I-Connect007 Presents

February 2017

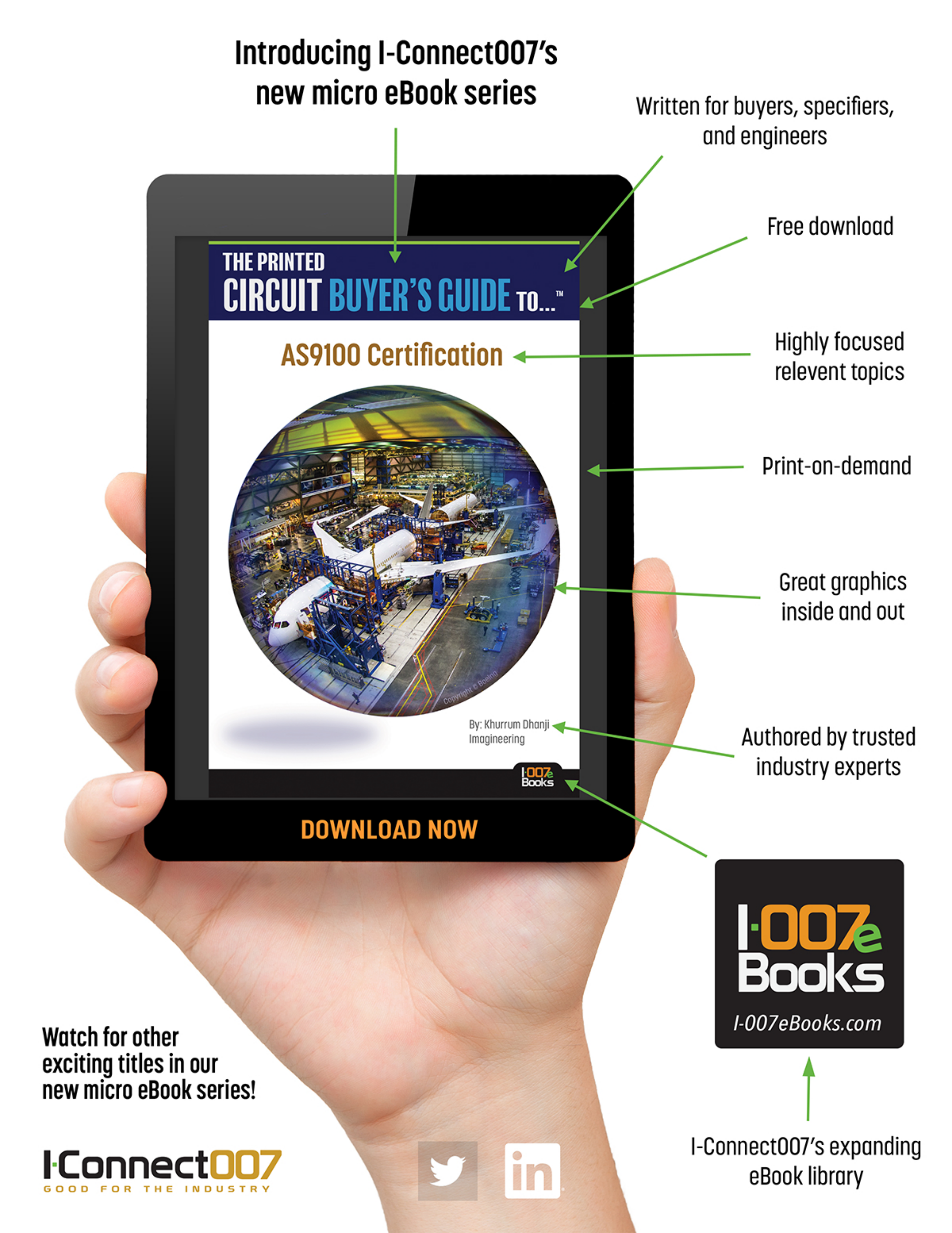
the pcb magazine

12 **Emerging Technology, Training for the Future, and the Next Industrial Revolution**

16 **Vertical Conductive Structures—a New Dimension in High-Density Printed Circuit Interconnect**

Much More!


Get the spark you need to tune up your sales team.
When an engine doesn't fire on all cylinders, performance is limited. The same goes for your sales team. We provide the spark to get your sales to the next level ...and beyond.
We've helped dozens of companies big and small improve their bottom line.
db MANAGEMENT GROUP
Learn how we can help YOU
207-649-0879
danbbeaulie@aol.com

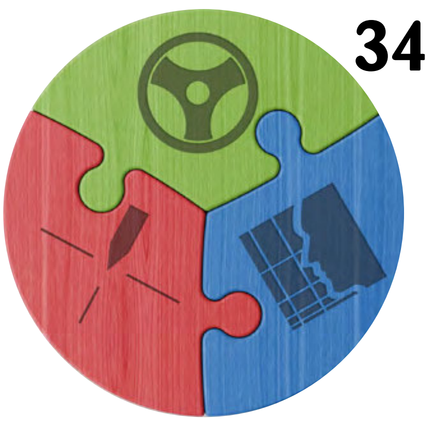

Introducing I-Connect007's
new micro eBook series
Written for buyers, specifiers, and engineers
Free download
Highly focused relevent topics
Print-on-demand
Great graphics inside and out
Authored by trusted industry experts
THE PRINTED CIRCUIT BUYER'S GUIDE TO...™
AS9100 Certification
By: Khurrum Dhanji
Imagineering
I-007e Books
DOWNLOAD NOW
I-007e Books
I-007eBooks.com
I-Connect007's expanding eBook library
Watch for other exciting titles in our new micro eBook series!
I-Connect007
GOOD FOR THE INDUSTRY

I-Connect007 Presents

the pcb magazine

February 2017

Featured Content

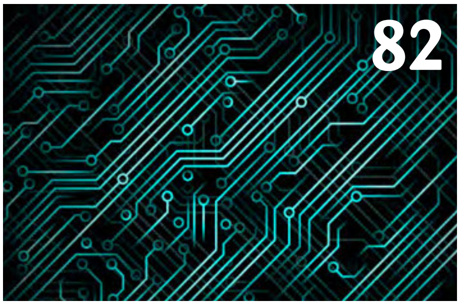


New Technologies

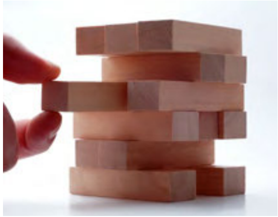
As technology moves increasingly faster, so do our equipment, materials and chemistry suppliers to help us to enable that next greatest invention. Are you ready for the next thing, to keep pushing forward? This month, our contributors shed a little light on that path forward. Meet the future!

I-Connect007 Presents
the pcb magazine

February 2017
Vol. 7, No. 2
thepcbmagazine.com


More Content



185HR

High-Tg, Low-CTE Materials with High Thermal Reliability

FEATURES

- High Thermal Performance
  - Tg: 180°C (DSC) (Base Laminate)
  - Td: 340°C (TGA @ 5% wt loss)
  - Low CTE for reliability
- T260: 60 minutes
- T288: >15 minutes
- Lead-free Compatible and RoHS Compliant
- UV Blocking and AOI Fluorescence
  - High throughput and accuracy during PCB fabrication and assembly
- Superior Processing
  - Closest to conventional FR-4 processing
- Industry Approvals
  - IPC-4101D-WAM1 /98 /99/ 101 /126
  - UL – File Number E41625
  - Qualified to UL's MCIL Program
- Core Material Standard Availability
  - Thickness: 0.002″ (0.05 mm) to 0.060″/0.062″ (1.5 mm)
  - Available in full size sheet or panel form
- Prepreg Standard Availability
  - Roll or panel form
  - Tooling of prepreg panels available
- Copper Foil Type Availability
  - Standard HTE Grade 3
  - RTF (Reverse Treat Foil)
- Copper Weights
  - ½, 1 and 2 oz (18, 35 and 70 µm) available
  - Heavier copper available upon request
  - Thinner copper foil available upon request
- Glass Fabric Availability
  - Standard E-glass
  - Square weave glass fabric available

KEY APPLICATIONS

- Heavy copper, 6 & 12 oz automotive applications
- Military
- Medical
- Industrial

ORDERING INFORMATION:

Contact your local sales representative or visit **www.isola-group.com** for further information.

Isola Group
3100 West Ray Road
Suite 301
Chandler, AZ 85226
Phone: 480-893-6527
info@isola-group.com

Isola Asia Pacific (Hong Kong) Ltd.
Unit 3512 - 3522, 35/F
No. 1 Hung To Road, Kwun Tong,
Kowloon, Hong Kong
Phone: 852-2418-1318
info.hkg@isola-group.com

Isola GmbH
Isola Strasse 2
D-52348 Düren, Germany
Phone: 49-2421-8080
info-dur@isola-group.com

isola

New Technology Heading our Way–Faster than Ever!

by Patty Goldman
I-CONNECT007

Way back when, in the early 1980s, I worked for a small PCB manufacturer in Danbury, Connecticut. We all loved new stuff, as in nobody wanted to make normal PCBs—just crazy impossible stuff. We did full panel soft gold (for wire bonding); we made about 90% of the first circuits (all gold-plated) that went in the early digital watches (for TI and Timex); we worked with Ohmega material and embedded resistors; we were making 5-mil line/space innerlayers in volume for IBM and even prototyped a 2-mil line/space multilayer (this was more than 30 years ago, mind you); we made the first (or darn close to the first) polyimide gold-plated chip-on-board multilayers to which something like 42 chips were gold wire-bonded (HP). Talk about new technology—we were deep into it!

And now, have we seen or done it all? Not even close! As technology moves faster and faster, so do our equipment, materials and chemistry suppliers to help us to enable that next greatest invention. We are all at the forefront of IoT, the fifth industrial revolution, autonomous and connected—everything, all those things that were unimaginable even 10 years ago. It's hard work, there is no sitting back or relaxing, and those looking for an easy 9-to-5 job, forget about it. Are you ready for the next thing, to keep pushing forward?

As an excellent introduction to this issue, IPC's John Mitchell gives us a wonderful overview of what emerging technology is and what we need to do to keep up. One thing he emphasizes is a trained and competitive workforce. Indeed, in our recent hiring survey we learned that an overwhelming percentage of you are concerned about a shortage of skilled and qualified people. John's column is a great call to action.

Next, we have a very intriguing interview with Joan Tourné of NextGIn Technology BV, conducted by I-Connect007's Pete Starkey. Joan talks about a new interconnect technology he calls "vertical conductive structures" or VeCS.

With VeCS one can achieve much higher interconnect density using existing equipment and processes. He talks of cost reductions associated with reduced material usage and provides an interesting illustration of this novel technique.

Apparently one of the most significant new technologies these days is jet printing solder mask. You may say, "Inkjet? Not new. Soldermask? Not new." But put them together and the challenges are huge and the technology is right on the cutting edge. As such, we bring you several articles and interviews on this very subject.

Henk Goossens of Meyer Burger BV in The Netherlands provides a wonderful introduction to the thorny subject of direct digital inkjetting of soldermask. Removing steps like artwork generation, developing, and waste treatment, and reducing materials and process time, all equals to cost savings...of course we want to inkjet. Henk gives us a great view of the subject from the equipment perspective.

We have two interviews conducted by Publisher Barry Matties that explore the material/equipment partnership between Taiyo and Schmoll to develop an inkjet soldermask that is compatible with the inkjet machine. Dick Crowe of Burkle (U.S. distributor for Schmoll) contributed an excellent introduction. The first interview is with Taiyo's John Fix, with Walt Custer of Custer Consulting, contributing. The second is an interview with Schmoll's Thomas Kunz, who discusses not just the partnership but the technology, working with OEMs, and more.

Barry Matties and Pete Starkey bring us an interview with Agfa's Frank Louwet, who explains Agfa's partnerhsip with Electro Polymers to develop a nanoparticle ink. One can learn a great deal about the soldermask inks and the inkjet process from these interviews.

EIPC's Alun Morgan gives us a great report on their recent workshop on PCB BioMEMS—aka PCB-on-a-chip. With a CAGR of greater than 25%, BioMEMS devices are a definite market of interest. This detailed article provides a wealth of information on the subject and certainly should be required reading for anyone involved in PCB fabrication.

Steve Williams of Right Approach Consulting takes us far away from soldermask to a look at the new Trump administration and what its promises may mean to our industry and business in general. He even includes a "Top Ten" on deregulation. Read on!

Back to some technical content with Michael Carano, of RBP Chemical Technology, as he delves into the metallizing difficult-to-plate substrates, in this case with electroless copper. Mike always includes some troubleshooting info as well as much practical advice in his columns.

Next, NTI's Keith Sellers discusses various test methods to ensure that your incoming (or outgoing) PCBs perform as intended and that you "get what you pay for." He proceeds from the basic incoming inspection through more in-depth analysis involving cross-sections, thermal stress testing and more, including some additional ones to determine basic laminate properties and suitability for the job at hand.

And finally, in his usual inimitable fashion is Barry Lee Cohen of Launch Communications. Each month Barry provides another piece to the marketing communications puzzle. This time his subject is e-newsletters and always worth a read, not to mention a commitment to follow-through.

And so you have it—our line-up for February. Lots of good new tech stuff to keep the wheels turning upstairs, plus some immediate things you can put into practice today or tomorrow at the latest. Next month our subject is "The Wide World of Flex." Do tune in and read about all things flex—from the various types to the materials to the processing of same. We promise another issue of cover-to-cover value. If you haven't yet subscribed, do so right now and be one of the first to get it in your e-mailbox. **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.

