figure 7b shows the cost

of various hoist systems as a function of how many panels per year (two shifts per day) they can process.

Horizontal ConveyORIZED

Horizontal conveyors are the oldest type of mechanization in printed circuit manufacturing. These closed machines, as shown in Figure 6a, have increased in their applications, from historic photoresist developing, stripping, cleaning, and etching, to drill-smear removal, oxide-treatments, electroless copper, final finishes/coatings, and now to metallization (i.e., electroplating).

Specialized Material Handling Systems

Another Class E and F unit is the automatic guided vehicle (AGV). I have visited three automated PCB fabricators that used AGVs. Two used them throughout the facility, the third only for transport between AQL/shipping and the loading dock.

A special type of automatic transport system is the automatic storage & retrieval system (AS/RS). This system was used by the PCB fabricator for all the cut panels, backup supplies and indirect materials (except chemicals) used in this

Transport Systems



AGV



Figure 8: A few of the many AGVs commercially available today. They can follow painted stripes on the floor, be wireless guided or use GPS location.

fabrication process. It was built on one corner of the eight-story facility and feeds each floor with the right materials, in the right quantities and JIT for the lot flow. The AGV and AS/RS units are seen in Figure 8.

Conclusion

Since automation can be system information and mechanization, its value is more than just saving labor costs. The improved quality, reduced or eliminated handling errors and rejects, improved safety, increased output, reduce pollution and the opportunity to handle more complicated processes makes automation something that even small shops need to consider and can do within their budget. The key is to have a plan and I hope this has given you some points to do just that. **PCB**

References

1. Holden, H., "Justifying Process Automation," NEPCON West, Anaheim, Calif., April 1972.
2. "Computerization Comes to Plating," *Metal Finishing* magazine, May 1978.



Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, Nan-Ya/Westwood, Merix, Foxconn and Gentex. Currently, he is the co-editor, with Clyde Coombs, of the *Printed Circuit Handbook*, 7th Ed. To contact Holden, [click here](#).

NASA, Virginia Tech Test Management Platform for Unmanned Aircraft Traffic

Efforts to protect air travelers are becoming essential as business leaders ramp up efforts to use unmanned aircraft for agriculture, real estate, inspections, and commercial purposes, officials from the Virginia Tech Mid-Atlantic Aviation Partnership said today.

The most recent step is an effort involving the NASA's Ames Research Center and the six Federal Aviation Administration-designated unmanned aircraft systems testing sites, including Virginia Tech's, to test NASA's unmanned aircraft system traffic-management platform.

In the first in a series of tests of the research platform involving non-NASA aircraft, pilots from the six test sites recently flew 22 aircraft simultaneously.

"Virginia is pioneering the use of unmanned aircraft systems," said Gov. Terry McAuliffe. "Our research teams are clearing the way for the use of unmanned aircraft for pipeline inspections, search and rescue efforts, and commercial applications still in the ideation stage. Moving this technology safely into the nation's skies has tremendous potential to create new opportunities that will be invaluable for a new Virginia economy."



The Virginia Tech Mid-Atlantic Aviation Partnership oversaw flights in Blacksburg, Virginia, and in Maryland with its partners at the University of Maryland.

"About halfway through that first flight window, when NASA called and said, 'Congratulations, everybody, we've exceeded our success criteria. You're all clear to land as needed'—that was a really satisfying moment," said John Coggin, the chief engineer for the Virginia Tech Mid-Atlantic Aviation Partnership in Virginia. "Then we caught our breath and got ready for the next window."

Flight teams at all of the Federal Aviation Administration-selected unmanned aircraft systems test sites in Virginia, Maryland, Alaska, New York, North Dakota, Nevada, and Texas communicated with the traffic management system at the NASA Ames Research Center in Silicon Valley, California.

"The unmanned aircraft system initiative at Virginia Tech has resulted in historic flights that demonstrate the enormous potential of this technology to help people," President Tim Sands said.

Flexible Circuit Fabrication and Cleanroom Manufacturing

by **Dave Becker**

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Facility cleanliness is a vital part of process control for flexible circuit fabricators. As higher density requirements continue a relentless drive toward finer traces and spaces, particles and foreign material can cause problems in a number of operations. A particle can cause conductor width and spacing issues at imaging. Conductive material can cause current leaking when trapped under a coverlay or embedded in solder mask. Dirt, dust, or other unintended material may reduce layer-to-layer adhesion. Engineering models suggest hair and fibers can affect insulation resistance and impedance.

How big does a particle need to be to cause issues? Consider that typical outdoor ambient air has a normal distribution of particles that can be as small as 0.5 microns and as large as 16 microns. An ultra-high-density flexible circuit might get to 25 micron spacing. Roughly speaking, one 7–8 micron particle could cause a conductor width and spacing quality criteria violation if it landed on coated resist, or on the

photo artwork, or is deposited directly on the photo-sensitive resist during image exposure. With circuitry at ultra-high density, particles in ambient air might cause issues, however, particle size is not the only factor. Quantity and/or density of particles is also a consideration. Ambient air contains 35 million particles per cubic meter, so in an uncontrolled environment, thousands of particles might easily be deposited in a small area. And even if particles don't settle on material, they can refract collimated light sources that are often used during exposing for creating the circuit image. These particles also accumulate on work surfaces and are a risk to contaminate in-process materials or operators.

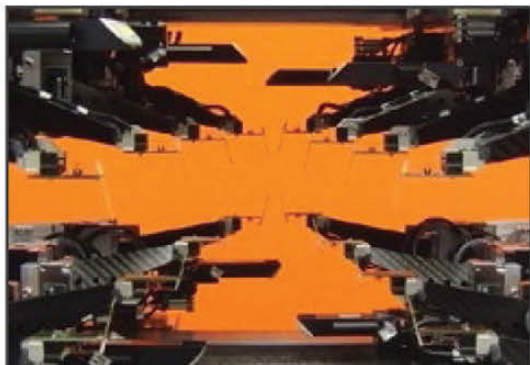
It is certainly fair to say the biggest source of contamination is not from ambient air, but the human operator. Human hair is approximately 60 microns in diameter and can be several millimeters in length or longer. A human hair landing on the artwork or coated resist is sure to obstruct the light required for proper imaging



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enough to cause a defect. In addition to hair, there are skin flakes, dander and fibers from garments—all much larger than typical particles in ambient air.

In order to prevent air particles, hair, skin, fibers and large flakes of dust from affecting fabrication yields on high density circuits, critical processes are performed within a cleanroom environment.

A cleanroom for electronics manufacturing may have the following features and more:

- Special high performance air filtration systems
- Non-shedding surfaces on walls, floors and ceilings
- Special clothing or gowns for operators
- Unidirectional airflow (from ceiling to floor)
- Cleanroom protocols
- Highly controlled entrance and exits

Cleanroom environments are commonly designated by classes. Typically the class designations are:

- Class 1
- Class 10
- Class 100
- Class 1000
- Class 10,000
- Class 100,000

The smaller the class number, the lower the maximum particle count in the room. The class designation numbers actually correspond to the number of 5-micron particles or greater per cubic foot. So a class 100,000 cleanroom would allow 100,000 particles of 5 microns or greater in a cubic foot. That sounds like a lot, but remember ambient air is starting at over 200 times that density. Air filtration, room construction, layout and operation protocol will differ from one class to another. The lower the class number, the higher the construction and operation costs of the cleanroom.

Each manufacturer needs to determine a cleanliness strategy that will best serve its needs. In addition to high capital and operating costs, cleanrooms can throttle agile manufacturing ef-

forts and compromise flexibility in process flow and facility utilization. Manufacturers often adopt a strategy of using portable “soft wall” cleanrooms combined with clean workstations. A clean workstation may be a single machine or small area that is contained in a plastic curtain with a unidirectional HEPA air shower. For example, a large area might be controlled to a class 100,000 level, but within that large area isolated workstations are controlled to a class 10,000 level. Operators may be required to wear hairnets and cleanroom smocks to enter the class 100,000 areas, but may be required to put on a coverall, shoe covers, gloves and facemask to work in the class 10,000 area.

Circuitry Fabrication Cleanliness Considerations

- Work in process (WIP) needs to be kept clean during processing within cleanroom stations. Taking product out of a cleanroom and then bringing it back in should be minimized to avoid contamination. Clean pass-throughs and clean storage cabinets are frequently utilized to avoid bringing material out of a cleanroom. When material is taken out of a cleanroom, the material and container should be cleaned before returning.

- Imaging operations require the highest level of cleanliness. This includes resist coating, laser direct imaging (LDI), photo exposing and screen printing.

- Coverlay assembly is a critical area and is best performed in a highly controlled clean environment. Along with contamination introduced into a cleanroom with product transportation, the biggest potential issue is operator hair or clothing fiber shedding onto the coverlay material.

- Drilling operations, including laser drilling, are done in a non-cleanroom area, but in most cases the material goes through wet process after drilling so it will get cleaned before imaging.

- Wet process areas are generally not performed in a cleanroom. These operations include etching, micro-etching, developing, stripping and plating. The final stage of these chemical operations includes a rinse and dry which will result in very clean material. Another focus

area is how the material is handled as it comes out of process machinery. Parts should be immediately placed in a clean container, covered, and transported to a clean area to avoid contamination.

- Once the circuit pattern is defined and a dielectric layer or coating is bonded, foreign particles will have less of an impact on circuit yields. However it is still sound manufacturing practice to maintain some level of cleanliness control. Finishing steps include automated optical inspection (AOI), excising, electrical testing and assembly. Excess particles on the surface can create issues at AOI by creating false readings for shorts. If the part is being electrically tested to very tight tolerances, then fibers and human hair cause false readings. Hair, fibers and dirt can also create poor solder joints during component assembly.

Keeping the entire facility clean is a good manufacturing practice and will make it easier to keep the controlled areas clean. Materials such as cardboard, paper, wood, open cell foam and

powders should be kept out of the factory area including the non-controlled rooms. The cleaner the entire factory is, the easier it is to keep the cleanrooms up to specification. Epoxy coatings on floors, frequently cleaned and painted walls, and ceiling tiles will not only help keep the factory cleaner, but will influence attitudes and perceptions of the employees and visitors, making them more vigilant in adhering to cleanroom practices. While the processing required for semiconductor fabrication takes cleanliness discipline to an entirely new level, the increasing high-density demands in the world of flexible circuits requires cleanroom processing to produce circuits at high yields. **PCB**



Dave Becker is the V.P. of sales and marketing at All Flex Flexible Circuits LLC. To contact Becker, or read past columns, [click here](#).

This Just In: Handling Errors Survey Results

No doubt about it, there's a strong interest in automation. In fact, it is almost the new buzzword. Everyone is automating. Some are even claiming, "Automate or die!"