Emerging Technology, Training for the Future, and the Next Industrial Revolution

by John Mitchell
IPC—ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

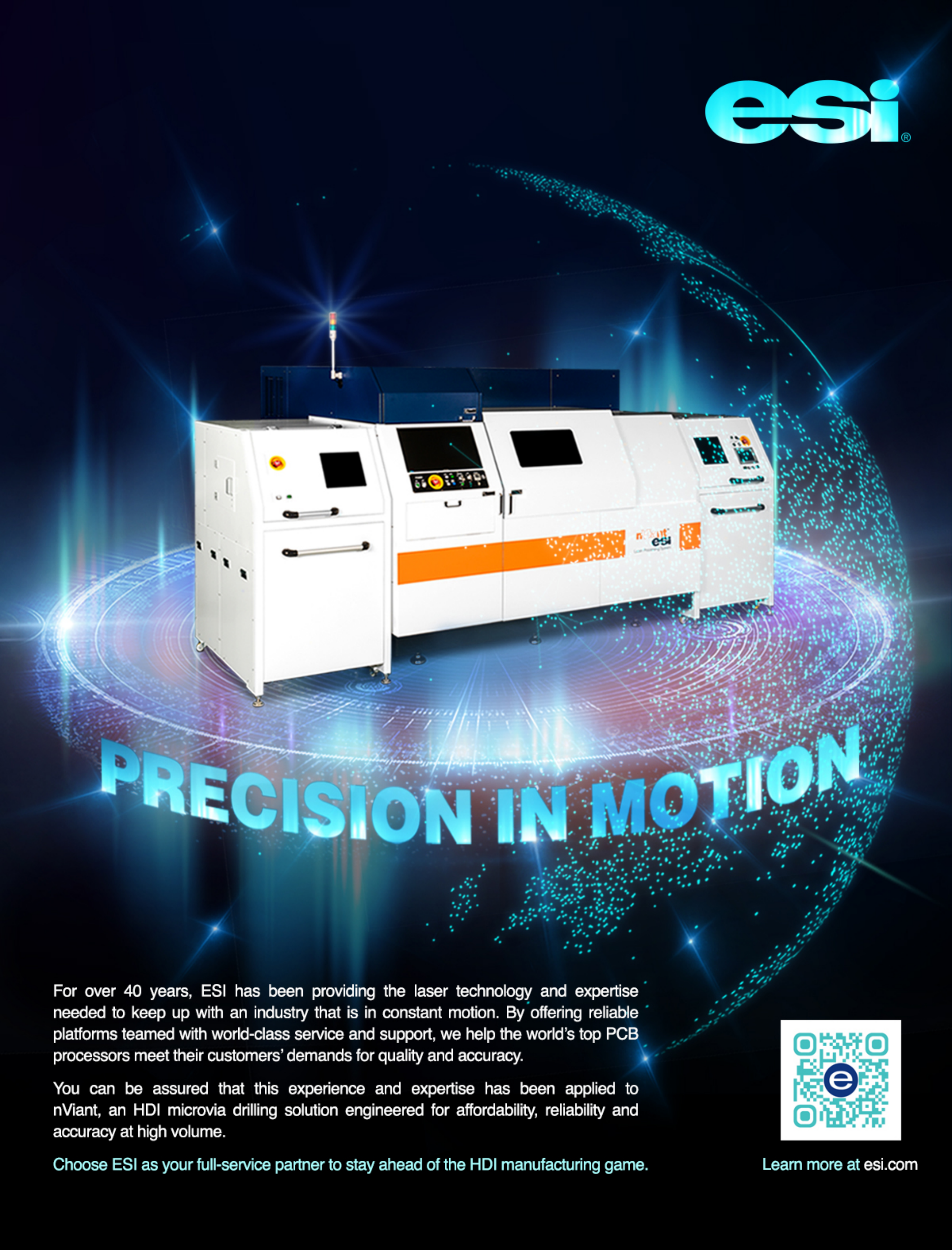
Technology isn't just a tangible entity. It moves beyond what we can see, feel, and touch. It is ideas and theories. It includes philosophy and risks. In a way, technology itself is like the stock market. Different industries hedge their bets on emerging trends. These trends develop into useful products that change our world. It isn't just enough to simply guess where a new technology may fit, or how emerging technologies will advance the industry. You must understand how the ebbs and flows will impact your business, and how new technologies will leverage against existing systems.

So, to be successful, we need to do our best to first spot trends in the industry, and understand how these trends point to a paradigm shift in the way we operate. You see, every few years, technology finds a way to revolutionize the entire manufacturing process. Dating back to the first Industrial Revolution, when manufacturing started to move from hand production to steam power, there was a great shift in how manufacturing impacted the economy. From there, the utilization of electric power to create mass production, and then the usage of electronics to automate has opened the door for where we are today.

We are on the doorstep of the fourth great revolution in manufacturing, which has put an emphasis on connecting the factory, the workforce, and the end-user. It is this connected factory and the Industrial Internet of Things (IIOT) that has created never-before-seen opportunities to include new technologies ranging from robotics to 3D printing.

But as technologies continue to advance so quickly, some may find it difficult to anticipate what comes next. Just because there are new technologies doesn't mean you should be complacent with new improvements. Even the best-connected factory today will experience shifts in production down the road. Adjusting is more than a single upgrade. It is creating a dynamic environment that can adapt to fluctuations today, while adjusting to include emerging technologies tomorrow.

And one of the best ways to ensure that we are adaptable to all coming technologies is to


esi®
PRECISION IN MOTION
For over 40 years, ESI has been providing the laser technology and expertise needed to keep up with an industry that is in constant motion. By offering reliable platforms teamed with world-class service and support, we help the world's top PCB processors meet their customers' demands for quality and accuracy.
You can be assured that this experience and expertise has been applied to nViant, an HDI microvia drilling solution engineered for affordability, reliability and accuracy at high volume.
Choose ESI as your full-service partner to stay ahead of the HDI manufacturing game.
Learn more at esi.com

make sure our workforce is competitive. As during previous Industrial Revolutions, the economy is expected to grow. This indicates a growth in jobs as well. But to truly grow, manufacturers need to reinvest not only in innovation, but in employees. Now is the time to focus on training employees on new technologies. A report on advanced manufacturing[1] released in 2016 by the Subcommittee for Advanced Manufacturing of the National Science and Technology Council stated that, "Over the next decade, we will need to fill nearly 3.5 million manufacturing jobs, although two million of these positions may remain unfilled due to a skills gap. In fact, at this moment, 80% of manufacturers currently report a moderate or serious shortage of qualified applicants for skilled and highly-skilled production positions."

Much like when Henry Ford rolled out the assembly line, there is a push for workers to further hone and specialize their skills. The result of this is reduced waste, and a higher quality end-product. Investing in new technologies may require funds up front, but this is worth it when you consider the reduction in assembly time and the increase in production rate. So, it isn't enough to simply adopt these technologies, but rather adopt a shift that includes training and preparing a workforce that can handle current technologies and be adaptable to adjust to whatever may come down the road.

In the end, the technology we have today comes as the result of hardworking individuals. Sure, Ford made great strides to advance the way factories produced goods in 1914. But he also put an emphasis on his employees, ensuring they knew how to operate the machines that would change the world. Thus, he produced quality automobiles and revolutionized the American class of blue collar workers.

While the digitization of our factories is a great example of improving production while decreasing waste, there needs to be a focus on ensuring the employees can operate machines across the entire connected factory floor and train others to do the same. Much like IPC's Connected Factory Initiative states, it is important to establish a baseline of communication to achieve Industry 4.0 benefits. For "plug and play interoperability" of devices to succeed, employees need to be able to understand and utilize the technology.

Until the fifth Industrial Revolution comes, we will need to innovate our processes and uncover new ways to make today's systems work better. Manufacturing will continue to grow in the United States and across the globe, but it will require a concerted effort to learn, adapt, integrate, and evolve. **PCB**

References

1. Advanced Manufacturing: A Snapshot of Priority Technology Areas

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

Global Printed Electronics Market to Reach $65B by 2024

Key players in the global printed electronics market have been vying to retain leadership with new product development, implementation of newer technologies, and product innovation. Transparency Market Research observes that some of the leading players in the global market are Samsung Electronics Co., Ltd., Xerox Corporation, Thin Film Electronics ASA, Optomec Inc., and Intrinsiq Materials Inc. These companies are also expected to focus on mergers and acquisitions and strategic business alliances to remain relevant.

According to a recent research report, the global printed electronics market was worth $25.4 billion in 2015. For more information click here.

Vertical Conductive Structures—a New Dimension in High-Density Printed Circuit Interconnect

by Pete Starkey
I-CONNECT007

From our previous conversations, I knew that Joan Tourné was working on a novel high-density interconnection concept. Having eagerly awaited the chance to discuss the technology in detail, I was delighted when he contacted me to confirm that his IP had been secured and that he could now talk openly about VeCS, the Vertical Conductive Structure designed to provide a cost-effective alternative for complex fan-out from fine-pitch grid array components.

Knowing Tourné's long-term background in high-end PCB technology, from his many years as technical director at Mommers Print Service in the Netherlands, and subsequently as advanced technology and business director with Viasystems, I was curious to learn about his latest enterprise.

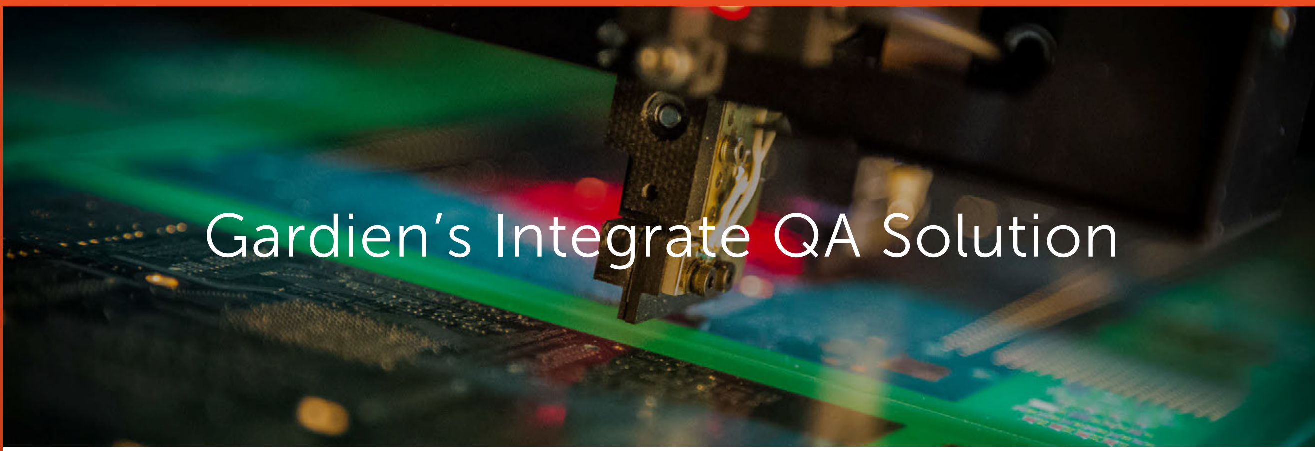
Starkey: Joan, it's great to speak with you again. Tell me a little about NextGIn Technology BV.

Tourné: Yes, Pete, good to see you. NextGIn is a fabless shop based in the Netherlands, with extensive experience in the design and manufacture of high-end circuitry and a "make it happen" mentality. We are developing interconnect solutions for our partners in the semiconductor packaging and printed circuit board industries who need to advance their product performance or to cost-reduce their product. Presently we are working with a small group of selected OEMs in datacom, telecom and data processing markets to design and test our VeCS technology.

Starkey: What was the rationale behind the development of VeCS and what is the need for an alternative PCB concept?

Tourné: The big limitation of established HDI technologies is the density of vertical interconnections that can be achieved without going through many stages of sequential build-up. Grid array packages are driving PCB complexity, and PCB manufacturing technology is lagging. Through-hole techniques take up too much space, and we have got to the stage where holes cannot be placed closer together. Sequential build-ups are an expensive solution, and as the build-up construction gets more complex, the yield goes down. The challenge of routing

Gardien



Gardien's Integrate QA Solution

WHAT IS INTEGRATE?

Integrate is a new approach to bare board PCB quality assurance. We address and are responsible for 100% of your tail end QA needs, whether it's AOI, testing, final inspection, or a combination of all three. We can provide the service in one of our service centers or fully integrate within your facility.

WHAT MAKES IT DIFFERENT?

Partnership pricing. Payment is based on product that actually passes quality assurance, not on panels produced or tested. Our success is built entirely on how successful we can help you become.

3900 jobs tooled per month

18100 orders processed per month

24,500,000 boards processed per month

Find out if our Integrate solution is right for you!

www.gardien.com/why-integrate

conductors under fine-pitch grid arrays becomes increasingly difficult and is effectively a constraint on package development. And power distribution into the core of the package becomes difficult and expensive.

Joan Tourné

***Starkey:** So how does your "vertical conductive structures" concept overcome these limitations?*

Tourné: Not only can we achieve higher interconnection density by packing more vertical connections in a smaller space, at the same time we can increase conductor routing channel density under grid array components. And we can do this without reducing line widths or spacings, so we can maintain high transmission line speed and enhance signal integrity by better signal-to-plane reference and higher current-carrying capacity in and out of the grid array. And because we don't need to use sequential build-up technology, we reduce cost.

***Starkey:** That sounds very impressive. What are the key characteristics?*

Tourné: VeCS is based on special formed cavities that can connect to multiple internal layers using less space than vias or microvias, leaving more room for conductor routing under area array components like BGAs. For example, a 0.65 mm pitch BGA can be successfully routed with VeCS, whereas a fan-out would not be possible with traditional vias. And VeCS causes much less disruption to ground and power planes and reference layers, which with traditional via technology would be reduced to a few small slivers of copper under the BGA. At the moment, we have test vehicles in manufacturing with a 0.4 mm pitch using single lamination processes.

***Starkey:** From the PCB fabricator's point of view, does VeCS technology require substantial capital investment or significantly different process chemistry?*

Tourné: No, to both parts of the question. No direct new capital equipment is required, and the technology is well within the established capability of any high-end board shop after appropriate training and licensing.

***Starkey:** So how do you form these cavities?*

Tourné: There are several options, but let me describe a very basic example: Drill a row of holes, in the diameter range 0.1 mm to 0.5 mm, close together and separated by narrow webs of material. Remove these webs of material by drilling, routing or laser cutting, preferably on the same machine to achieve best registration. Once the structure has been formed, use standard PCB processes to clean, metallise and plate-up, then image and etch the surface conductor pattern. Finally, selectively remove copper from the plated cavity by drilling, to leave vertical copper traces where conductors are required. Perhaps a schematic diagram would help you to visualise the result (Figure 1).