To help us better understand our readers' views on automation, we conducted a survey titled "Automation vs. Reducing Process Steps." As always, results are never what one would have predicted. Here is a sampling:

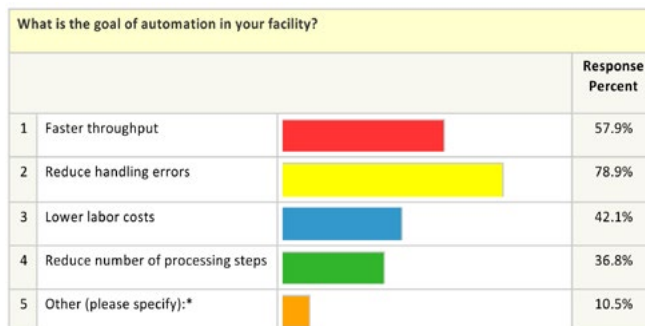
Nearly 50% of the respondents were PCB fabricators with 90–95% classifying themselves as high mix/low volume and the remaining as high volume. A question on automating a process versus eliminating process steps was split nearly 50-50, with several comments stating that both are important. One added, "We have islands of automation rather than real process automation." Perhaps a fine line?

In a multiple choice question on the goal of automation in a facility, it seemed obvious that all the given reasons were important (see chart). "We want it all!"

*Generally, these comments mentioned more consistent results, quality, reduce opportunities for operator error, etc.

Regarding the most important areas to automate, answers included everything from innerlayer processing and the lamination area to wet processing and test/inspect, and especially handling, at all of these steps.

Didn't take our survey? You still can: [click here](#).



*Generally, these comments mentioned more consistent results, quality, reduce opportunities for operator error, etc.

Zentech CEO Matt Turpin Recognized at IPC APEX 2016

Zentech Manufacturing Inc. is pleased to announce that our CEO and President, Matt Turpin, was named as one of the electronics industry's Rising Stars by IPC at the recent IPC APEX EXPO in Las Vegas, Nevada.

Catching up with...PNC: Open House Planned for May

I'm a great believer in open houses. Any time customers and vendors get together to learn and talk about what they can do for each other it's a good thing. That's why, when I heard that PNC, in Nutley, New Jersey, planned to hold an open house on May 20, I wanted to learn more about it. So I called my friend Sam Sangani, the company's owner, to learn more about it.

Northrop Grumman Awards Radar Contracts to Kitron

Kitron has been selected as an international source for manufacturing of a sub-assembly related to the JSF Radar system developed by Northrop Grumman Corporation (NYSE: NOC) for the F-35 Lightning II.

All Flex Launches Online Heater Design Course

All Flex announces the launch of an online flexible heater design course that provides technical information to the engineering community. This useful tool self-educates about the design requirements for polyimide and silicone rubber heaters.

Novel Miniaturized Circulator Opens Way to Doubling Wireless Capacity

Researchers have developed a microelectronic substitute for larger-scale magnetic components and opened a pathway to more efficient communications and more capable radar systems.

Newbury Electronics Supports NOC to Discover More about the Deep Sea

Newbury Electronics' connection with the National Oceanographic Centre (NOC) in Southampton started in the early 1990s. Since then both the research science and PCB manufacturing processes

have made considerable advancements but Newbury Electronics has kept pace with the scientific demands and continues to supply an extensive range of bespoke boards to the NOC, an internationally renowned research organisation.

NASA Begins Testing of Revolutionary E-Sail Technology

Testing has started at NASA's Marshall Space Flight Center in Huntsville, Alabama, on a concept for a potentially revolutionary propulsion system that could send spacecraft to the edge of our solar system, the heliopause, faster than ever before.

Missile System Would Greatly Increase Defense Capability in South Korea

Right now, the United States and South Korea are in discussions regarding the feasibility of deploying a Terminal High Altitude Area Defense, or THAAD system there, along with its associated radar, while nearby China has voiced objections to the idea.

Program Aims to Facilitate Robotic Servicing of Geosynchronous Satellites

Servicing vehicle jointly developed with a commercial partner would leverage DARPA's successes in space robotics and accelerate revolutionary capabilities for working with satellites currently beyond reach.

DoD's Focus on Increased Training a Boon for Military Technology Market

The Department of Defense (DoD) training and simulation budget is expected to increase throughout the fiscal years defense plan (FYDP) to compensate for the previous years' training shortfalls.



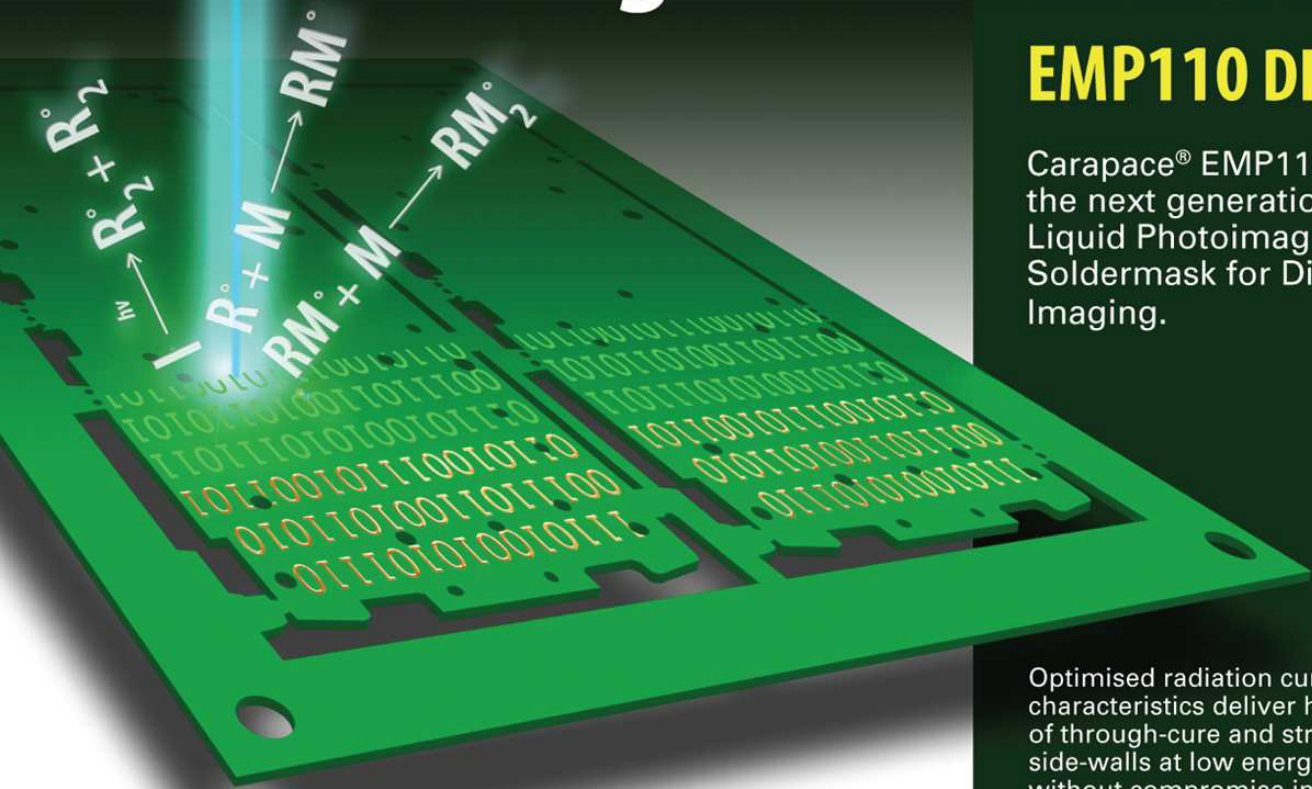


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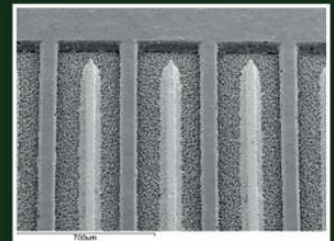
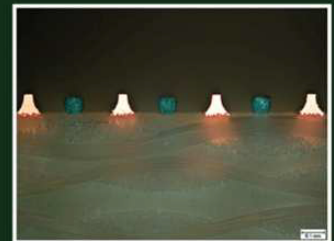
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Automation is the Talk of the Town at CPCA Show 2016

by **Pete Starkey**
I-CONNECT007

Editor's Note: At the recent CPCA show in China, I-Connect007 editor Pete Starkey interviewed a number of people, and one of the main topics of interest was automation. In keeping with our feature topic this month, we have excerpted select parts of his conversations and compiled them for you here.

As Starkey's interviewees point out, the case for automation is not just about moving things faster, but also reducing handling and handling defects, improving consistency and reliability, and of course, reducing costs.

Excerpted from, "Morgan and Starkey on CPCA 2016, Automation, and the Upcoming ECWC14"

Pete Starkey: *Alun, you mentioned efficiency. Now one thing I've noticed in talking to people in the show is the trend to increasing automa-*

tion, the trend to increasing integration, and the Chinese equivalent of Industry 4.0. I think a perceived characteristic of the industry over here is that there are lots of people doing lots of manual things, and these people are, I think, quite rapidly being replaced by machines.

Alun Morgan: A very good point—I think it's no longer the case, the degree of automation is now massive in these companies. If you look around this show you see loads of equipment for automatic handling, many small robots, loading-unloading machines, automatic guided vehicles running around moving components, moving pieces. Actually I think the factories that are successful here are hugely automated and there are good reasons for that. You can think of labor being cheap, of course, that's always a nice model—think cheap labor, therefore you can make the boards easily. But actually, machines make boards far more reliably, so you have far more consistency of production. I think that's why automation has come around, because when you're making tens of thousands of units, they must all be the same. Doing it by hand is rather tricky; if you can automate the

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Pete Starkey with Alun Morgan

process then actually you get a far more consistent product, and the high quality is what's required to sell it.

So, that definitely is the trend. If you look around this show I've seen no end of automation equipment here. You see the big drilling machines, the big plating lines, the big production screen printing lines, and imaging lines. Then you see on the front and back end of these machines a lot of automation for handling, so you see this being really hands-off now.

Starkey: *So really it's a bit of paradox because the perception is "manufacture is low cost in China because of low cost labor," but if you automate the whole process it's really just down to intelligent choice of process and the right capital investment in the right equipment, the right automation and not many people involved. So, could you not just lift that automated model and place it anywhere else in the world?*

Morgan: Well, yes. There is no doubt that it started out here because of low cost labor but now they are going to a very large automated model. In the end they'll become self-sustaining; if you look around now, the supply base is really in China and in Asia. This means for everything—you think of raw materials, chemistry, equipment—it's all here.

All that really isn't here are two things: the start and the end! So design is largely not here,

and the consumer market is largely not here either. Design authorities are mostly still in North America and Europe and the biggest consumer market in the world is still Europe, followed by North America. So actually, the middle of it is all done here with the supply chain all around.

If you think about Europe, think about North America, think of all the chemical supply companies and laminate supply companies that used to exist. There are very few now, and these are concentrated into very large successful operations, many in Asia supplying an Asian market. So you couldn't pick up just the PCB bit any more, you'd need to pick up the whole supply chain as well, and that's too much.

Starkey: *I think you've clarified my understanding with your explanation; thanks very much.*

To read the full interview with Alun Morgan, [click here](#).

Excerpted from, "The ESI Solution: High-Throughput Roll-to-Roll UV Laser Drilling of Thin, Flex Materials"

Pete Starkey: *Patrick, you've explained to me that China is a large and diverse market for you. Specifically, you have been addressing some of the problems of machining roll-to-roll flex circuits. Could you describe some of the realities of handling and machining these materials? What are the problems? How do you address them, and what you can offer with an ESI laser system?*

Patrick Riechel: We actually pioneered UV laser drilling for roll-to-roll material back in the '90s, together with our partner Northfield Automation Systems, who worked with us on our 5000 laser platform. So UV laser drilling with roll-to-roll handling is something we've been doing for many, many years, basically since the beginning. Handling 12-25-12 materials—that's 12 micron copper, 25 micron polyimide, and 12 micron copper—has become a very normal

thing now in the flex processing industry. It's now pretty standard and almost every handler in the industry can do that reasonably well. The problem is that, once you start processing at high throughputs, you're moving the material very quickly and the roll-to-roll handler needs to be able to keep up with that fast movement. When you talk about thinner and thinner materials, which we're processing more frequently now, those thinner materials are more prone to wrinkling and stretching.

Many of our customers have run into issues where they can no longer keep the tight tolerances they need and the accuracies they require as they go to these thinner materials, because the material starts warping. We decided that this was an ideal time to bring to market, together with our partner Northfield Automation, a roll-to-roll handler that addressed the problem. And we believe that the ESI RollMaster is the solution to the problem of processing the thinner and more sensitive flexible circuit materials at high throughput. It has a very responsive "dancer," which is basically the part of the roll-to-roll handler that responds quickly to motion by the stage inside the laser drilling tool. As the stage moves back and forth, the dancer has to maintain the tension on the roll-to-roll material.

Starkey: *Just to be clear, are we talking about machining on a constantly moving web, or in a step-and-repeat mode?*

Riechel: It's a good clarifying question. The ESI tools have a patented compound beam positioning technology, which continuously moves the stages, the galvanometers and, in our case, also acoustic optic devices on the 5335 and GemStone tools. What happens there is, because you're moving these three beam positioning technologies at the same time, you have to move the material back and forth continuously. It's not just moving in one direction, as you would with most wet process technologies, for instance. You're actually moving back and forth, forward and backward, continuously.

The challenge there is that you have acceleration and deceleration that is, in some cases, random and very fast, and the web handler needs to be able to compensate for that continual ac-

celeration and deceleration, and do so very responsively. If it does not do it very responsively, the result of that can be wrinkling of the web and other types of stretching issues. The reason being, if the dancer is dragging against the motion of the stage, you are pulling here going one direction and pulling by the dancer in the other direction, it can cause stretching or wrinkling.

Starkey: *What sort of position or tolerances are you able to achieve?*

Riechel: The 5335 flex processing product family for ESI maintains processing accuracies of 20 microns. After aligning to all of the alignment points on the material, we maintain plus-minus 20-micron accuracy across the entire panel processing area, which we do up to 533 x 635 mm.

Starkey: *Are we talking purely about a drilling operation or are we talking about a part drilling and part profiling operation?*

Riechel: We have the ability both to drill and do routing or profiling. Typically with roll-to-roll processes, however, you limit yourself to drilling because if you cut out profiles, then where does the cut-out material go? You could get around that by having laminated PET material on the bottom of your flex material. Some customers do that, but more often they will do that sort of routing or profiling opera-



Patrick Riechel

tion in panel format because then you're loading manually, you take it off and then you can remove the excess material from the work table afterwards.

Starkey: *What is the laser technology that you're using?*

Riechel: We have historically used UV nano-second lasers, but as we've expanded our laser portfolio we are moving from not just diode-pumped UV lasers, but to fiber laser technologies such as on our GemStone product.

Starkey: *Your laser will cut clean through copper-Kapton-copper, straight through the three layers?*

Riechel: We can perform this type of through-cut processing, as well as blind-via processing on very thin materials. It's very important to have excellent power control and also control other factors related to what we call laser fluence. Laser fluence is the laser energy per area that you're drilling on. To have very good control of that fluence is critical to not overdosing a specific area of material and cutting too far through your blind-via area. So for a blind via to stop in that second layer of copper, and not damage the material, you have to have very good control of the laser fluence. We do that very well. We also do through-vias, through copper-Kapton-copper. In some cases, in multi-layer constructions, we are cutting through not just the copper-Kapton-copper, but adhesive materials as well. And in some situations we're cutting through four or five layers of copper.

To read the full interview with Patrick Riechel, [click here](#).

Excerpted from, "Orbotech's Gaby Waisman: 'The Future is Digital'"

Pete Starkey: *If we begin with your assessments of the market requirements, what information do you need to feed to your development*



Pete Starkey with Gaby Waisman

people and your design people? What do you need to be producing to satisfy that market requirement?

Gaby Waisman: We need to offer digitalization. Digitalizing the production floor, we need to cater for thinner materials, tighter line-space. We need to do it faster and we need to do it more efficiently. We need to find ways to also increase the yield. And I will discuss it specifically with one of our machines. If we take a look at the booth over here, the first machine that is catering to such requirements is the Sprint, which is basically an inkjet. Its purpose is simply to digitalize the world of silk-screen, converting it from analog to digital.

Now this vision is not new. This is not the first time for us to present the inkjet machine. I believe we've been doing it for the last ten years, approximately. But we've moved gradually from offering solutions to quick turnaround, mid-production levels. For the first time now we can offer a solution for mass production. We are looking at the markets over here, Asia Pacific and definitely in China. The need is for mass production. We can offer a machine that offers similar, obviously better, cost performance, and cost per print, compared to the analog, silk screen solution. And in addition, it addresses the waste, saving steps along the process, saving on operators, saving on other factors related to the abilities of silk screen in general. And it offers better registration, alignment and



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so forth, and obviously automation. We can really offer, for the first time, a solution that can overhaul this industry, the mass-market, mass production industry, with this machine. This machine will be fully automated, offering up to 95 prints per hour. It offers superior quality, registration and all those aspects that not only can replace traditional silk screens but make it more efficient, save on the ink and material, make this a greener type of solution to something that is considered a base line production in the industry, and as I mentioned, in an automated way.

Starkey: *I think you've made a very significant statement in saying that you now have developed inkjet printing to the level where you are confident to place it in a mass production environment. Always the association of inkjet is that it is a great technique for quick turn, small batch. In the past that's never really been suitable for the sort of volumes and the sort of throughputs you've been talking about.*

“It has been an evolutionary way, but it is a revolutionary step.”

Waisman: Very true. For the first time we've really managed this breakthrough from, as you mentioned, the small batch, quick turnaround, to mass production. It has been an evolutionary way, but it is a revolutionary step. This is the Sprint 200 that we're showcasing here, and I'm very confident that we are now seeing the beginning of the revolution, the era of turning analog into digital in this specific production phase.

Starkey: *You have approached digital from two separate directions. You have for many years been identified as the leader in laser direct imaging for primary imaging. Now at the other end of PCB manufacturing sequence, you've brought a different digital imaging technology*

into play that can handle the sort of volumes and, as you say, you're helping to drive the industry into a fully digital, fully digitalized imaging technology.

Waisman: You're absolutely right, this is an additional step in the digital revolution that started about 10–15 years ago. It's obviously apparent in each and every one of our tools. We haven't discussed the general advantages of digital versus analog—I think this is quite clear by now, with the flexibility and the other capabilities. But I think that specifically in silk screen this very important also because of the green trends and the need to have greener technologies that are digital, cost efficient, etc., and reduce the material waste. I think this is all very important in transforming this particular part of the industry.

Starkey: *I can understand clearly what you're saying from personal background. I saw what could be achieved with screen printing. And screen printing can achieve very good, very precise, very high throughput results. Probably not to the level of definition that's required by today's design technology. There was a period when the interim solution was with a photoimageable ink but, as you make the point, it is a very wasteful process—probably 95% of the ink you use becomes an effluent treatment problem for you. With a digital process that's capable of very high definition, high resolution and high precision of registration, you're only using a fraction of the ink when you would be using, and you're not really creating any effluent problem at all.*

Waisman: You're absolutely right. There are many other benefits, whether its serialization or enabling different types of prints in a much more flexible way, which we haven't discussed. I think the main points here are really the ability to have a digital, automated, mass market, mass production product in this tool.

Starkey: *We see an increasing amount of automation in PCB manufacturing. We're very conscious of Industry 4.0, the Internet of Things, and all of the things that you have mentioned are modules that will build into this fully integrated system.*

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Waisman: It's all pieces of the puzzle. I think we're getting to a point in which we have the full puzzle sorted out, and this is obviously a critical piece.

Starkey: *Again, from a personal point of view, I've seen the evolution of Orbotech over many years. In the beginning you were associated with optical inspection, you were associated with pre-production tooling. You've moved on from there to be an imaging company and, as I said earlier, you're imaging at the primary-image stage and you're imaging at the final-image stage. You are progressing more and more and more towards full automation. We see this as, as you said, the manufacturing concept for the future.*

Waisman: When we are talking about automation, we are addressing the different types of automation required by different manufacturers, whether they need to be in line, to be side by side, and now we have roll to roll. It's all part of the need to be more efficient, have better cost per print, and have cost reduction in general. This is all part of the same trend.

Starkey: *You also mentioned your ability to produce information, which is not just manufacturing information, but can give you an awful lot of feedback from the point of view of manufacturing management, business management, analysis, etc.*

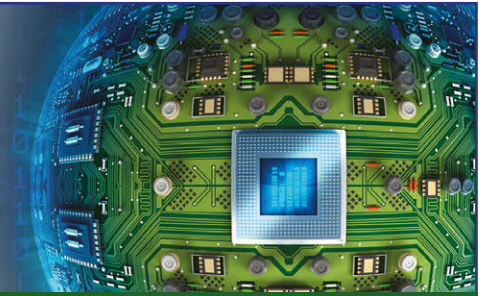
Waisman: We will have a short demo to show you exactly what we're referring to. I think this is a very powerful tool to increase the efficiency even further. Trying to synergize between different data that we're receiving from different tools on the production floor—just another layer of efficiency using this kind of unique synergy. The second tool is concerned with yield enhancement. As you know, 75% or so of yield issues are caused by shorts. Here we have the tool, the Ultra PerFix, which is designed for automatic optical shaping. We have definitely led this kind of concept and over the year we've perfected the machine, basically in order to increase the throughput of reworking shorts.