***Starkey:** So how does this compare with conventional through-hole interconnection?*

Tourné: The hole is replaced by a vertical trace or half-cylinder. The vertical trace is preferred for signal integrity performance. The structure can be filled and overplated depending on the application. More vertical connections can be created for a given surface area and, for imped-

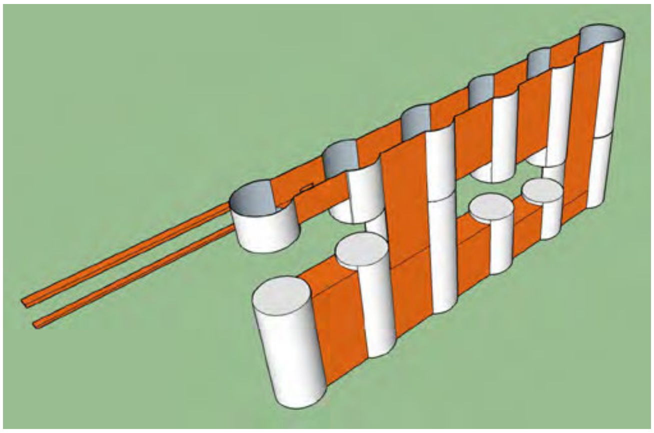


Figure 1: Schematic diagram of VeCS.

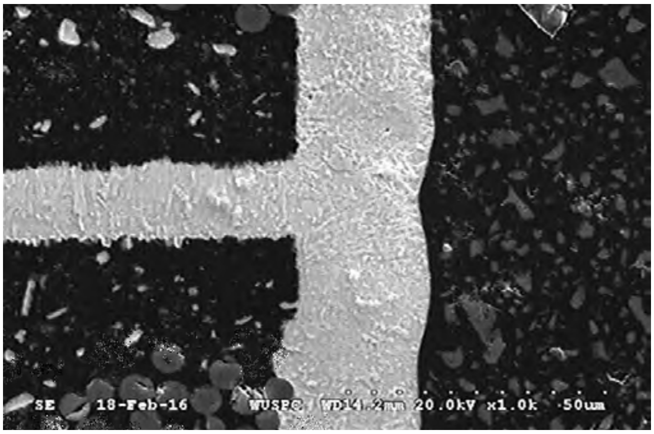


Figure 2: Cross-section of the interconnect with the innerlayer.

ance control, signal and ground conductors can be designed to face each other across the cavity. Another benefit is that there is no CAF path between vertical traces.

Starkey:** **You mentioned cost savings. How do costs compare with conventional constructions and where are the savings made?

Tourné: The cost reduction is realised by making more efficient use of the conductor routing space and therefore reducing the layer count of the board. We offer design analysis service to demonstrate how VeCS can reduce cost in your product. With the use of more expensive materials, the reduction in the BOM cost is becoming significant. In various analyses conducted last year, we have demonstrated cost reductions in the range of 15% to 40%. In future articles, we can present cases of the cost reduction analysis.

***Starkey:** How far down the road are you with VeCS technology?*

Tourné: We've progressed a long way since demonstrating the initial proof of concept, and we continue to work closely with leading OEMs and fabricators. One manufacturing example is a 12-layer test board, 2.2 mm thick, on MEGTRON6, with 0.5 mm, 0.75 mm, 0.8 mm and 1.0 mm BGAs routed on the same panel. We have subjected samples of this construction to six reflow cycles at 288°C, and found no evidence of interconnection failure. Results after six solder shocks at 288°C were similar (Figure 2). And we have taken daisy-chain test panels through multiple reflow cycles followed by thermal cycling to failure, with results comparable with through-hole examples. Regarding impedance control and signal integrity, I can show you some remarkably good TDR traces from the area under the BGA.

***Starkey:** What about design? Do any of the major CAD vendors offer the capability to generate designs based on VeCS technology?*

Tourné: At the moment, we have two CAD software houses working on the technology and they have demonstrated capability already.

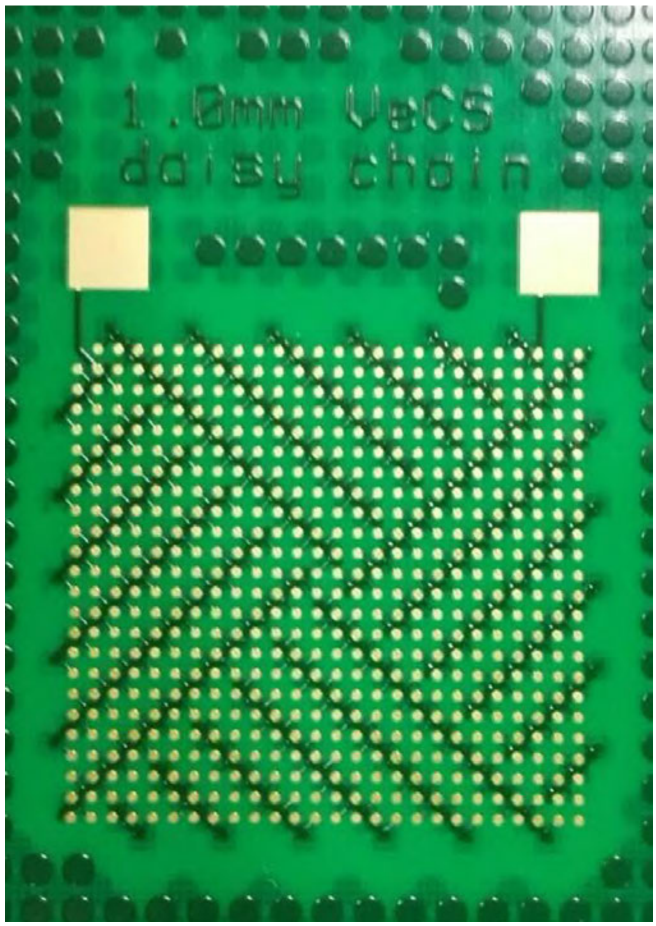


Figure 3: Board with daisy chain on 1.0 mm pitch using VeCS technology used for reliability testing of the interconnects. The fabrication and testing is done by WUS.

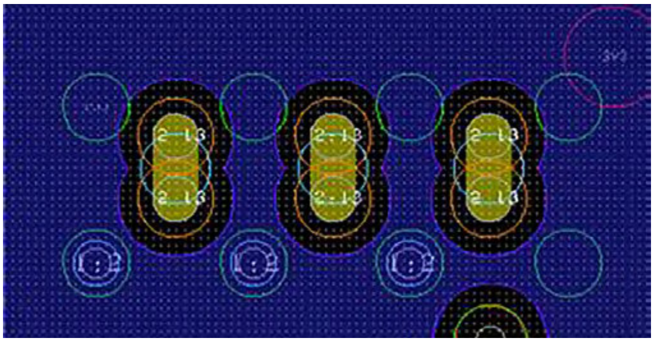


Figure 4: VeCS technology in Altium design system.

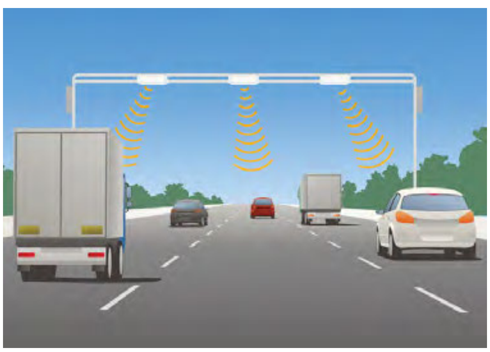
They have seen the advantage of the technology and continue exploring VeCS technology. We have also developed workarounds in some of the CAD systems, as shown in Figure 4. There is still some manual work, but we can demonstrate the technology and gain advantage of the VeCS benefits. We can also train and qualify your preferred PCB suppliers, and offer training to the OEM under a license agreement.

Starkey: Joan, I am very grateful for your time in introducing me to what I could confidently describe as a potentially disruptive PCB technology.

Tourné: Thanks for your interest, Pete. But I have only given you a glimpse of what this technology has to offer. I hope you have gained an understanding of the fundamental principles of what we can achieve. There is so much more I could explain about practical aspects, application opportunities and the VeCS technology roadmap. I would be delighted to prepare a series of detailed articles if you believe they would appeal to the designers and fabricators among your readers.

Starkey: That's a splendid offer, Joan, and well worth pursuing. Many thanks, again. PCB

Telematics to Shape Cockpit and Cabin Strategies



One in four passenger vehicles sold by 2025 is poised to feature digital instrument clusters, dedicated passenger infotainment systems, and integrated biometrics with bought-in device functionality. Original equipment manufacturers (OEMs) are grappling to design components that are in line with fast-changing technology trends and customer expectations.

"The luxury segment car of the future will have augmented reality HUD, OLED displays, interactive cabin doors and windows, advanced biometrics, and ample infotainment for passengers," said Frost & Sullivan Intelligent Mobility Research Analyst Joe Praveen Vijayakumar. "The mass-market car segment cockpit will have temperature-controlled seats, Combiner HUD, TFT LCD displays and substantial biometrics features for vehicle security, Driver Monitoring and Health Wellness and Wellbeing (HWW)."

Cockpit and Cabin Strategies of Automakers, 2016–2025 is part of Frost & Sullivan's Mobility: Automotive & Transportation Growth Partnership Service program. According to the research, advancements in technology will influence every component of the cockpit, ushering in an era of new travel experience, dedicated instrument clusters and infotainment screens.

Leading players have adopted various strategies to gain market share and competitive advantage, including a light-diffusing fiber, which is an alternative to separately weaving light-emitting diode into interior fabrics for ambient lighting, developed by Corning; a solar-powered, organic, light-emitting-diode-fitted transparent car roof in partnership with BASF, in development by Philips.

"Biometrics will be an integral part of cockpits and cabins of the future, and OEMs and suppliers should pursue partnerships with innovative biometric companies or fund relevant nascent startups," noted Praveen.

FEATURE

INDUSTRY 4.0—Inkjet Technology is Changing the World of PCB Manufacturing

by Wouter Brok, Klaus Ruhmer and Henk Goossens
MEYER BURGER (NETHERLANDS) B.V.

Introduction

When the Germans coined the term Industry 4.0 back in 2011, it wasn't clear to many what it actually stood for. Although the debate about all the nuances of the term's meaning is still ongoing, one aspect of it is undisputed: The "computerization of manufacturing" is at the heart of it. Manufacturing techniques throughout many industries continue to become more and more digital. This is also true for PCB manufacturing. Several manufacturing steps offer incredible potential for digitalization. One prime example is the application of solder mask material using industrial inkjet technology.

Solder Mask Printing

The current manufacturing standard for solder mask application involves several process steps which have a significant cost impact:

1. Pre-treatment of the PCB
2. Full board coating (e.g., curtain coating)
3. Artwork film production (photomask)
4. UV exposure
5. Development
6. Post cure

Figure 1: The process flow that is traditionally followed in PCB solder mask application.

Figure 2: The process flow when using a digital inkjet printer to directly apply the patterned solder mask.

Utilizing state of the art digital inkjet printing for the application of solder mask on PCB boards, the number of process steps can be reduced:

1. Pre-treatment of the PCB
2. Digital inkjet printing including in-situ UV curing
3. Post cure

The benefits of this simplified manufacturing process are obvious. Besides the reduction in required capital equipment and associated labor, the digital process also significantly reduces the use of process chemicals and therefore also the related handling and disposal cost. Overall, the environmental benefits are enormous. Last but not least is the reduction in manufacturing turn-around time—an important asset in today's fast moving electronics business.

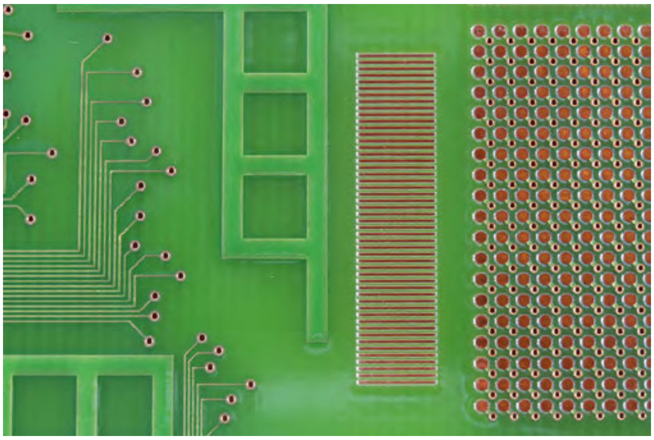


Figure 3: Example of a board with inkjet printed solder mask layer.

Unique Characteristics of Inkjet

Inkjet technology is widely used in homes and offices all over the world for traditional printing applications. Although the fundamental concept of modern industrial inkjet applications is comparable to those printers, there are significant differences. Industrial use of inkjet technology is characterized to a large degree by the type of materials which are deposited. Instead of traditional ink, materials such as resists, adhesives, conductive inks, polymers and their likes are deposited.

Inkjet is a selective coating technology. This means that material is only deposited where it is needed. In the case of solder mask printing, this not only reduces material consumption, but also avoids solder mask material in via holes and other areas where it is difficult to remove or simply not desired. Flushing uncured solder mask material from high aspect ratio holes in the development step is a known challenge in the PCB industry and is completely avoided by inkjet printing.

The use of inkjet technology to directly pattern solder mask material renders the use of a photo-lithography patterning process unnecessary. Hence, post exposure development becomes obsolete as well—a great benefit as the risk of removing small solder dams between IC contacts during this step is completely eliminated.

Another unique characteristic of inkjet is its flexibility. Not only can it cope with different surfaces, but it also enables the creation of different surface finishes. In addition, different layer thicknesses can be accomplished and even different materials can be deposited.

The digital nature of inkjet technology also offers critical benefits in regards to pattern alignment and scaling: The digital print image can not only be accurately aligned to the underlying pattern, it can also be scaled as needed. Especially in tough manufacturing conditions with varying process requirements, this flexibility is critical for cost efficient production.

Cost Benefit of Inkjet

As always, in challenging manufacturing industries "cost is king." Based on data from PCB manufacturing operations, we can explore the actual cost savings associated with direct printing of solder mask material.

When comparing the traditional photolithography process as described above, it becomes apparent that inkjet has a large impact on a number of cost factors. First of all, the cost of capital equipment is an obvious contributor. Secondly, the cost of the traditional processing sequence includes more consumable materials including photomasks and the additional chemicals required for the photo process including their disposal cost. The cost of water consumption, waste water treatment and containment of solvents are significant in most operations. Less obvious cost factors are labor cost and floor space. Besides the cost savings potential, this offers the opportunity to increase output with the same labor force and factory space. The negative environmental impact of the traditional process is difficult to quantify and therefore not being considered as a direct cost factor. Nevertheless, the need for large scale photo litho operations can have a significant impact on permitting of new factory space or expansions, just to give one example. Eliminating the above-mentioned cost adders further enhances the cost picture of inkjet printing.

Equipment Requirements for Solder Mask Printing

Inkjet printing of legend ink has already been widely accepted; the PCB industry has familiarized itself with digital manufacturing and acknowledged its merits. However, a production-worthy inkjet equipment solution for PCB solder mask printing has some very specific requirements that significantly differ from a legend printer. This includes high precision and fast moving motion stage, high-precision vision system, and raster image processing, to name a few. In a production system all these elements need to combine in such a way that they maximize quality and productivity and minimize cost. Figure 4 shows the different relevant components of a solder mask printer.

Designs for manufacturing are usually generated via a CAD program that stores its designs in one of the various vector file formats, typically in Gerber RS-274x format. Vector files represent designs in terms of coordinates, lines, arcs and other elements that can easily be manipulated by operations such as translation, rotation and

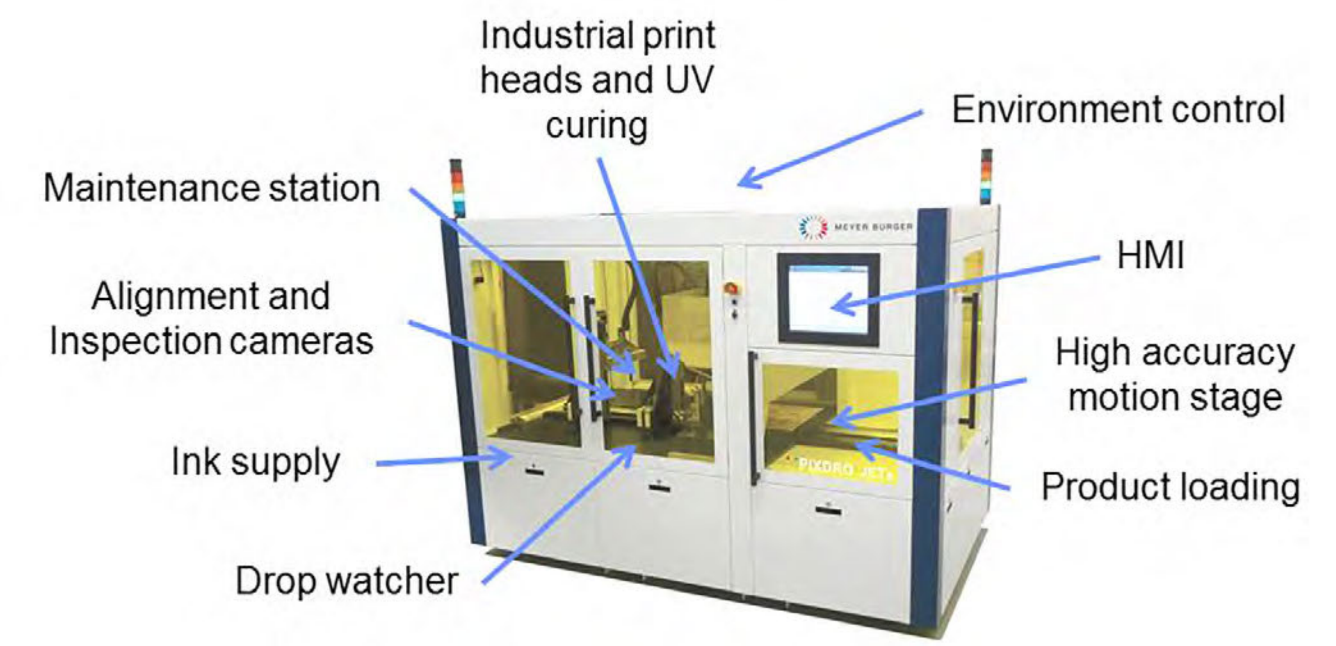


Figure 4: Meyer Burger JETx solder mask PCB production system with various components indicated.

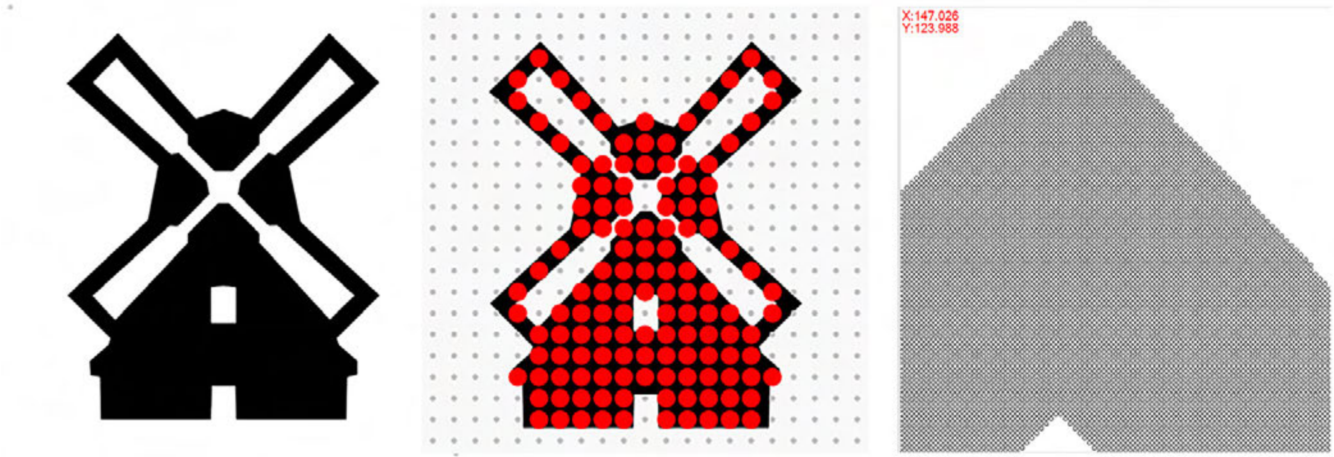


Figure 5: (Left): artwork in a vector file format. (Middle): simplified representation of enabling pixels on a raster. (Right): detail of image rasterized at a realistic grid.

scaling. However, a digital inkjet printer prints droplets on a rectangular grid, represented by a raster type file format such as BMP, TIFF, PNG, JPG, etc. When preparing a recipe for the inkjet printer, a conversion needs to take place from vector to raster file format. This conversion is done by a piece of software called raster image processor (RIP).

The raster image processor receives a vector file as its input, as well as various conversion parameters such as the resolution at which the file needs to be rasterized. Figure 5 illustrates this process: the artwork represented by a vector image is shown in the left panel. In the right panel a raster is overlaid on the design. A pixel is enabled at each location where a raster point coincides with the design.

The resolution used for this illustration is very low. In practice the design will be rasterized on a much denser grid, as shown in the right panel of Figure 5. The resolution of this grid is bound between values determined by the minimal resolution needed for droplets to overlap sufficiently to form closed layers and by a desire to print thin layers of material. Typically, the resolution will be in the order of 1000 dpi and upwards.

In practice, the RIP engine will perform a much more advanced operation than illustrated above. For example, it can account for the flow of inkjet droplets on the surface and compensate in advance for that. Or, it can account for the fact that the periphery of features in the design need to be reproduced well, but that inside regions just need to be covered and might require a lower resolution.

More advanced features can be included such as individual product alignment based on fiducials on the PCB to compensate for stretched or warped boards due to temperature differences, something which is not available when using phototools.

Once the artwork is ready and the substrate has been prepared, it can be loaded into the printer. Automated product handling is an option and recommended for volume PCB manufacturing operations. The board is positioned onto a substrate table and clamped by means of vacuum. The position of the substrate is automatically determined for pattern alignment purposes, after which printing can commence.

The printing process in its essence involves scanning a substrate and a print head with respect to one another. Essentially, the substrate passes underneath the print head(s) in several passes. During each pass a swathe of the image corresponding to the width of the print head(s) will be printed. Depending on the recipe, one pass might complete that swathe of image, or it passes over it more than once in order to build up the required layer.

The print head is a critical part of the overall process. Several different types, brands and models are available and well-suited for solder

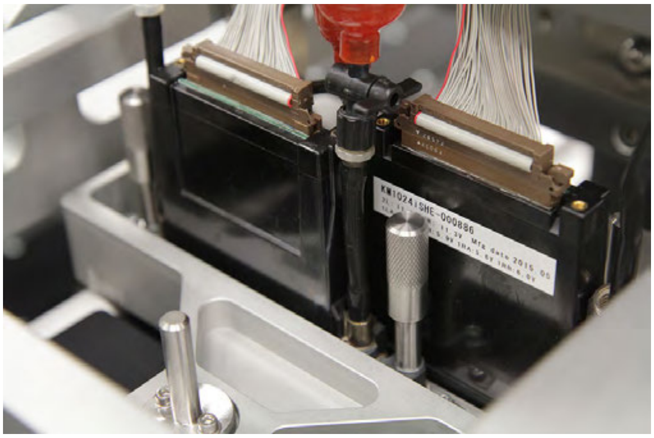


Figure 6: Example of a print head array containing over 2,000 individually addressable nozzles.

mask printing. Most production printers operate with an array of print heads for increased productivity. Different heads have different drop size, straightness, drop speed and jetting frequency specifications. Therefore selection of the most suitable print head which offers the desired resolution, reliability and print quality is very important.

Precise alignment of the PCB to the substrate stage is a must in order to achieve overall high accuracy of the solder mask. The inkjet printer is therefore equipped with a substrate facing camera. It can locate features on the substrate, such as alignment holes or pre-applied fiducial marks and determine precisely the location and orientation of the substrate. An example of such a camera setup is shown in Figure 7. A camera registration of less than 2 µm has been demonstrated when high precision fiducials are used.

Additionally a very accurate motion platform is needed for precise solder mask application. A well calibrated granite-based motion platform with linear motors can reduce motion errors down to 1 micron. At the same time, such a stage can support printing speeds up to 1 m/s. The combination of a fast moving stage with a wide head array containing a few thousand parallel nozzles, yields a very high throughput.

The quality of the printed layer is of utmost importance. Therefore, consistency of the printing quality of every nozzle must be monitored during printing in real time by a suitable diagnostics system. If a nozzle is found to start deviating from its normal operating behavior, the printer must be able to automatically apply a head maintenance routine, even before the suspected nozzle is actually failing. This means that the printer must be equipped with nozzle inspection and maintenance modules. Typically the nozzles are inspected by visual drop monitoring, while maintenance functions are purging (pressing a small amount of ink through the head) and wiping. These functions are automatically performed by the printer to ensure operation without operator interference.

Finally, a UV curing source is needed to perform photopolymerisation of the solder mask material. This curing step not only prevents the ink to flow out and enhances feature size, it also makes the panels tack free when they leave the printer. For high throughput a high power LED source is most suitable and should be mounted close to the print heads in order to reduce ink flow out and enhance the accuracy of the printed pattern.

Inkjet Equipment Technology

Suitable inkjet production equipment such as the PIXDRO JETx systems from Meyer Burger are specifically designed for printing solder resist on printed circuit boards using the considerations as explained above. The requirements are such that solder mask layers can be manufactured fast and cost effectively.

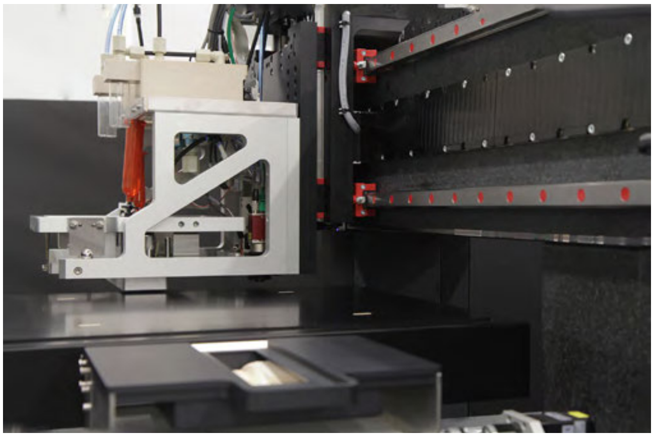


Figure 7: Inside view of an inkjet printer showing granite base, linear motors, print head array with ink supply lines and alignment camera, and wiping station.

Six reasons why outsourcing CAM Engineering can be a great idea for you:

...and here is the delivered value:

	In-House	With Entelechy
Availability	48 weeks	52 weeks, 24/7
Overhead Cost	>30%	0%
Scalability	Limited	Unlimited
Redundancy	Variable	100% Bulletproof
Operational Efficiency	Status Quo	Continual Improvement
Total Cost	Fixed	Significantly lower

"In our company, the CAM department was the bottleneck. As a result of our working with Entelechy, we can now accept orders that we had to refuse in the past."

-Thomas Hofmann, CEO/Owner

HOFMANN LEITERPLATTEN

Click here to check out our risk-free Quick Start program»

We deliver the highest quality PCB CAM and Mechanical CAD engineering services to customers around the world. We can help you beat your competition by teaming up with us.

ENTELECHY GLOBAL

www.entelechyglobal.com

Figure 8: Cross-cut of IC pad section of a PCB with printed solder dams. The spacing between the copper pads is 5 mils.

The JETx-SMP printer produces solder mask layers with the following specifications.

- Line/space: down to 75/75 µm
- Edge roughness: 20 µm
- Solder mask openings: down to 100 µm in diameter
- >10 µm solder mask thickness on copper
- Layer thickness: 30–80 µm, can be varied over the board to reduce material consumption
- Alignment accuracy: <2 µm using automated fiducial alignment

At this moment a number of green and black solder mask materials are either commercially available, or close to commercial launch.

Conclusion

Recent advancements in inkjet equipment technology are definitely confirming the trend towards digital PCB manufacturing. Where legend printing is already widely accepted, the industry has already familiarized itself with digital manufacturing and acknowledged its merits, direct digital solder mask printing is certainly going to be the next all-digital process step in modern PCB manufacturing. **PCB**

Wouter Brok is manager of Innovation with Meyer Burger.