Starkey: *I've observed the evolution of this system from the original concept.*

Waisman: We've focused on two axes, one to increase the throughput and the other to reduce the line-space. We started around 25 or 30 microns. Now the Ultra PerFix you see here on the floor goes down to 10, and it's not only addressing the rigid but also the flex. Again, full automation, roll to roll, different table sizes. This is another specific example of how you see yield improvement in general. Now, it's not only the yield improvement when we are referring to a standard base production. People tell us okay, we've improved the yield, perhaps this will no longer be required. From our experience it's not only doing it on a regular basis but also when you change technology for processes, when you need to change production needs basically; this is a fantastic tool to verify that you don't have a drop in yield while you are doing that. When you are moving between different kinds of technology, different kinds of processes and requirements, you can maintain your yield level using these kinds of machines. I'm very proud to say that this has become a tool of record for the advanced HDI and flex industry. This is the second example.

The third example refers to perhaps our core, our legacy of being AOI market leader. In that respect we've also invested quite a lot in ensuring that we deal with two axes of throughput and line-space. So this AOI over here, the Ultra family, offers machines that go down to five microns basically. So we're referring to PCB and substrate industries, or segments within the industry. As you know this is a very unique technology offering dual light source, both blue and red. Here we're showcasing a machine that goes down to 15 microns, and this is obviously the leader in the flex industries. Now we're seeing another wave of machines going down to 10 microns in the substrate realm. We are already offering machines that have five microns with very unique technologies that can address very flexible ability to manage five to 20 microns with the same machine, and a very sophisticated optical system.

To read the full interview with Gaby Waisman, [click here](#). **PCB**



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Primary Imaging for Pattern Plating, Part 1

by Michael Carano

RBP CHEMICAL TECHNOLOGY

It is the job of the PCB process engineer to ensure that a quality circuit is delivered. This process starts with sound mechanics of the imaging system that include surface cleanliness and resist lamination parameters.

Introduction

You've heard the expression "garbage in, garbage out." This also applies to anything related the manufacturing of printed circuit boards. More specifically the subject of primary imaging for pattern plating comes to mind. There are several key process steps that must be properly executed in order to insure that the electroplated copper trace conforms to dimensions that were intended. This also means that the plated trace is uniform in shape. Of course the electroplating process itself plays a significant role in the quest to obtain a uniform trace.

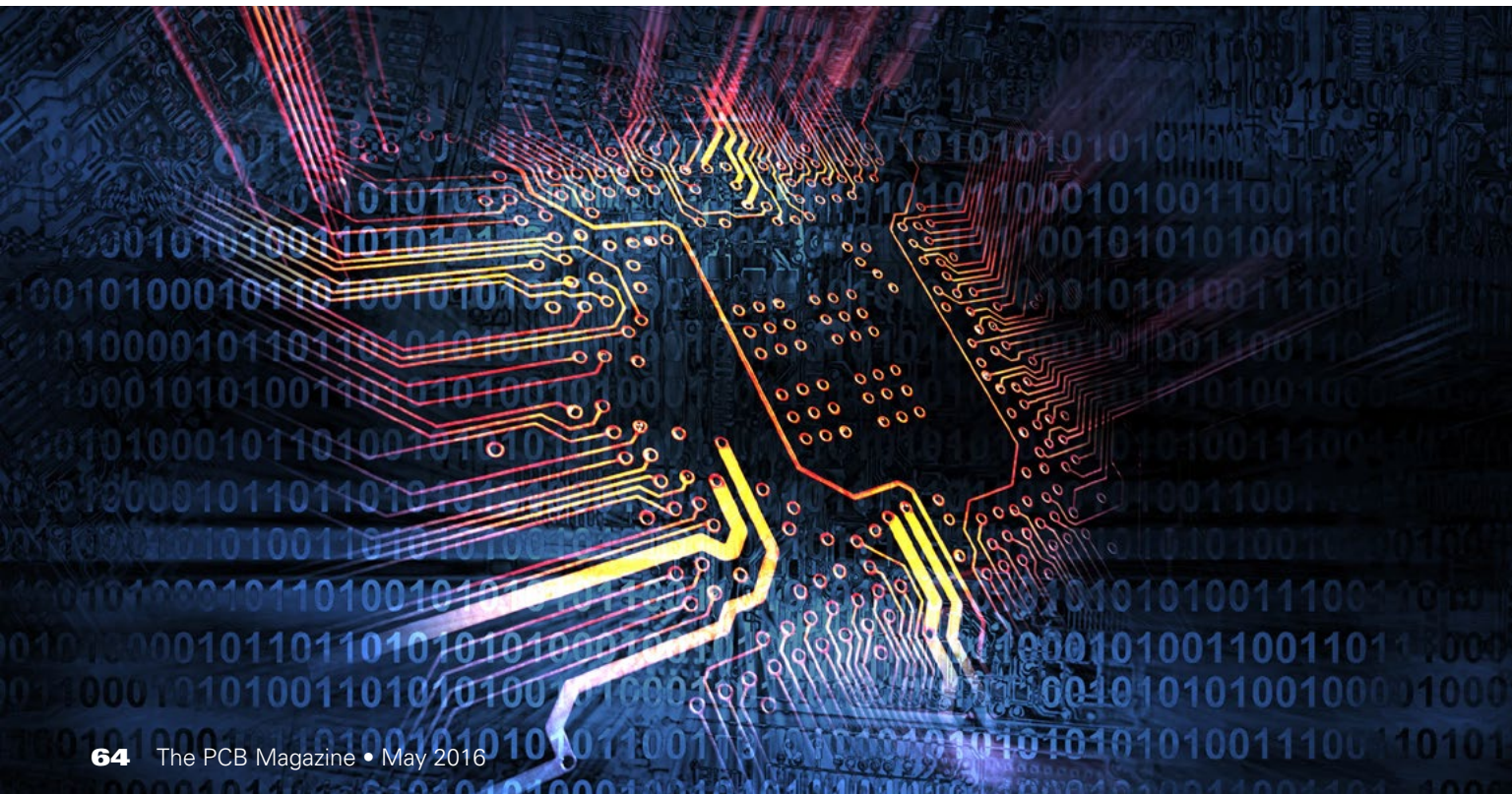
The plated trace should be as free as possible from pitting, undercut, plated copper overhang (plating of metal up over the primary resist) and ragged edges. Again, this all starts with a properly controlled imaging process. In a future column this author will discuss electroplating of copper in more detail.

Primary Imaging

There are several process steps in imaging:

- Resist lamination
- Exposure
- Development

In the process of lamination, the dry film resist is applied onto a base material, typically a copper clad dielectric (for innerlayer imaging) or an outerlayer surface of the printed circuit

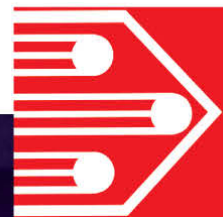


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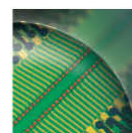
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board just prior to pattern plating. In the case of pattern plating, the resist laminated onto to a surface that has either been processed with conventional electroless copper or with one of several alternatives (carbon based, conductive polymer, etc.).

The lamination step is designed to achieve intimate contact between the resist and the copper surface as a protective coating against plating or etching chemical attack. By utilizing heat and pressure, contact between the resist and the copper is achieved. Essentially the dry film resist flows and is able to conform to the surface. This is explained as follows:

“Flow is achieved by lowering the resist viscosity and applying a pressure differential for a certain amount of time. Viscosity is then lowered by heating the resist. A pressure differential can be created by pneumatic, hydraulic, or mechanical (springs) pressure on the lamination hot rolls of a hot roll laminator or by applying a vacuum to a vacuum laminator^[1].”

There are several concerns that need to be pointed out in the primary resist lamination process. First consider that the printed circuit boards have been processed through wet processes (either conventional electroless copper or direct metallization) prior to resist lamination. In order to effect optimum adhesion of the resist, the boards must be free as possible from moisture (particularly in small vias) and on the panel surface. Secondly, the copper surface must be free of oxides. Oxidation on the copper surface may increase the chance of resist lock-in and subsequently prevent proper development and/or resist removal. With respect moisture in the holes, this author highly recommends a horizontal dryer or vertical box system that sufficiently removes the moisture. In order to prevent oxidation after metallization, de-ionized water rinsing followed by anti-tarnish (benzotriazole-

or citric acid-based) are beneficial in preventing oxidation.

Some type of cleaning and surface structuring is required in virtually every step of the printed circuit manufacturing process, from preparing the raw laminate for etch or plating resist to final assembly board cleaning before shipment. Many cleaning procedures are integral within certain manufacturing processes, such as plating and innerlayer imaging.

Through mechanical, chemical, or electrochemical processing, the copper surface's chemical composition and topography are prepared for optimal dry film adhesion and subsequent clean release. Processes will vary, depending on the type of copper surface to be prepared (vendor copper, electroless, electroplated). Surface preparation processes typically roughen the surface to increase film contact area and remove chemical impurities and anti-tarnish coatings, which could interfere with film adhesion. The mechanism of resist adhesion is a function of the contact area of the copper surface, resist film thickness and flow characteristics and lamination variables.

In general, surface preparation is done to assure good adhesion of metal, dielectric, photoresist, or soldermask to the prepared surface,

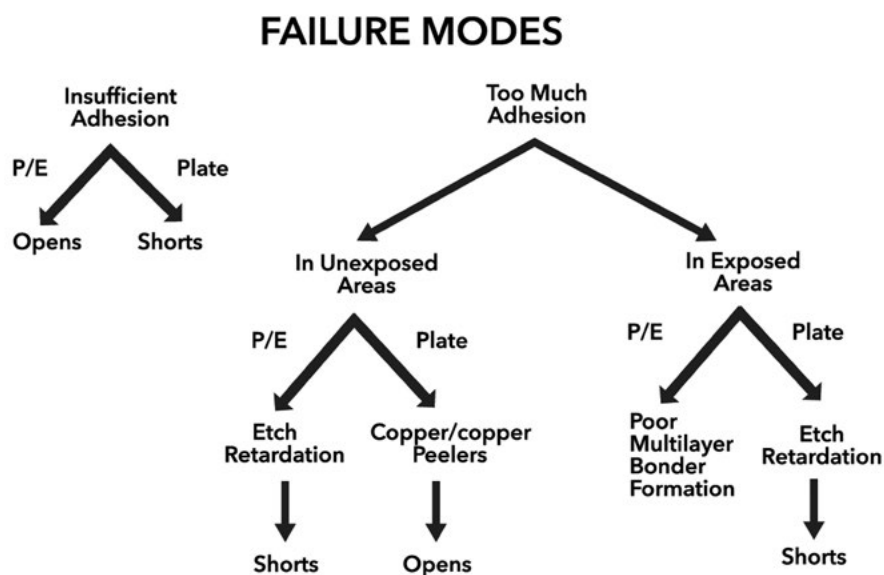


Figure 1: Possible failure modes due to poor surface preparation (Source-IPC 740).

although avoiding excessive adhesion could also be the objection. Take the example of surface preparation before dry photoresist lamination (Figure 1):

- Failure to achieve good adhesion in a print-and-etch process will cause etchant attack under the resist and ultimately an open defect.