Klaus Ruhmer is head of Micro/Nano Systems Sales with Meyer Burger.

Henk Goossens is manager of Marketing and Business Development with Meyer Burger.

Additive Manufacturing: A New Twist for Stretchable Electronics?

Stretchable electronics may soon be used to power electronic gadgets, the onboard systems of vehicles, medical devices and other products. And a 3D-printing-like approach to manufacturing may help make stretchable electronics more prevalent, say researchers at Missouri University of Science and Technology.

New bendable electronic devices like the one pictured here could become more common in the future.

Writing in the January 2017 edition of the journal Micromachines, Missouri S&T researchers assess the current state of the emerging field of stretchable electronics, focusing on a type of conductor that can be built on or set into the surface of a polymer known as elastomer.

These conductors could one day replace the rigid, brittle circuit board that powers many of today's electronic devices, serving as wearable heart or brain sensors that adhere to the skin to measure activity.

Supply Lines Highlights

Panasonic Commercializes High-Heat-Resistance Circuit Board Material for Automotive Use

Panasonic's High Heat Resistance Halogen-free multi-layer circuit board material will contribute to improving reliability of automotive ECU circuit boards, even when they are directly mounted on engines.

Trouble in Your Tank: Via Formation and Mechanical Drilling, Part 2

In this month's installment of Trouble in Your Tank, I will further explore the critical drilling parameters required to drill a good hole and provide information on some little-known parameters required for this operation.

It's Only Common Sense: Seven Ways to Become the Greatest PCB Rep

Most rep firms don't give any thought to becoming well-known in their territory and in their industry, which is a shame because if you make sure everyone knows what a great rep firm you have, life will become a lot easier. It will be easier to get new customers, partners and, most importantly, principals. In fact, principals will be beating a path to your door.

Isola Signs Distribution Agreement with Tech Knowledge

Isola has inked a distribution partnership with Tech Knowledge (Yeda Tech), headquartered in Tel Aviv, Israel, to deliver Isola products, making Tech Knowledge the exclusive distributor for Isola in the State of Israel.

CCI Eurolam Names Detlev Kübler New Sales Manager in Germany

Detlev Kübler joined CCI Eurolam in Germany as Sales Manager effective January 1, 2017.

New Vehicles using Aismalibar Materials on Display at the North American International Auto Show

AISMALIBAR invites you to spot new model vehicles at the North American International Auto Show using Cobritherm Ultrathin and Flextherm Insulated Metal Substrates in their lighting systems.

Ventec's Martin Cotton to Showcase Ultra-Low Dk PCB Materials for High-Speed Low-Loss Applications at DesignCon 2017

Ventec International, a world leader in the production of polyimide and high-reliability epoxy laminates and prepregs, is participating at the 2017 DesignCon show in Santa Clara, California, from January 31 to February 2, as both an exhibitor in booth #118 and technical presenter.

Advanced Copper Foil Secures a Non-Provisional Patent for New Product: Poly-Supported Copper Foil

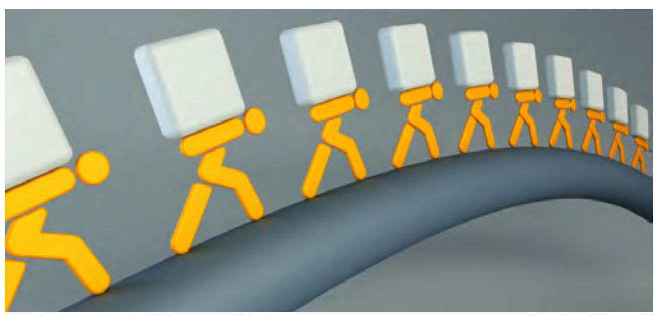
Advanced Copper Foil has secured an international patent for poly-supported copper foil, promoted under the name ACF-SCREEN. This patent is non-provisional under International Application number PCT/050938.

Park Electrochemical Names Frank Alberto President of Asian Business Unit

Park Electrochemical has appointed Frank Alberto, Jr. as President of Nelco Products Pte. Ltd., Park's Asian Business Unit based in Singapore. Alberto will report to Chris Mastrogiacomo, Park's President and Chief Operating Officer. Alberto is succeeding retiring President Ron Brett.

Panasonic Commercializes Low Transmission Loss Flexible Multi-layer Circuit Board Materials

Panasonic's low transmission loss flexible multi-layer circuit board materials are designed for high-speed large-volume data transmission and used in thinner mobile devices.



THE POWER OF THREE

A Solder Mask Solution for North America

by Dick Crowe
BURKLE NORTH AMERICA

Technology and process developments in mature industries like the printed wiring board industry are not always easy. Many new products are evolutionary enhancements of existing processes. Often, these developments enhance the process and improve overall process control.

The concept for direct digital imaging, as an example, has been around for some time, beginning in the early 1980s. Early pioneers were Excellon Automation and Eocom, in Orange County. At that time the industry was entrenched with dry film photo imaging and, at least in the North American market, there was little interest in pioneering a concept as revolutionary as direct imaging along with its attendant issues of cleanrooms and other environmental aspects. Dry film was viewed as a more robust application. Market adoption of liquid resist was also tempered by the high cost of the liquid material versus dry film.

Often, the equipment provider has a visionary leader who brings technology changes forward, but the collaboration between the equipment provider and the consumable supplier is often not a close one, or it's nonexistent.

As digital technology started to penetrate other applications, for example, digital cameras, the vision of lowering costs and improving image quality began to take hold. But the equipment was, and still is, very expensive and requires high-cost service contracts. Nonetheless, fabricator after fabricator began embracing the newer product offerings for primary imaging, but not solder mask, which was an entirely different requirement.

Taiyo, as the leading supplier of liquid solder mask products in North America, also had a visionary concept moving forward. During IPC APEX EXPO 2016, executives from Taiyo and Schmoll sat together and worked out a testing plan that Taiyo would implement to develop a solder mask product that met the North American marketplace needs.

Schmoll provided the equipment for the testing and development, Taiyo the development protocol, and Burkle North America the installation and maintenance expertise. The result is a solder mask product and process that is being introduced during IPC APEX EXPO 2017.

Read further (pages 36–48) for the views of both Schmoll's Thomas Kunz and Taiyo's John Fix as they address this program.

Taiyo's John Fix on New Materials, Products in the Works

by Barry Matties
PUBLISHER, I-CONNECT007

At the recent electronica show in Europe, I sat down with industry icon Walt Custer, and Taiyo's John Fix, who went into detail about the company's newest direct image and thermal management solder masks.

***Barry Matties:** John, can you tell our readers a little bit about Taiyo and what your focus is?*

John Fix: Taiyo is a world leader in solder mask products and solder mask-related products. We make via fill materials and legend inks, which are our main products that we service to the circuit board industry.

***Matties:** How many years have you been in business?*

Fix: Taiyo America just celebrated 26 years, and Taiyo overall recently celebrated 63 years servicing in the business. They've been doing solder masks since the late '70s.

***Matties:** Yes, a lot of experience there. Now you guys are currently working on a couple of new products or maybe more than that, but two that I'm aware of.*

Fix: Yes. We are working on several items. Some of the newer ones are direct imaging solder masks. Another area that we're focusing on is thermal management products. A newer one is a heat spreader solder mask.

***Matties:** Can you describe that product?*

Fix: Sure. As the industry advances, everyone is making smaller circuit boards and that requires more copper or heavy copper, which creates more heat. Within the automotive industry, everyone wants to put circuit boards closer to the engines and that's just more heat. LEDs create a lot of heat, so there are issues with the circuit boards getting hotter; to extend reliability, how do you manage the heat?

Years ago, Taiyo developed a first-generation type of heat spreader material. This was a material that would go onto the circuit board and

you would image how you wanted the heat to be dissipated onto the circuit board.

Then you would coat your solder mask over it so a lot of our customers thought that was a great idea, but you just added cost to the process because now you've created an extra layer to the circuit board. We went back, thought about it more and said, "Well, let's try to put that technology into the solder mask itself, eliminating that layer and just create a solder mask that is just a heat spreader in itself."

That's what we are introducing now. We've taken it to some of the OEMs in the automotive and LED markets first because those are the areas that really must deal with the thermal management issue initially. We're getting some positive feedback, so we have this new heat spreader-type material. It comes in a thermal-cure solder mask as well as a photo-imageable type solder mask. We've got two varieties that service the whole industry. Like I said, we're looking first at the automotive and LED markets to see their interest and there's quite a bit of interest there.

Matties: ***I would think so. How effective is it at dissipating the heat?***

Fix: It's about 10 times that of a standard solder mask. The material we have as a photo-imageable does about 2 watts per meter-kelvin. It's quite a level of improvement over a standard solder mask. We found some special type fillers that help dissipate that heat. We also found certain ways to design the circuit board and enhance how the heat is dissipated—so we can work with the designers as well as the circuit board manufacturers to give them those keys on how to make the product work even better.

Matties: ***Is there a new standard that will be developed around a product like this, and is this the only type of product of its kind on the market?***

Fix: Right now, for solder masks, it's the only kind. A standard, that's an interesting concept; we haven't really thought much about designing a standard around it.

Matties: ***Seems like it would make sense, right? From your point of view.***

John Fix

Fix: Yeah, absolutely.

Matties: ***How long was the design or the development cycle timeline?***

Fix: We've been working on thermal management products for about five to seven years. Our first iteration, like I said, was a product that was a standalone, and then we had to modify it to turn it into a solder mask. That product came out years ago, and it took us three or four years to turn it into a solder mask.

Matties: ***You're doing all of your R&D at your facility in Carson City?***

Fix: Actually, the heat spreader was designed and developed in Japan. A lot of our new type technology comes out of Japan. Most of the work that's done in Carson City is more for local markets, so the DI work that we were mentioning earlier was done in our Carson City lab. That's where we've gotten some equipment from, for instance, Schmoll. They were kind enough to put their latest unit into our laboratory, which enabled us to work much quicker in developing some DI solder masks that work very well on their equipment. One of the things about designing solder masks for the North American market is that customers don't deal with the volumes that China does so there are issues with UL costs. We try to do our best to satisfy our customer base, where, "Can you change the solder mask to stay within the UL specs so they don't have to requalify everything?"

That was our major goal when we started on the DI mask; can we modify our big selling products, the BN product, the HFX products, the MP products, our main bread-and-butter products for the North American market, and make it simple for our customers to make a switch from those products to a DI and utilize this new equipment that's coming to the market?

Having that equipment in our lab enabled our chemists to develop it so much faster than had we been developing an ink, then flying it to a customer somewhere, running a test, and coming back to the lab. We've greatly appreciated everything that Schmoll did for us. They really enhanced our development cycle and now we have a product to offer to the market that really enhances production speed. There are no UL issues for them to have to deal with.

Matties:* *It made it easier to get past that hurdle.

Fix: Right, so any user that already specs a BN or an HFX or an MP, this product falls right in there with it. All the final properties are the same. The process is the same except that instead of using your old flood exposure, now you're using a direct image exposure.

Matties: Is there a customer approval that needs to happen or do they just do it and ship it?

Fix: Essentially, they just do it and ship it.

Matties: Customers don't care.

Fix: From an end user standpoint, the material hasn't changed. The final properties are the same, the UL is the same, the IPC SM-840 testing is all the same. It's quite convenient for the customers.

Matties: Are you already selling this and marketing commercially or is this just now coming out?

Fix: It's just coming out now to the market. We're eager to introduce it and get the market base going on it.

Matties: You're developing it on Schmoll equipment, but obviously, it's compatible with all the others?

Fix: Yes, and that was a difficult thing to start with because we've counted well over a dozen other DI machines out in the market.

Matties: And more are coming.

Fix: Yes, and everyone's designs are a little different. Like I said, Schmoll was very generous to work with us. Trying to find a system that's going to work with everyone is difficult and we did our best with what was in our hands with regard to equipment, to design a product that's very wide and flexible. This product will work on various equipment and it works well.

Matties: With the Schmoll equipment, basically they just gave you the equipment. There was no involvement in the development other than that?

Fix: Correct. They were kind enough to install it and make sure it was all set up. They installed all the test patterns that we needed for our testing and the unit conveniently fit into our laboratory. It's not a very large unit and it was quite convenient for us. There wasn't a lot that we had to do from our end to make it fit into our lab.

Matties: Good. In terms of solder mask, what are the greatest challenges that people face in that area?

Fix: The biggest challenge we face when designing a solder mask is that everyone wants to work fast, and working with a new light system is just the physics of trying to get light through a thick coating. As I mentioned before, everyone's using thicker copper, so they're putting down thicker coatings of solder mask. You're

trying to get a light beam through a thick coating of highly pigmented solder mask because everyone wants that dark green color or they want some other dark color.

One of the biggest challenges right now is the white solder mask because white solder mask is made to be reflective. They want to reflect the light. That's what LEDs are all about. How do you make a white product and get it exposed with light when the solder mask is there to reflect the light? That's one of the biggest challenges right now—to try to find DI equipment that can work with a white solder mask because you're fighting that. You're designing a white product to reflect light and now you're trying to get it to shine through it to expose it.

It's understandable that when the customer buys a piece of equipment like that, they want it to work on all colors. They don't want to hear "it works on all colors but white." Now you've got to buy a different machine for white. That's probably the biggest challenge right now is finding something that will work for the white solder mask.

Matties: Does this Schmoll equipment work on white?

Fix: We're still finding a challenge with the white. It's mainly for the speed because the DI was created for speed. You want a fast exposure illuminating the artwork so that's been the challenge. We're still working on it. The equipment is still in our lab so we haven't given up, by any means.

Matties: Other than that, there are no obstacles for your customers?

Fix: No, not at all. Any obstacle is up to us from a chemical standpoint, finding the chemistry to make it work. We think we can figure it out.

Matties: You've been around long enough. You have a big pool of knowledge to draw from, that's

for sure. You are serving the global market, and of course, you're here in Europe. How's the European market for you?

Fix: The European market is going well. It's very similar or evolving into what the U.S. market was. The U.S. market used to be a thriving market, which over the years has become more specialized into high mix, low volume. We're starting to see the same evolution in Europe. A lot of the larger shops have shrunk a bit and there are more partnerships with China. There are still larger shops here in Europe, there are still some very large shops serving the automotive industry, but you still see that change happening. They're not as large as they once were and they're starting to look at making those higher layer circuit boards that create more value. DI has been a driving force as well. A lot more HDI types are being built. More prototype, which I think will be a driver as well here in Europe.