- Failure to achieve good adhesion in a plating process will cause tin/lead underplating, ultimately leading to shorting defects ("shorts").

- Failure to achieve good release of unexposed resist during development can cause etch retardation in a print-and-etch process, ultimately leading to shorts.

- Failure to achieve good release of unexposed resist during development in a plating process can cause poor adhesion of the plated copper to the copper base ("copper-copper peelers").

- Failure to achieve good release of exposed resist in a print-and-etch process on innerlayers can inhibit the formation of multilayer bonder on such a copper surface.

- Failure to achieve good release of exposed resist in a plating process can cause etch retardation.

Resist Lamination Variables

There are several factors that one can control during the resist lamination process. First and foremost achieving intimate contact between the resist and the copper surface is required in order to meet adhesion standards. Failure to obtain optimum contact can lead to the creation of open circuits (Figure 2).

One should also be aware of the laminate weave texture and overall topography of the copper surface. Heavy glass weaves make it difficult for the resist to conform to the surface. However, do not attempt to increase lamination temperature above the resist manufacturers' recommendation to compensate for heavy weave texture.

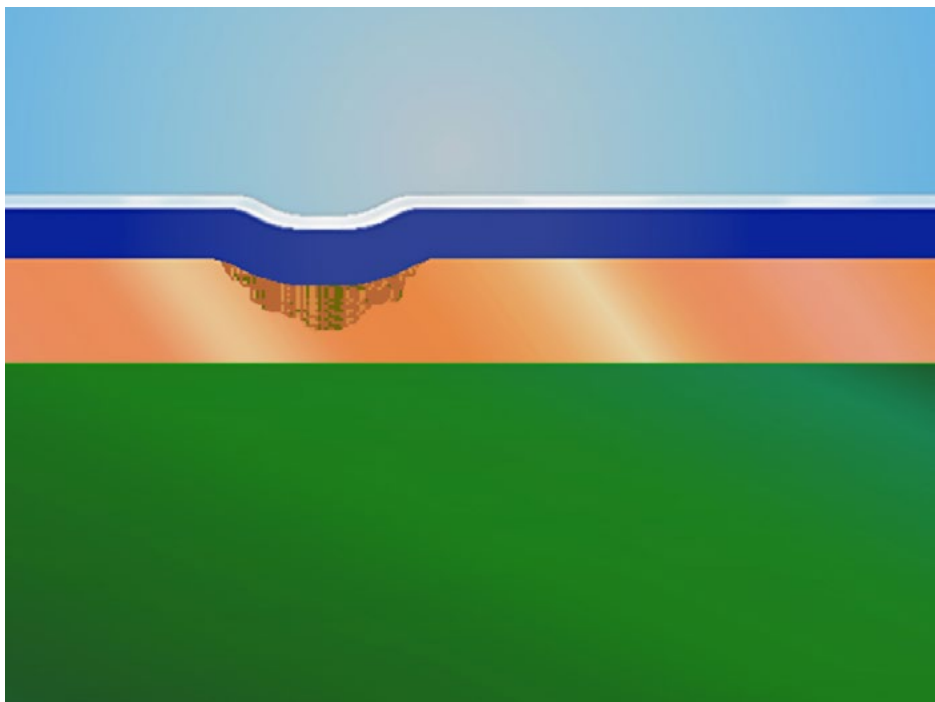


Figure 2: Resist does not completely conform to surface, causing potential for nicks or opens in the circuitry. (Source: IPC Picture archive-Bannockburn, Illinois)

Secondly the line operator can control the contact time between the resist, the board and the hot roll laminator. Additional contact time will improve the adhesion of the resist to the surface. While it is critical to ensure the proper hot roll lamination temperature (as suggested by the resist supplier), do not attempt to increase the temperature above that recommended. The excessive temperature will damage the photoresist. **PCB**

References

1. IPC Process Effects Handbook 5001 (IPC, Bannockburn, Illinois).



Michael Carano is VP of technology and business development for RBP Chemical Technology. To reach Carano, or read past columns, [click here](#).

Electronics Industry News

Market Highlights



A Flexible Camera: A Radically Different Approach to Imaging

A team led by Shree K. Nayar, T.C. Chang Professor of Computer Science at Columbia Engineering, has developed a novel sheet camera that can be wrapped around everyday objects to capture images that cannot be taken with one or more conventional cameras.

Researchers Use Single Molecule of DNA to Create World's Smallest Diode

Researchers at the University of Georgia and Ben-Gurion University in Israel have demonstrated for the first time that nanoscale electronic components can be made from single DNA molecules.

Manufacturing Overcapacity Constrains Industrial Robot Market Growth in China

The Chinese market for industrial robots reached an estimated \$1.3 billion in 2015. This market is expected to grow at a compound annual growth rate (CAGR) of 20%, reaching \$3.3 billion in 2020, according to IHS Inc.

Collaboration to Build New Brain-Inspired Supercomputer

Chip-architecture breakthrough accelerates path to exascale computing and helps computers tackle complex, cognitive tasks such as pattern-recognition sensory processing.

Hannover Messe: New Hybrid Inks Permit Printed, Flexible Electronics without Sintering

Research scientists at INM have combined the benefits of organic and inorganic electronic materials in a new type of hybrid ink. In one example, electronic circuits may be applied to paper directly from a pen.

Producing Electronics without Semiconductor is a Reality

A new study by an international team of researchers, affiliated with UNIST, has found a new way to produce electronic devices, such as diodes, logic gates and sensors without the need for semiconductors.

3D Printing: The Next Industrial Revolution, 2016 Update

3D printing is an additive manufacturing process. In recent years, 3D printer prices have dropped substantially, and a wide variety of printable materials is available.

Enterprise Adoption of Wearable Devices is Expanding into Larger Deployments

Enterprise adoption of wearable technology is beginning to move beyond pilot projects and technology trials and into full-scale deployments, according to a new white paper published by market intelligence firm Tractica.

Researchers Develop New Semiconducting Polymer for Flexible Electronics

Polymer semiconductors, which can be processed on large-area and mechanically flexible substrates with low cost, are considered as one of the main components for future plastic electronics.

PC Shipment Decline Continued in First Quarter as Expected

Worldwide PC shipments totaled 60.6 million units in the first quarter of 2016, a year-on-year decline of 11.5%, according to the International Data Corporation (IDC) Worldwide Quarterly PC Tracker.





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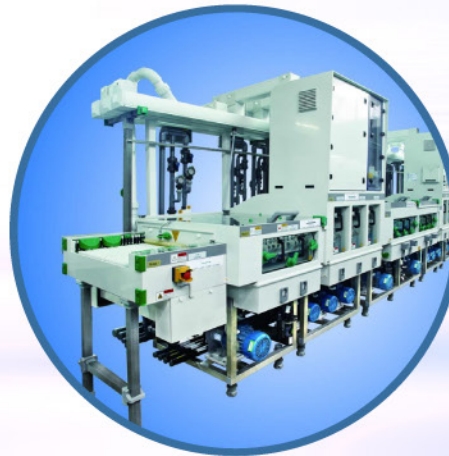
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Quality Management and the Hidden “I” in Team

by Todd Kolmodin

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Today, businesses of all types are jumping on the quality bandwagon. The more critical the product, the more the consumer/customer wishes the highest possible quality in the goods or services requested. Customers send surveys with buzzwords like ISO, QMS, and AVL for their suppliers to complete so they have confidence that what they receive is of the highest quality.

But what does all of this mean? ISO certifications such as ISO9001 are standards whereby a quality management system (QMS) is created so that products and/or services are produced in a repetitive manner that is monitored for effectiveness and continually improved. Surveys from customers to suppliers mainly consist of queries about whether the supplier has a QMS or attributes therein to satisfy their require-

ments. This allows the supplier to be placed on their approved vendor list (AVL). So with that said, suppliers create processes, manuals, work instructions and monitoring criteria for key performance indicators (KPIs). The entire QMS is then audited for effectiveness and adherence to the standard. The end result is that the supplier is certified.

A lot of work you think? It can be. However, what often happens is a company gets so wrapped up in creating all the necessary documentation, processes and monitoring criteria that they overlook the fundamental variable that is the most important factor in whether a QMS succeeds or fails: the individuals (“I”) that actually work with the QMS system every day.

Success of a QMS requires all systems to operate smoothly and correctly. However, even





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though most quality systems encourage the team approach, when it comes right down to it, the hidden “I” in team plays a significant role in the success or failure. For example, all of the individual pieces of a process must work together for the desired outcome. In the case of a work instruction, an individual must perform those steps for success. Quality managers and quality staff prepare these instructions for the system but many times focus more on satisfying the standard without taking into account the people who will perform these tasks.

So here is where the hidden “I” emerges. For a successful QMS or any significant process to be successful, the individuals must buy into it. People performing the tasks in a process must feel they are part of the success. If operators fully understand the tasks they are doing and know what their contribution does for the overall success, they will be much more likely to pay close attention to what they are doing. If instructions are not clear (not successfully trained) or steps are monotonous (wasteful) the individual may

lose focus and deviate from the required steps. For a team to be successful the individuals must feel empowered on their own level, that they make a difference, and with their contributions to the team, the hidden “I” provides the foundation to a robust quality system with all integrated parts operating effectively.

To close, I’ll quote the Russian-American avionics engineer and inventor Igor Sikorsky: “The work of the individual still remains the spark that moves mankind ahead even more than teamwork.”

See you next month! **PCB**



Todd Kolmodin is the vice president of quality for Gardien Services USA, and an expert in electrical test and reliability issues. To read past columns, or to contact Kolmodin, [click here](#).

IMPACT Washington, D.C. 2016 — Preliminary Report

In mid-April, top management from IPC-member companies representing PCB, EMS, equipment and materials suppliers met in Washington at IMPACT Washington, D.C. (formerly, Capitol Hill Day). Congressional and executive branch leaders listened carefully

to IPC’s advice on how to best address the most pressing concerns of our industry.

This year, three issues were chosen by the IPC Government Relations committee to follow up on with members of Congress and staff. The agenda was limited so as to not dilute the message nor distract the intended audience.

Addressed at this IMPACT were:

- **TSCA**—The EPA’s interpretation of the Toxic Substances Control Act makes it more difficult to recycle chemicals like copper etchant than to simply treat and dispose. IPC’s argument: We want to do the right thing and recycle as much as possible.



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- **Workforce**—New proposed regulations would significantly raise the baseline salary of those who can be considered exempt from federal overtime pay regulations, effectively making more

people eligible for overtime pay. The rule does not take into account the impact on workplace flexibility, career advancement and workplace efficiency. IPC wants to work with the Dept. of Labor towards a better solution.