> "We're starting to see the same evolution in Europe. A lot of the larger shops have shrunk a bit and there are more partnerships with China."

Matties: In terms of DI in America, there are still quite a few shops from what I understand that have not committed, or they want it but they have not installed it yet. Just seems to me that it's a no-brainer. What would be the reasons that they wouldn't do that, other than financial?

Fix: It's mainly financial.

Matties: You would think the ROI would be relatively quick, especially when you start looking at the process that you're talking about. The solder mask and the elimination of all these other steps in other areas. It just seems like it would be a quick ROI.

Fix: Sure. Like I said, I still see it moving more and more. We think probably in the next three years it might be all DI by then. I think you'll see the technology change relatively quickly now that there are more options.

There was quite a bit of change initially, with the LDI, which was the first option for essentially everybody. Now that you have a dozen-plus equipment manufacturers out there, it gives everyone so many more options.

Matties: Right, and pricing becomes a little more competitive.

Fix: Absolutely. Now you have more options and you have more market-to-price competitiveness. Everyone's offering something that's a little different and there's something for everybody now.

Matties: By the way, what was Walt's [Custer] question from a little earlier?

Fix: Walt was asking about its electrical properties and its great crack resistance. What we've found with our heat spreader material is that it is shown to have better crack resistance than some of our standard automotive-type solder masks. We think a contributing factor is that it's dissipating some of the heat.

Walt Custer: What about the moisture and insulation resistance?

Fix: We find that the moisture and insulation resistance is comparable to the standard solder mask. We're not seeing any absorption of moisture into it. The curious thing we were probably more surprised with was that the crack resistance was as good as it was. The theory behind it was that a lot of the heat is being transferred out of it so it's not in there to cause any stresses.

Custer: Solder masks have so many requirements. When new suppliers bring them out, the first thing they think is it's green and it images but then all the electrical properties, resistance to various assembly operations and things like that. I see a lot of naïve people that say, "Oh, we have a new solder mask." Especially the equip-

Walt Custer

ment manufacturers. They decide they're going to sell a piece of equipment so they're going to sell their own solder mask with it. I remember at this show or one of them recently, where they came out with a new direct imaging system and they said, "Oh, we're using our solder mask." I started asking questions and the guy got really defensive. It was the an executive of the company and he really got mad at me. He said, "Oh, it's IPC-SM-840," but that's just the beginning of the problems, trying to figure out what this thing was doing. I think a lot of people are very naïve of all the things a solder mask has to do. With all the kinds of assembly operations they see and substrates and everything else, it's really a challenge.

Fix: Yeah, there's so much more to a solder mask. People try to simplify it to, "Well I cured it and it's hard."

Custer: Yeah, and it's green.

Fix: Yeah, it's green and it's hard. I got a pencil hardness. We see a lot of that where people will design a new oven. "Oh, we designed a new oven and we can cure your solder mask in two minutes." How do you prove that? "We proved it because we cured it and it's hard." There's a lot more to a solder mask than it's green and it's hard. You've got all kinds of electrical tests. You've got to take a solder mask and put it through these harsh environments. Is it still electrically capable after all those heat excursions? Those are all the reliability tests on it that all the end users need that we're familiar with because we've been doing this for so many years.

Custer: You would know because you sell a lot of it. There are a lot of people who decide to get into the market and they really don't know.

Fix: Yeah. The thing people don't realize is a solder mask goes on and it stays on there. It's on there forever. It's not like a plating or etch resist where you put it on, it does its thing and you strip it off.

Custer: If it fails, it's an expensive problem.

Matties: Very much so. Making it compatible with all these machines sure opens it up for a lot of other players to come in.

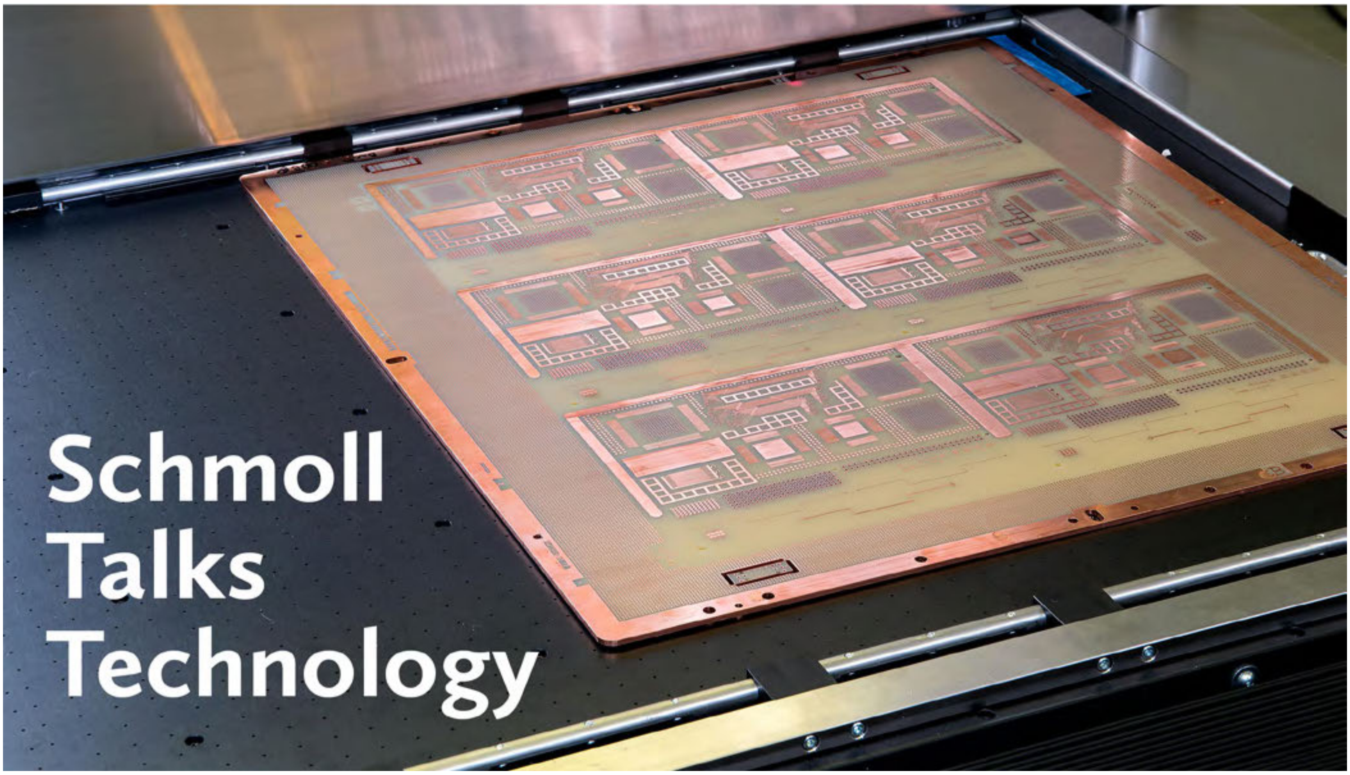
Fix: Sure. You have to be compatible to the hundreds and thousands of conformal coats that are out there. All the different final finishes. You've got gold, immersion tin, hot air level, OSPs, and you have variations within those as well—the cleaners, acids, and the bases. Then you have all the lifetime issues with it, like the military who buy a circuit board and sits on a shelf for years and then when it gets plugged in and used, it still has to work.

Matties: Is there anything else you would like to cover?

Fix: I think those are two of the main areas we're concentrating on right now, the DI and the thermal management material. Come visit us again in February and we'll have more to talk about.

Matties: Good. I look forward to it. John, thank you very much. I appreciate it.

Fix: A pleasure. Thank you. **PCB**



Schmoll Talks Technology

by Barry Matties
PUBLISHER, I-CONNECT007

Schmoll's Thomas Kunz and I had a chat recently at the HKPCA show. In our short discussion, we covered several topics, including Schmoll's approach to the U.S. market, their work in direct imaging, and the nature of their relationship with ink suppliers.

***Barry Matties:** Thomas, please provide some background on Schmoll for our readers.*

Thomas Kunz: We are in the drilling, routing and laser machine business and trying to get new technology out, especially in functionality and features and coping with new requirements of the market. We are also going forward with our optical technologies, mainly in niche markets, and we have found a nice application there for us to do the job for our customers.

***Matties:** And you're in the direct imaging arena as well?*

Kunz: We have already been doing this for a few years. As you may remember, we are coming out of the Bacher Corporation from several years ago, so we are not really a new player; we launched our newest equipment to the market two years ago. Since then we have installed more than 20 systems. This year, IPC APEX EXPO 2017 will give us a chance to cope with the requirements of the U.S. market, and we are well prepared for that.

***Matties:** Now, with the American market, we were working on a piece with Taiyo, and they're coming up with some material to run, specifically through direct imaging equipment. My understanding is that Schmoll has provided them some equipment for their testing.*

Kunz: Basically, we work with every supplier in the world. They each have their different niches. Of course, in the U.S., Taiyo is the place to be. We provided them equipment prior to displaying it at the IPC show, to get extensive testing to adapt their inks to what we've got. I think it has worked out quite well, and we can present something to the market that is attuned to latest ink technology in detail, and we can talk about this at the show.

***Matties:** The equipment that they're working on, the ink is for solder mask, correct?*

Thomas Kunz

Kunz: The equipment is basically for both processes, photoresist and solder mask work, but of course Taiyo is concentrated on solder mask. For this reason, this venture was about solder mask.

Matties: When you develop your equipment, during that process of coming up with new technologies, how critical is it to have a partnership with Taiyo and the other ink suppliers?

Kunz: It is very important. On one end, we have certain wavelengths available, and this has to match with the inks, or vice versa. Second, we have certain flexibilities in our wavelengths to adjust to different power levels. We must also learn from the ink suppliers how we can do that and to what extent it is useful. Of course, the ink manufacturers can help us to convince customers that their existing inks are maybe not very suitable for the future. Two years ago, customers of ours said, "Oh, nearly impossible to change the ink for our customers," but we see a trend in the market that this is changing. Also, their end customers are thinking they have to go this way because they want direct imaging at a decent cost.

Matties: When direct imaging and a modified or new ink enter the market, how do the OEMs react to this? Is there a whole new qualification process that they go through for your technology and the inks combined?

Kunz: There are different ways. Some are easy to change. Some, they are okay with if the ink remains basically the same but you just change the percentage of the components. Of course, there are others where it's very difficult because they must run a full qualification—like aerospace or automotive. So it's very mixed, but the supplier of PCBs has the problem that they cannot do one thing for one customer and another thing for another customer. So they should run one thing, maximum two things. They must find a common way for everybody, and this is the critical part.

Matties: Now, with the direct imaging of solder mask, this is something that isn't exactly new but that hasn't been fully embraced yet. How is that process of acceptance coming along?

Kunz: Yes, it's true. Resist work was done with the DI systems for many years. Obviously, the lasers were not suitable for the ink, and the inks were not suitable for the lasers or other light sources. The standard light sources, with a broad wavelength range, had to be adapted to the DI technology.

For this reason, after starting with two wavelengths, we have adapted our systems to four wavelengths to give us the best opportunities to address to the specific characteristic of the ink.

Matties: When someone adopts the technology, what sort of process step reduction or cycle time reduction should they generally expect?

Kunz: Well, I think the biggest advantage is that they get a better quality. They look for registration, whereas saving the cost of films is a side issue which finances the purchase of a direct imaging machine, but basically, they look for registration, quality, less scrap. I think this is the main driver.

Matties: Is there a speed component to it as well? Is there a cycle time in that process, from traditional to direct?

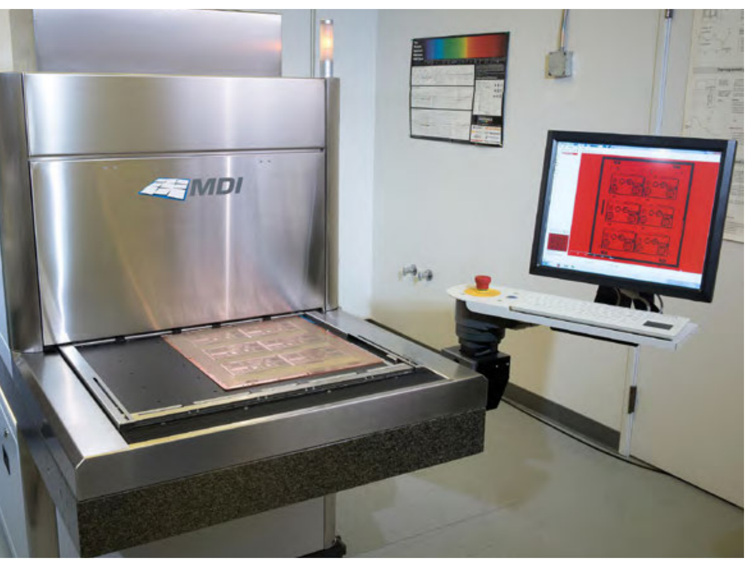
Kunz: In the complete process, you may have some savings, but generally the DI system is slower than a conventional system. As you may know, a conventional system has quite a lot of power, so you can just flood it like hell, but the DI is limited in some respects. This means we have to bring the cycle times on the market that compete, but then, by concept, it is only one side, and the conventional system often does two sides at once. So there is a cycle time disadvantage, basically—but we offer a much better quality.

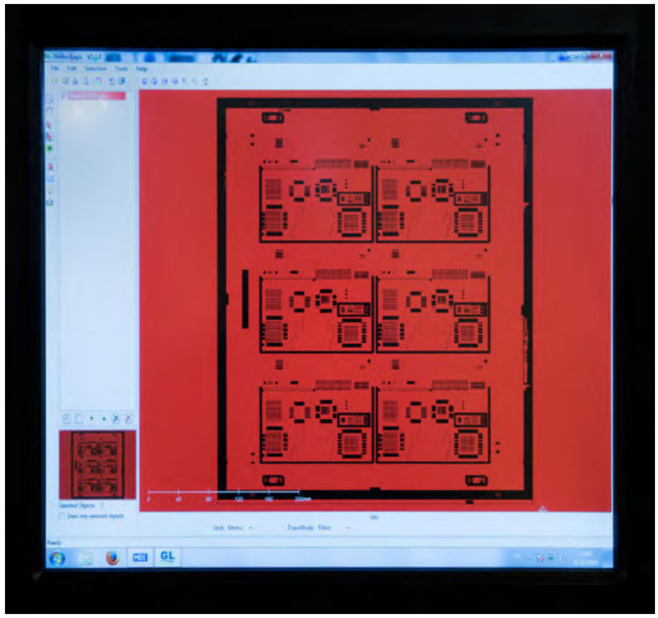
Matties: Yeah, reduction in handling and scrap and overall quality.