- **NNMI**—the National Network for Manufacturing Innovation is a public-private partnership that draws on the resources of the federal government, local governments, universities, research institutes and industry to accelerate manufacturing innovation. IPC is urging full funding and long-term planning for the network of institutes of which IPC is a member of three.



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MACFEST

Manufacturing Advanced Coatings for Future Electronic Systems

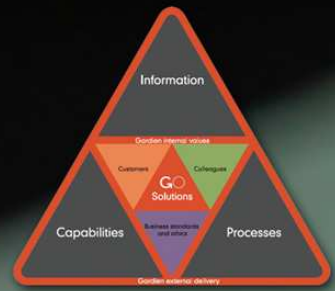
**by Dr. Andrew Ballantyne
and Prof. Karl Ryder**

UNIVERSITY OF LEICESTER

Now in its second year, MACFEST is a collaborative research project involving partners A-Gas Electronic Materials, C-Tech Innovation, MTG Research, the Institute of Circuit Technology, the University of Leicester and Merlin Circuit Technology. Partly funded by Innovate UK (formerly the Technology Strategy Board), the aim of the project is the development of new “universal” PCB surface finishes which are suitable for both solder reflow and gold wire bonding. This will help PCB manufacturers meet the performance demands for high value electronic systems, ensuring long term reliability, even in harsh environmental conditions. In addition, the use of deep eutectic solvents (DESs), a patented technology of the University of Leicester, offers the ability to significantly reduce the environmental impact of a number of PCB plating technologies, reducing the requirements for use of cyanide and toxic/corrosive acids in plating baths.

DESs are a novel class of solvents similar to ionic liquids (ILs). Whereas ILs are composed exclusively of ions, DESs are liquids composed of a salt and complexing agent, commonly a tetraalkylammonium salt, such as choline chloride, and a hydrogen bond donor (HBD), such as 1,2-ethanediol or urea^[1]. When mixed together the HBD binds to the anion, resulting in a large depression of the melting point. At Leicester we have used DESs in the development of immersion silver^[2, 3], electroless nickel-immersion gold (ENIG)^[4] and hot air solder levelled electroless nickel (HASLEN) processes, each of which offer its own benefits over existing processes^[5] from the reduced safety and environmental concerns mentioned above as well as, in some cases, the removal of existing failure mechanisms such as black pad.

The MACFEST project is building on this previous work in the development of a new, state-of-the-art PCB surface finish for use in both reflow and wire bonding applications. Taking inspiration from the electroless nickel/electroless palladium/immersion gold (ENEPIG) surface finish, we have developed a novel nick-



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el/palladium/gold coating where both the palladium and gold have been deposited through an immersion process from DESs. This coating is termed electroless nickel/immersion palladium/immersion gold (ENIG).

Because of their inherent thermodynamic properties, electroless processes are fundamentally unstable. This can lead to spontaneous bath breakdown or extraneous plating which

requires either bath replacement or scrapping of the Pd-plated PCB, both of which can be very costly. However, immersion plating baths are fundamentally stable and not prone to either of these issues. Nevertheless, it is still essential that a uniform adherent coating is produced to prevent the underlying nickel substrate from oxidation. Using the DES Ethaline 200, a uniform Pd coating of ~100 nm thick can be achieved in 20 minutes using palladium chloride as the Pd source. An example SEM image is shown in Figure 1 where the characteristic nodular structure of the electroless nickel can be observed. Few other features are apparent, despite the presence of ~100 nm palladium on the surface, because of the uniformity of the coating.

Currently, immersion gold plating processes from aqueous chemistries for ENIG and ENIG coatings utilise potassium gold cyanide as the Au source. However, by using DESs, gold(I) chloride can be used as the gold source. In addition, acid is required in aqueous media to help prevent passivation of the nickel surface; this is linked to the black pad phenomenon where hyper-corrosion occurs near the grain boundaries resulting in a poorly solderable coating. Because of the unique behaviour of metal salts

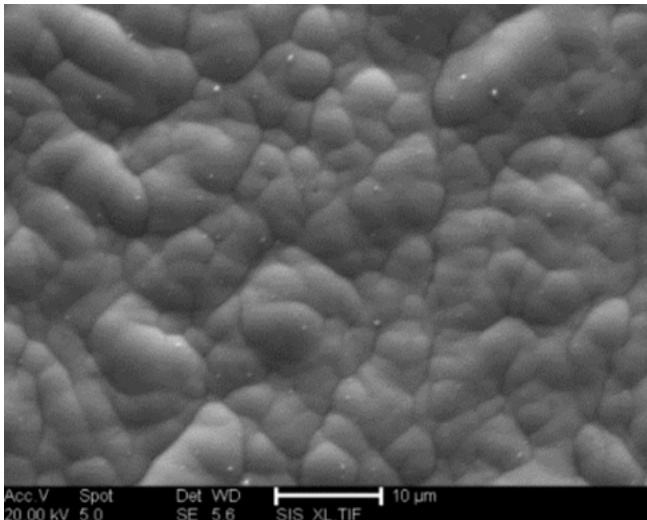


Figure 1: SEM of an electroless nickel - immersion palladium coating.

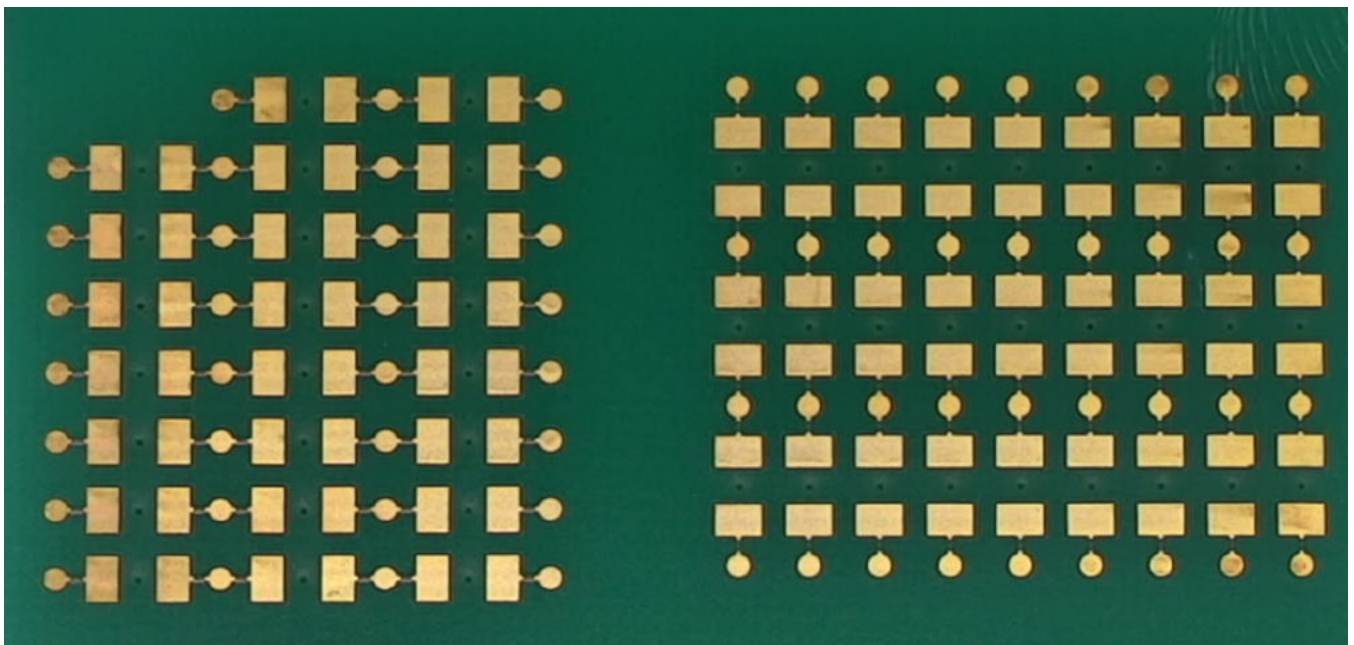


Figure 2: PCB with an ENIG surface finish, pad sizes are 2.0 x 1.5 mm.

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in DESS, no acid is required in the plating formulation helping to minimise the risk of “black pad.” A bright uniform gold coating, as shown in Figure 2, is possible in a short period of time (~5 minutes).

With nine months left, the project is proceeding according to the initial timeframe. Laboratory scale trials at the University of Leicester, while still ongoing, have resulted in a number of interesting plating formulations for both immersion palladium and gold plating processes, some examples of which have been described above. We are now engaged in further validation of the coatings. Working with Bob Willis of The Smart Group, our coatings will form part of a trial to evaluate the properties of a number of surface finishes in a variety of assembly and soldering conditions. This exciting opportunity will provide us with the chance to directly quantify the quality of our coatings against the current industry standards with testing being carried out by a well-known, impartial, industry expert. In addition, C-Tech and Merlin will further develop scale-up protocols for the process, developing an understanding of plating behaviour along with bath evolution and replenishment procedures. **PCB**

Acknowledgement

This project is co-funded by Innovate UK.

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Dr. Andrew Ballantyne (left) is a research associate and **Karl Ryder** (right) is professor of physical chemistry at

University of Leicester in the UK.

Breakthrough with New Generation Robots

The robotics industry is on the precipice of a major breakthrough. Soon, industrial robots will be used at lower cost in small-scale production thanks to the operating system developed by the Dutch-German partnership SlnBot. Doctoral research by Maarten Essers from the University of Twente shows that the results from preliminary tests are promising.

Major companies in the manufacturing industry are using smart robots for mass production more frequently. This is not economically viable for small production runs, because reprogramming industrial robots is an expensive and time consuming process. An additional problem is the hierarchical structure



of the operating system, which means that significantly more machines are involved than strictly necessary.

Smart Factories are Everywhere

The new design architecture results in more flexible robots that are easier to use in smaller production environments. Essers predicts that “factories will get a complete overhaul in the near future, especially with respect to small and medium enterprises. Smart factories will pop up everywhere and small-scale production will become completely automated with the help of self-learning smart robots. They will be used in the food, feed and metal industries as well as in other manufacturing sectors.

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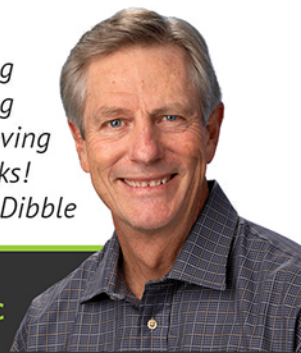


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Learn more about the roadmap used to build great companies with a high level of profitability in this article from the March 2016 issue of **The PCB Magazine**.

For 25 years we have been doing Four New Agreements consulting and training, significantly improving businesses. This stuff really works!

—David Dibble



Electronic Packaging Levels

by Karl H. Dietz

Electronic packaging refers to the integration of electronic elements into a functioning device by forming connectivity at different levels.

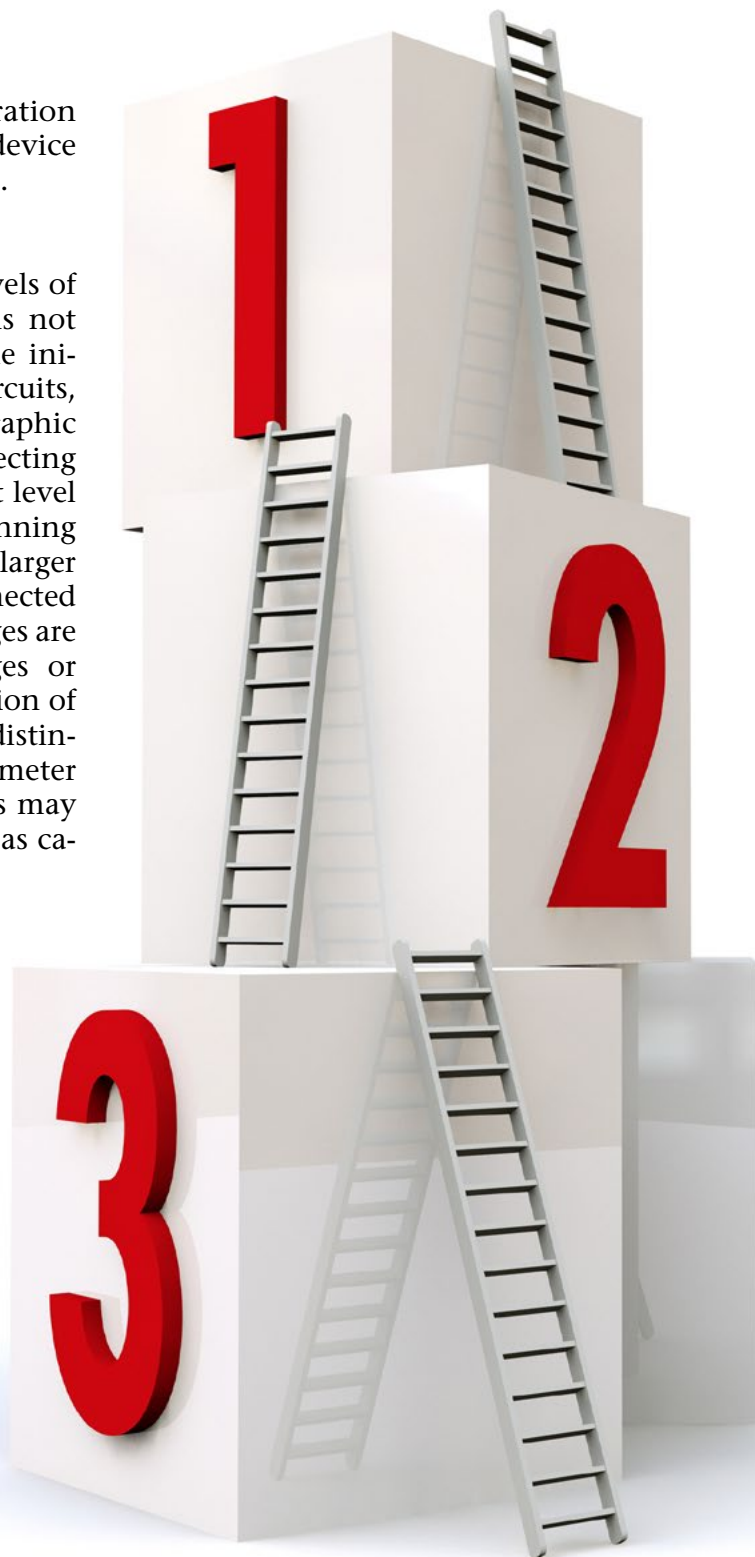
Levels of Electronic Packaging

One distinguishes between different levels of electronic packaging, a convention that is not always consistent. It typically refers to the initial connection of the chip (integrated circuits, central processing unit, memory chip, graphic processor, etc.) to other elements or connecting structures as first level packaging. Such first level packages typically serve the function of fanning out the very tight I/O grid of the chip to a larger pad footprint that can be more easily connected to other elements. Examples of such packages are leaded components, wire-bonded packages or flip chip packages. Depending on the position of the connecting pads on the package, one distinguishes between dual in-line packages, perimeter arrays, and area arrays. First level packages may also incorporate passive components such as capacitors or resistors.

Second level packaging typically refers to the fabrication of a circuit board (PCB, motherboard) and the mounting of first level packages and passive components (capacitors, resistors, inductors) to such a board (assembly).

Third level packaging normally refers to the connection of assembled boards to elements such as power supplies, displays and ultimately to the "box," which is the final electronic device.

Occasionally, the term "zero level packaging" is also used. It refers to the formation of interconnect features on the wafer before it is cut up (singulated) into individual chips. Such zero level packaging might encompass the formation of so-called redistribution layers



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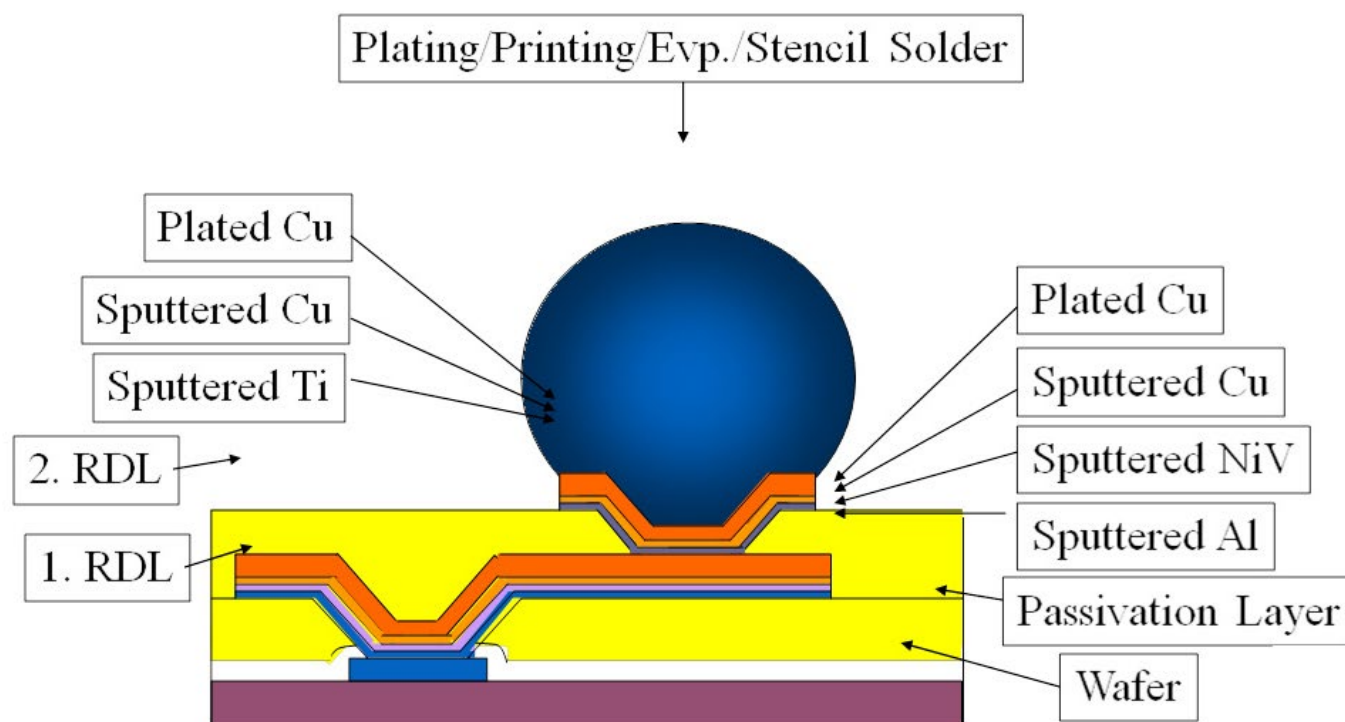


Figure 1: Bumped wafer with redistribution layers, under-bump metals and solder bump.

(RDL) and their conductive paths with the purpose of rearranging the I/O pattern, e.g., from a perimeter array to an area array. These redistribution layers may also contain passive components. Zero level packaging processing would also include the bumping of pads which includes the deposition of under-bump metal layers (Figure 1). Alternatively, the plating of copper pillars onto pads needs to be mentioned here. In addition, the formation of TSVs (through-silicon vias), their metallization, filling, and interconnect to form stacked chips, could be called zero level packaging. Furthermore, the attachment and removal of supporting tapes during any wafer-level operations belongs here.

Figure 2 illustrates first and second level packaging. In this case, an area array flip chip (shown in upper right) is connected in first level packaging to a flip chip substrate (or package) which features a double-sided rigid core (yellow) and two build-up layers with microvias on each side (green). This package is then connected to a PCB, shown on the lower lefthand

side as a populated (assembled) board. Its cross-section is shown on the lower right. One can see a filled and an unfilled plated through-hole, mixed dielectric material layers (yellow and green), which is not as common as single dielectric constructions. The board also features a single microvia layer on each side.

1. Zero-Level Packaging: Material and Processing Requirements

In general, wafer-level packaging uses processes and equipment that differ from the customary PCB processing equipment such as conveyorized spray modules, automatic contact or laser printers, etc. Wafers are typically processed individually in, for example, spin coaters, "fountain platers," steppers, etc. Materials have to be compatible with such processes. Many deposition processes are vacuum processes, so that outgassing from organics can become an issue. A high degree of purity of chemicals is demanded, especially the control of ionic contaminants at very low levels.