Kunz: Yes.

Matties: That's got to be a pretty tough sell. How expensive is a unit? For someone to invest in direct imaging, how much would they expect to invest? A quarter of a million dollars, or something along those lines?

Kunz: It can be from that level up to one million, depending on the number of heads, throughput and automation levels. So I think there's no border for whatever you want to do, but the nice thing is that unlike two, three, four years ago, you can start a one-head system with $250,000–$300,000 and just get into the business and maybe only do part of your produc-





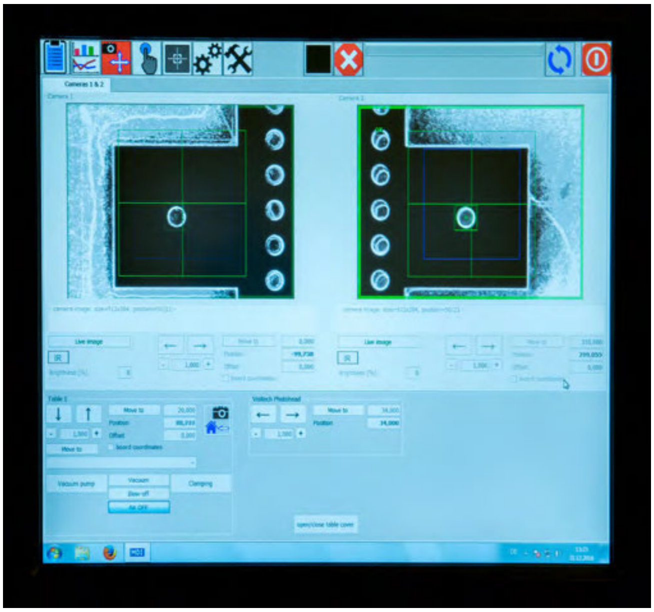
tion where it's necessary or really beneficial. Whereas, early times you would have to spend at least double or three times. But now you have a good start up, for acceptable money.

Matties: Is there anything that we haven't talked about that we should be discussing about direct image and solder mask?

Kunz: For solder mask, there are also some handling issues, because the boards are completely different than photoresist work. Resist work usually has no holes inside. This means that in solder, the vacuum system is much more difficult. Our machine for solder is usually equipped with some mechanical clamps. We have seen customers not using the vacuum at all and just clamping with the mechanical clamps because they have boards that are badly bowed and the vacuum is not able to handle it. So there are different varieties, whereas with photoresist, there's one resist and it's done. You have bowed panels, panels with many holes, or panels with different colors. Solder mask is a completely different thing than doing resist work.

Matties: It sounds like the mechanical is working just fine, though.

Kunz: That's OK.



Matties: ***Yeah. Do we need the vacuum in there, or is it just there because of the resist work? It's a dual-purpose machine?***

Kunz: It could be dual purpose machine depending on the options. Of course, if the panel is flat, you would like to handle it with vacuum. But if you cannot, then you do it with mechanical clamps. They have the disadvantage that you cannot handle the panel all over the place. There will be a bow in the panel, but it is clamped on the edges. But the bow in the panel can be nicely compensated for by auto-focusing the axis which runs across the panel in the right height. For this reason, you can use this function in that way.

Matties: ***Right. Then curing is done off-line? It just goes out, or do you do a tack cure in those processes?***

Kunz: You could apply a curing inside the machine, but it must be adapted very carefully. It creates some heat, so we've found it much more efficient to do it offline, after exposing. This could create some 20, 30, or 40% less energy. This gets you back into the levels of the standard exposure system, concerning cycle time.

Matties: ***Good. Congratulations. How is business in general for you now?***

Kunz: Well, we cannot complain. 2016 was the first year after many years where we had a pretty steady load in our factory. It was not skyrocket high, but it was on good levels, and no peaks and downturns like we had over the years in 2015, '14, and '13. For this one, we're quite satisfied that we could work, let's say, in normal manner, which gives us a little bit of continuity.

Matties: ***When you start looking at new technology, what drives you? How do you determine what the next piece of equipment will be, or the next, not incremental step in feature, but substantial step in feature? How do you come up with those strategies?***

Kunz: It's a mix of looking at global trends and talking directly to customers. That's why we're at trade shows, so you get a level of information within a few days that you can put together to a certain idea of how it should be done in the next one, two, or three years; to look further than that is not possible today.

Matties: ***Is that your window, usually a two- or three-year window for technology? Or do you say "Ah, we can do something short order, six months or less?"***

Kunz: Of course, there are elements that you can do more quickly, but the big scale development takes us two or three years, because it must be adapted to markets; you must look at functionality costs, accuracy, reliability. Usually, such a machine is not built in one step.

Matties: ***What are we going to see from you in the next couple years?***

Kunz: That will be productronica. We've only just considered what we will bring to the next one in 2017, so I cannot answer this question.

Matties: ***All right, very good. Thank you for spending time with us today. I greatly appreciate it.*** **PCB**

Electronics Industry News
Market Highlights

Seeing the Quantum Future...Literally

Sydney physicists have demonstrated it is possible to overcome the most significant hurdle to building reliable quantum technologies, in a major technical achievement. The research is published in Nature Communications.

Globalization and Cloud Computing Usher in New IoT Realms

Leaders of the global internet of things market in 2015 included the likes of Google, Inc., Apple, Inc., Microsoft Corp., Amazon, Intel Corp, and Cisco Systems. As seen, a lot of the key players in the global internet of things market are predominantly from consumer electronics or ICT fields, and a majority of the market leaders are headquartered in the U.S.

Laying the Foundation for UAE's Advanced Communications Infrastructure

Masdar Institute has launched two research centers aimed at accelerating development of the UAE's communications infrastructure and preparing the country for the next generation of wireless communications networks, known as 5G wireless.

Growing Need for Automation to Lead to Mass Deployment of Industrial Robots

The global market for industrial robotics is extremely fragmented in nature, states Transparency Market Research (TMR) in a research report. The competition among the players is expected to intensify over the next couple of years as the degree of product differentiation is extremely low and the barrier to entry for new participants is also flexible.

IoT, Automotive Electronics Driving FPCB Industry Growth

Flexible Printed Circuit Boards Market report, published by Allied Market Research, forecasts that the global market is expected to garner $27 billion by 2022, growing at a CAGR of 10.4% from 2016–2022.

Additive Manufacturing: A New Twist for Stretchable Electronics?

Electronic components that can be elongated or twisted—known as "stretchable" electronics—could soon be used to power electronic gadgets, the onboard systems of vehicles, medical devices and other products.

Over 69 Million Automotive LiDAR Sensors Will Ship in 2026

Critical autonomous driving functions, including obstacle detection and simultaneous localization and mapping (SLAM), will drive the automotive industry's adoption of LiDAR sensors.

Share of In-Cell Solutions in Smartphone Display Market to Reach 29.6% in 2017

The latest research on touch display solutions by WitsView, a division of TrendForce, finds that the share of In-Cell products in the global smartphone display market will expand to 29.6% by the end of 2017.

A Remedy for Bad Altitude

"Taking control over an airplane isn't as easy as flying a drone; an attack is more likely going to be simulating malfunctions so a pilot loses trust in his or her aircraft," said Mike Worden, a Raytheon engineering fellow and the company's principal investigator for cyber hardening projects.

A Flexible, Stretchable, Self-Healing Ionic Conductor

Scientists, including several from the University of California, Riverside, have developed a transparent, self-healing, highly stretchable conductive material that can be electrically activated to power artificial muscles and could be used to improve batteries, electronic devices, and robots.


TECHNICA, U.S.A.
Fulfilling Manufacturing Needs Throughout the Electronics Industry
Celebrating 30 YEARS
Halogen-free EM-890/ 890K and Halogenated EM-891/ 891K Ultra High Speed Laminates for 100 and 200GbE Applications
For more info, contact
Jason Perry
Director of Sales
JPerry@technica.com
503-318-0617
KEY FEATURES
4x
Ideal for multiple lamination cycles (>4x)
Compatible with FR-4 for Economical Hybrid Designs
Ultra Fine BGA pitch (<0.7mm)
Excellent Thermal Properties (10 X LF260 IR Reflow, IST > than 2K cycles)
Available exclusively through Technica, U.S.A.
1-800-909-8697 • www.technica.com
EMC
ELITE MATERIAL CO., LTD

Inkjet Printing Solder Mask

by Barry Matties and Pete Starkey
I-CONNECT007

Known for their film-based products, Agfa-Gevaert has turned its focus to the difficult task of inkjet printing the solder mask by partnering with solder mask expert Electra Polymers. Sitting down with Frank Louwet and Mariana Van Dam of Agfa Specialty Products, I-Connect007 Publisher Barry Matties and Technical Editor Pete Starkey learn more about the partnership and where they currently stand in the development of what will be a definite game changer.

***Matties:** Frank, you're a part of the Agfa Specialty Products group, and the three areas that you're covering are Advanced Coating and Chemicals, Functional Foils and Classics. Tell us a little bit about the Classics.*

Louwet: Classics are based on our core photosensitive Ag technology and contain three applications: Aerial, Microfilm and NDT, a film for non-destructive testing. This latter is an X-ray film used in industrial applications for checking weldings in pipelines and airplane engines.

***Matties:** And what about the functional foils?*

Louwet: The Agfa functional foils business is based on our in-house capability of producing and coating mainly polyester films. It can be done all in one place. Main application areas for these functionalized polyester films are media for security printing, synthetic paper and back sheets for PV. SYNAPSTM is the trade name for this synthetic paper. This high-duty polyester print medium is used for menu printing, manuals, advertising or name cards.

***Matties:** The area that we're talking about is advanced coatings & chemicals, producing and commercializing films and inkjet inks for the PCB and chemical milling industry. You said you have 40% of the film market, which is substantial. That's quite an accomplishment.*

Louwet: We have good products combined with a good sales and service organization. Agfa Materials has its own sales organizations in Europe, China, Taiwan, Korea, Japan, South East Asia and the U.S. The local sales teams have good technological capabilities, so they can give excellent service and support to customers. Customers appreciate this. We have very good inroads into this market and are now also developing UV inkjet inks to digitalize some of the

Ucamco
Former Barco ETS

SOFTWARE | PHOTOPLOTTERS | DIRECT IMAGERS | NEWS | SERVICES | COMPANY | DOWNLOADS | CONTACT

Frank Louwet

production steps as an alternative for the traditional analogue technology. We have a range of legend inks and etch resist already commercially available.

Van Dam: Agfa holds a wide experience in inkjet ink development for different graphic applications. We have now an integrated bigger team working on inkjet inks both for graphics and PCB.

Matties: So you aren't doing any equipment. You are a materials supplier only?

Louwet: Indeed, Agfa Materials does only materials. Our Agfa Graphic team does also equipment for graphics applications but we do not. It is both a strength and a weakness. A weakness is that Agfa Materials cannot offer the full solution to the customer. The strength is of course that we can interact with many printer manufacturers and have open discussions with them. The PCB industry does not like to be bound to a single source for hardware and ink.

Our printer partners are very important. A solution has to be offered to the customer. This cannot be done with the ink only; you need strong printer manufacturers to go along.

Matties: As we've been talking about your products, the etch resist and legend ink, I noticed that you are compatible and approved with most available inkjet equipment. That's a smart strategy.

Louwet: We started with the development of the legend inks. By now it's our fourth generation. It is not always spot on from the first time, but you learn a lot for the next generations and for the next products, like etch resist and solder mask.

Matties: The area of films and inks for the PCB industry was screen printing back in 1945, all the way to 2020, which will be additive inkjet printing. This is where we're not going to be etching boards at all, but we're just going to be printing our circuits?

Louwet: Yes, but 2020 is probably too optimistic. Basically, the PCB industry has now accepted additive legend IJ printing; etch resist IJ printing will be next, followed by IJ solder mask. The ultimate next step is of course that you print also the metal. For that Agfa developed a nanoparticle ink. With our extensive background in silver technology, Agfa has a proprietary nanoparticle silver dispersion which has been formulated for screen-printing inks. We are now also developing inkjet inks that can be used in a PCB environment.

Matties: Is there a lot of interest in the industry for this product right now? From a visionary point of view, are fabricators coming to you and saying, "What do you have coming for this kind of process?" Or do they even care?

Louwet: Yes, there are players that are interested and are coming to us.

Matties: Is it small scale at this point?

Louwet: It's small scale, but there are bigger companies doing some applications today where they want to replace the etching/stripping of the copper by printing of silver. And of course, there's already a lot of Ag screen printing in the printed electronics market today.

***Matties:** In the realm of what we're looking at here, what's the greatest challenge? Whether it's in inkjet or film for the industry today, what are the greatest challenges out there for PCB fabricators? What are they really struggling with in this area? Imaging? Film? Or is it just an evolutionary product?*

Van Dam: I think it's certain that the industry is under pressure because of cost.

***Matties:** Well, cost is always a pressure, and from a technology standpoint, speed is always a pressure.*

Louwet: And speaking in the sense of speed, not per board, but in getting the question from a customer and delivering the PCB board is also part of it, and of course the environmental impact.

***Matties:** What sort of environmental impact do you have?*

Van Dam: With the inkjet, you have a lot less chemistry.

***Matties:** So you reduce the waste, and setup is so much easier too.*

Van Dam: If you look at the etch resist, just as an example, and compare with the traditional process. You start from the laminate, then you have to apply your dry film which you need to image. For that you have to prepare the photo tool, then expose and develop. Then follows etching and stripping. If you use inkjet technology, you print immediately the pattern and then etch and strip. So that's 10 square meters versus 100 square meters and one person versus three to five people.