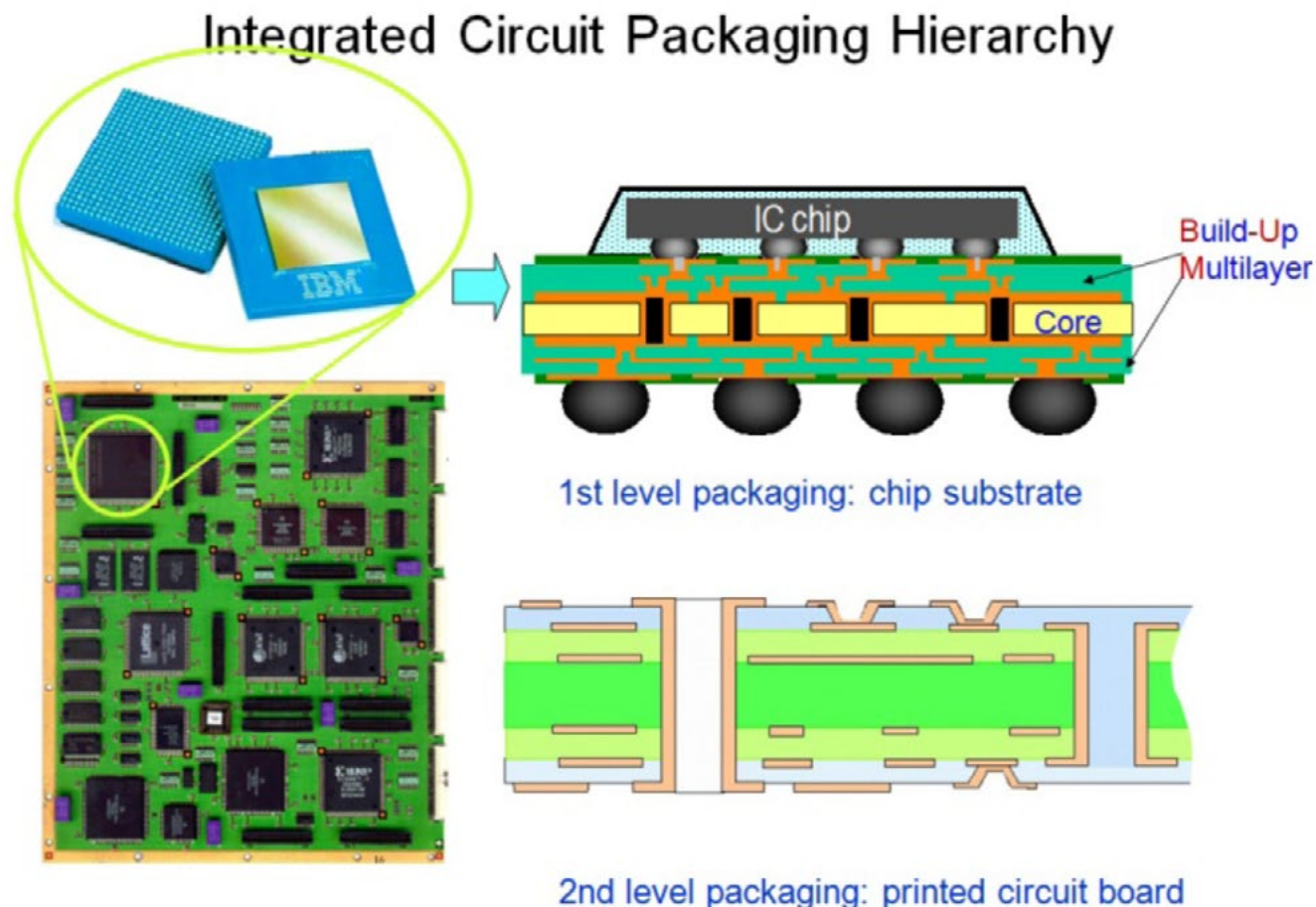


Figure 2: Illustration of first- and second-level packaging.

2. First-Level Packaging: Material and Processing Requirements

Material and processing requirements of first-level packaging depend somewhat on the nature of the package, but one can point out common requirements. Soldering temperatures for connecting the chip to the package are typically higher than the soldering temperature for connecting the package to the PCB. This translates into more stringent dimensional and chemical stability requirements for the materials that compose the dielectric layers. Since the dimensions of conductor lines and spaces are smaller than those for PCBs, the circuitization of build-up layers of flip chip packages often uses the semi-additive process which requires good adhesion of electroless copper to the dielectric film surface. In addition, the microvia dimensions on packages are often smaller than those

of HDI boards so that drilling, copper landing-pad cleaning and hole-wall desmear are more demanding than for HDI boards.

Since the first-level package is closest to the chip, near-matching CTEs (coefficient of thermal expansion) of all materials is desirable to avoid stress cracking during thermal excursions. The CTE of silicon is about 3–4 ppm/degree Kelvin, for copper and for lead about 16–17; for glass weave resin about 20 in the X/Y plane, but 60–70 in the Z-axis. CTEs of 40 or less in all dimensions are now required for dielectric layers.

3. Second-Level Packaging: Material and Processing Requirements in Comparison to First-Level Packaging

There are many electrical, mechanical, safety and environmental requirements for PCBs that translate into specific requirements for di-

electrics. Likewise, there are specifications for the conductors, typically copper, such as tensile strength, elongation, dimensional uniformity (height, width), and peel strength (adhesion to the surrounding dielectric material). Peel strength is of course a function of the nature of the chemical and mechanical interface between the copper and the dielectric and as such affects both—the copper, as well as the dielectric—and the preparation of such surfaces to achieve the desired peel strength. Compared to first-level packaging requirements, the second level packaging requirements typically don't include processability by the semi-additive circuitizing process, and they are less stringent regarding low CTE, high chemical and dimensional stability.

Requirements derived from PCB manufacture include desmear chemistry compatibility (i.e., the removal of resin smear from innerlayer copper with potassium permanganate chemistry), and the compatibility with conventional mechanical drilling as well as laser drilling. It should be noted that there is great reluctance in the industry to substantially change a process to accommodate a new material. Thus, processability and process fit are important considerations. Also, price/performance trade-offs are critical.

There is no single parameter of “goodness” for high-performance PCB materials. Performance parameters are driven by end-use requirements, processing needs, and by requirements derived from semiconductor characteristics, as specified by OEMs. Depending on the IC

performance and complexity, and depending on the end product, different performance criteria will make the “most critical” list.

There are acceptance/performance standards and test methods for PCBs. The most widely accepted standards and methods are developed and published by IPC. Examples are:

- IPC-A-600 Acceptability of Printed Boards
- IPC-4101D (Specification for Base Materials for Rigid and Multilayer Printed Boards)
- IPC-TM 650 [Test Methods Manual](#)

An example from the Test Methods Manual is Method 2.6.8 Thermal Stress (Solder Float). It requires the exposure of a sample to 288°C, for 10 seconds, 3–6 times. The sample is then inspected for breakages in circuits, through-hole metal, and dielectric, as well as for delaminations. **PCB**

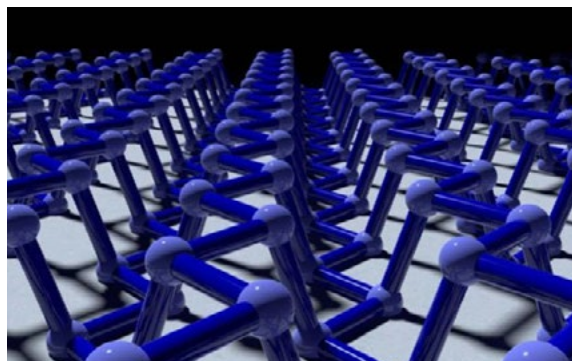


Karl Dietz is president of Karl Dietz Consulting LLC. He offers consulting services and tutorials in the field of circuit board and substrate fabrication technology. To view past columns or to reach Dietz, [click here](#). Dietz may also

be reached by phone at (001) 919-870-6230.

Exploring Phosphorene, A Promising New Material

Two-dimensional phosphane, a material known as phosphorene, has potential application as a material for semiconducting transistors in ever faster and more powerful computers. But there's a hitch. Many of the useful properties of this material, like its ability to conduct electrons, are anisotropic, meaning they vary depend-



ing on the orientation of the crystal. Now, a team including researchers at Rensselaer Polytechnic Institute (RPI) has developed a new method to quickly and accurately determine that orientation using the interactions between light and electrons within phosphorene and other atomsthick crystals of black phosphorus.



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TOP TEN



Recent Highlights from PCB007

1 **Happy's Essential Skills: Failure Modes and Effects Analysis (FMEA)**

Failure modes and effects analysis (FMEA) is a systematic process to evaluate failure modes and causes associated with the design and manufacturing processes of a new product. It is somewhat similar to the potential problem analysis (PPA) phase of the Kepner-Tregoe program.



2 **Walt Custer Elaborates on his Annual IPC APEX EXPO Forecast Presentation**

IPC APEX EXPO 2016 has come and gone, and this year, Walt Custer's annual presentation forecasting the upcoming year for the industry was much anticipated, as always. I met up with Walt at the show to learn about his presentation and dig deeper into his findings.



3 **IPC President John Mitchell on the Past, Present, and Future, Part 1**

We conducted this interview with IPC President John Mitchell on the show floor at IPC APEX EXPO to discuss the event, the changes on the IPC board, and the key metrics that IPC uses to measure their own performance and effectiveness. John also invites the industry to a unique challenge.



4 **American Standard Appoints Dave Olson Vice President of Operations**

Anaya Vardya, CEO of American Standard Circuits, announced the appointment of industry veteran Dave Olson to the position of Vice President of Operations.



5 **Weiner's World: March 2016**

Sellers of equipment at the Shanghai CPCA event complained of continued poor business. This was especially evident amongst those selling to firms building boards for phones and other portable devices as indicated below. However, not all reports were bad. Major fabricators such as Wu's in China, not dependent upon HDI or flexible products, stated that they were "satisfied" with their current business levels.



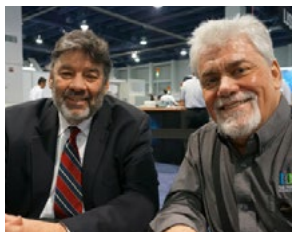
6 **Green Legislation and the Impact on Electronic Materials and Processes**

In general, "green" and "environmentally friendly" refer to manufacturing that involves the replacement of toxic substances with less toxic materials, the elimination of materials or processing steps, less consumption of chemicals (i.e., more efficient or higher yield processing), reduction of water use, reduction of energy use...



7 **Williams and Beaulieu: Board Shops and CMs Must Communicate Better**

Two well-known consultants in the PCB industry, Dan Beaulieu and Steve Williams, have joined forces to try to help close the divide between CMs and board shops. I



recently sat down with them at IPC APEX EXPO 2016 to better learn about their strategy for bringing the two sides together.

8 **IPC President John Mitchell on the Past, Present, and Future, Part 2**

In Part 2 of our on-the-show-floor interview with John Mitchell, conducted at IPC APEX EXPO 2016, John continues describing IPC's key measures, and then invites industry folks who are reading this to participate in a unique challenge—some might say experiment. The question is, will there be any takers?



9 **Rep. Mike Honda Visits Bay Area Circuits' California Facility**

"I am grateful to Bay Area Circuits for hosting me today," said Congressman Honda. "It's great to hear from the employees that have played a vital role in the company's success. It's a reminder of the contributions they make to this country's and California's economy."

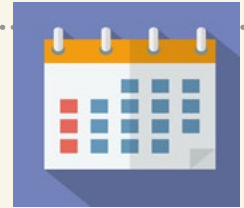


10 **The Sum of All Parts: Total Concept—Growing for the Future**

Last month, we discussed the importance of the PCB industry's need to focus on a "made in USA" philosophy. This month, we will go over how to methodically do this amid different company cultures and different logistical challenges.



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I-Connect007 Presents



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