***Matties:** What keeps people from throwing the old method away and just turning this on, if the value is so great? You eliminate a lot of equipment, a lot of labor and cycle time. Why do people still do that?*

Louwet: The main reason why it is not there yet is that the right inkjet technology was not yet available. But the printhead development is going to smaller picoliter droplets and higher frequency jetting. So they can really jet at high speeds and at high resolution now. It will come very soon.

***Matties:** So it is mostly a speed issue?*

Louwet: It's a speed issue, but also resolution.

***Matties:** And you've got the resolution solved?*

Van Dam: The resolution is more on the equipment side, and there has been a big evolution in recent months.

***Matties:** So the speed issue, how do we resolve that?*

Louwet: Of course, there is a tradeoff between the traditional process and the inkjet process with respect to volume. At the start, we are mainly targeting the prototype shops in North America and Europe. But even in China, they are thinking of this new production method to go digital with inkjet.

***Matties:** I'm wondering what the barrier to entry is? When you look at the inkjet all the way through the process, it seems like we're so close. How long before the speed issue is resolved and we see this in high-volume production manufacturing?*

Van Dam: The printer integrators are building machines with more heads as we speak, to allow higher volumes.

***Matties:** Are you working with equipment developers to say, "We want it faster. Here's what we want?"*

Van Dam: Yes, we have very close relationships with them.

***Matties:** It just seems like this could be something we could turn on today. The company that's*

serious about owning the high-volume production for this…it just doesn't seem like that big of a technical challenge to me from my limited point of view. That's why I'm asking what you think. What's stopping us?

Van Dam: We believe it's going to take off.

Matties: What should a PCB fabricator know that we haven't talked about regarding this technology?

Louwet: The next step is the inkjet solder mask.

Matties: Let's talk about that.

Louwet: It was announced last year at productronica. We decided to go in a joint development with Electra Polymers from the UK. Electra Polymers is an established solder mask supplier in the PCB industry. Agfa understands the inkjet business. So we decided, let's put our efforts together. What you see here is our first prototype, which we are testing with several printer manufacturers. This material has passed all the electrical tests. UL is also okay. You see here the nickel-gold finish, which is a very critical one. It is working quite well; the adhesion is good. Of course, there are still some issues that we have to solve. It is important to be sure that all the properties are OK before we go commercial.

Matties: Tell me about the curing of your material. Is it high speed?

Van Dam: Yes, it's UV, but then it gets a thermal post cure.

Matties: Do you still bake it?

Van Dam: Yes, for the solder mask and the legend ink. For the etch resist you normally need only the UV cure.

Louwet: Our goal is to show something more at IPC APEX EXPO 2017 in February. Today we are at the stage where we are starting to talk to end customers with a kind of three-way cooperation between AGFA, the printer manufacturer and the end customer.

Mariana Van Dam

Pete Starkey: The only question I have regarding this is that I see that the conductors are black. Have you done a special treatment to improve the adhesion of the material?

Van Dam: We tested several pretreatments, and this one is a type of micro-etch.

Louwet: We have been working with a team of 10 people very intensively on this and of maybe 15 different concepts that we have, a few survived and this is one of them; the adhesion of copper is of course an important part.

Starkey: From a personal point of view, I'm very excited. The real, working inkjet solder mask, is something I've been waiting 15 years for.

Louwet: It's still to be proven, but we are quite optimistic.

Van Dam: It looks very promising.

Matties: What about the cost of the product? How do you think that's going to run?

Louwet: We know that we have to be competitive with this inkjet technology.

Van Dam: The ink itself will be more expensive than the traditional ones, but there are a lot of savings in the overall production process. And of course, a digital additive process offers also a lot of other valuable advantages.

Louwet: What I can say is that we have been discussing this with some end customers and they have calculated some target prices and we are in the same ballpark.

Matties: That's good, so it's not outrageous. Here's the other thing. I would think every company that provides mask is looking for technology like this, and there might be a lot of choices and competitors for this product. How do you differentiate yourself?

Louwet: What's important here is to be first. A lot of companies are really thinking of digital production. It's important to be there now and to be designing with them.

Matties: You said you started the development of this product about a year ago?

Louwet: Yes, but of course, we've built a lot on the legend ink and the etch resist experience.

Matties: Is the time to develop the product in line with what you thought it would take?

Louwet: It's going faster than we expected.

Matties: You're about a year into it, and you're close to going into market now?

Louwet: It will take another year before we do a full commercial launch.

Matties: You're going to partner with some beta sites, I'd imagine. We'd be interested in doing the case studies for the beta sites as you follow this process along, if that's acceptable. Thanks for taking time to talk with us.

Louwet: Thank you. **PCB**

'Knitted Muscles' Provide Power

Researchers have coated fabric with an electroactive material, giving it the ability to actuate in the same way as muscle fibres. This opens new opportunities to design "textile muscles" that could, for example, be incorporated into clothes, making it easier for people with disabilities to move. The study, which has been carried out by researchers at Linköping University and the University of Borås in Sweden, has been published in Science Advances.

Developments in robot technology and prostheses have been rapid, due to technological breakthroughs. For example, devices known as exoskeletons, which act as an external skeleton and muscles, have been developed to reinforce a person's own mobility.

"Enormous and impressive advances have been made in the development of exoskeletons, which enable people with disabilities to walk again. But the existing technology looks like rigid robotic suits. It is our dream to create exoskeletons resembling items of clothing, such as "running tights" that you can wear under your normal clothes. This may make it easier for older persons and those with impaired mobility to walk," says Edwin Jager, associate professor at Division of Sensor and Actuator Systems, Linköping University.

Financial support for the research includes the Carl Trygger Foundation, the Swedish Research Council, the Smart Textiles Initiative (VINNOVA), the European Scientific Network for Artificial Muscles and the EU's 7th Framework Programme.


CPCA 2017 SHOW
7-9 March 2017
National Exhibition and Convention Center (Shanghai)
第26届中国国际电子电路展览会
China Int'l PCB & Assembly Show

EIPC Workshop on PCB BioMEMS

by Alun Morgan
EIPC

The Premier Inn conference centre at Heathrow Airport was the venue for the EIPC workshop on PCB BioMEMS. What, I hear you ask, is a PCB BioMEMS? This is an abbreviation for biomedical (or biological) microelectromechanical systems, otherwise known as lab-on-chip. Given the strong market pull for more BioMEMS devices (USD $2.5 billion in 2014 and anticipated to grow at CAGR of more than 25% from 2016 to 2023), the commercialization of lab-on-chip devices is currently the Holy Grail of the research community. The lab-on-PCB approach (aka PCB BioMEMS) is being followed in various research groups all over Europe, owing to its inherent upscaling potential: the PCB industry is well-established all around the world, with standardized fabrication facilities and processes is currently commercially exploited only for electronics.

The workshop began with an introduction from Dr. Despina Moschou, 50th Anniversary Prize Fellow/Lecturer at the Centre for Advanced Sensor Technologies at the University of Bath. It was Despina who first introduced the concept of PCB BioMEMS to the EIPC at its Summer Conference in Edinburgh in June 2016, which ignited interest. She asked why lab-on-chip is not already more established using PCB technologies to provide the needed integration between the microfluidics, the biological elements and the electronics required to form an analytical system highlighting the long-standing industrial infrastructure, microfabrication capabilities and intuitive integration of electronics.

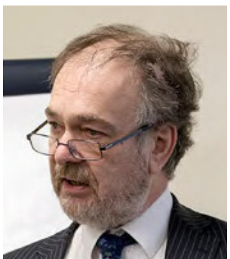

Dr. Despina Moschou

The first speaker was Dr. Yuksel Temiz of IBM's Zurich Research Laboratory. Dr. Temiz explained that although there are over 1,400+ infectious species and 347 significant diseases, less than 5% of their prevalence has been accurately


Dr. Yuksel Temiz

mapped. He postulated that the use of IoT-based devices linked to Smartphones or a handheld reader could revolutionise infectious disease mapping. He contrasted conventional lateral flow technology, such as that used in pregnancy detectors noting that microfluidics technology would require a much smaller sample size and optimised flow control to give much better quantitative results when used in a portable immunodiagnostic microfluidic platform.

Dr. Temiz then showed a fascinating video of a microfluidic system incorporating valve, reagent mixing, flow splitters and capillary pumps but on a microscopic scale. Being based in Switzerland, Dr. Temiz couldn't resist explaining "Chip-olate," which is a high-throughput fabrication and efficient chip singulation technology having closed microfluidic structures taking advantage of dry-film resists (DFRs) for efficient sealing of capillary systems. The outlook was shown as including microfluidic chips with autonomous capillary driven flow, integrated receptors with controlled release of detection antibodies, assay validation and compact readers including Smartphone integration. Dr. Temiz closed with an explanation of microflow monitoring with the use of integrated electrodes.


Dr. Peter Hewkin

Dr. Moschou then introduced Dr. Peter Hewkin, CEO of the Centre for Business Innovation (CfBI) whose organisation creates international collaborative communities and runs a consortium, MF-8, which brings together stakeholders in Microfluidics from across Europe and the USA.

MF-8 members were invited to the workshop with the purpose of bringing together European academics working on PCB-based LoC devices, providing the PCB industry with information on lab-on-chip technology/potential/challenges and to promote synergies between academics, PCB and the microfluidics industry amongst all interested stakeholders. Peter explained that microfluidics is about doing chemistry on a tiny scale and trying to emulate nature, in our bodies microfluidics is manifest in capillaries with their large surface area. It was noted that microfluidics is a term covering feature sizes in the range of 10^{-9} to 100 and a key feature is to use as little reagent as possible. Applications were identified as medical devices, drug delivery, point of care diagnostics, genomic diagnostics, high throughput screening, environmental sensing and chemical synthesis. Hewkin went on to describe how applications could be lead to personalised medication whereby drugs could be tested on a cell, tissue or even organ on a chip simulating an individual's personalised response before applying the drug to the patient. The potential for such personalised medication would lead to a drastic reduction of unnecessary or ineffective drug use and much quicker diagnostic and treatment regimes. For now, the focus is on medical uses, however the technology could also be beneficial in testing water, air, food and crops in a future connected world.

The traditional model of table top or large chamber reactors in laboratories employing large numbers of skilled analytical staff could be effectively replaced with single use microfluidics devices employed at the point of care. It was noted that workload of traditional testing laboratories is reducing by around 5% per year as diagnostics functions are becoming more distributed and less centralised.

Hewkin asked, "Is there a market?" This was answered with a resounding "Yes," supported by a series of charts showing growth in medical markets with the USA leading the way. Current mass market applications were identified as pregnancy and blood glucose testing. There are obstacles to gaining approval from regulatory authorities for new devices, but once approval had been granted this gives a commercial advantage as a barrier to competition.

Hewkin explained that the microfluidics market is highly fragmented and showed many examples of real product examples including a sweat sensor and an electrochemical immunoassay system. In concluding Hewkin highlighted the opportunity to embed microfluidic functionality into electronic devices and vice-versa and left us with the knowledge that 40% of all microfluidic disposable systems already integrate some electronics content.

Next, we heard from Prof. Lienhard Pagel, Professor for Microsystems at the Faculty of

Prof. Lienhard Pagel

Computer Science and Electrical Engineering at the University of Rostock, Germany. Prof. Pagel contrasted the differences between using silicon and PCB technologies for MEMs. He noted the advantage of rapid prototyping with PCB MEMs, but identified the disadvantages of minimum feature size in the 20- to 100-micron range and the relatively high tolerances. But he asked, "Who needs nano structures?"

Pagel went on to explain that systems could be categorized into two basic structures, microstructures in the range of 10 to 300 microns and macrostructures in the range of 0.3 to 10 millimetres. He explained that microstructures are characterised by low flow and features produced by chemical processes whereas macrostructures are characterised by high flow and features produced by mechanical milling processes. Some systems integrate both micro and macro channels in a single package and Pagel considered the key to success was the integration of microfluidics and electronics in a stacked system. He described a project whereby apertures to be used as microfluidic channels were formed in a PCB structure using multilayer lamination techniques. Pagel explained that the project faced some challenges, especially of delamination in the low-pressure areas but these were eventually overcome using a two-stage production technique and the application of no flow prepregs.

The next example was that of a CO2 insufflator, which is a device used to inflate body cavities during laparoscopic surgery and other minimally-invasive surgical procedures. These devices use flow rates of between one and 45 litres of gas per minute and achieve an intraabdominal pressure in the range of nine to 15 mmHg. Pavel showed the PCB design using embedded channels instead of discrete piping and integrated flow and pressure sensors. The PCB version of the insufflator achieved a significant size reduction from its predecessor and a cost reduction of 75%.

Pavel concluded by showing an example of a micro PCR (polymerase chain reaction) device for in vitro amplification of specific DNA or RNA sequences, allowing small quantities of short sequences to be analysed without cloning. PCR is a technique used in the diagnosis and monitoring of genetic diseases and studying the function of a targeted segment of DNA. The microfluidics version uses four integrated heating zones and eight CV (coefficient of variation) sensors in a single unit. The advantages of using PCB technology for this device were explained as short prototyping timeframe, low cost production and miniaturisation.

Dr. Angeliki Tserepi

Dr. Angeliki Tserepi of The Institute of Nanoscience & Nanotech at the National Centre for Scientific Research "Demokritos," Greece took the podium next. Tserepi expanded on the theme of DNA amplification principles using PCR and isothermal amplification, explaining that traditional techniques required 2–3 days for diagnosis; however, using a PCB solution could reduce that time to three hours. A microPCR design was shown fabricated on a thin flexible polyimide substrate with copper heaters defining each of the three thermal zones and a plasma-etched microfluidic channel. A flow rate of 8 µl per minute was established as the maximum flow rate for good linearity of the DNA amplification. Simulations performed allowed optimisation of parameters to achieve temperature uniformity and linearity of the temperature/resistance curve. The device demonstrated integration in lab-on-chip for a DNA-based pathogen detection system with sufficient amplification comparable to conventional thermocyclers. The system can use different thermal and flow templates to enable detection of a wide range of pathogens including salmonella for food safety and mycoplasma for pneumonia.

The benefits of using PCB technology for the system were explained as being quick, cheap, low power, reproducible and amenable to mass production. In addressing point of care/point of need diagnostics, food safety and in-the-field environmental analysis. Dr. Tserepi ended with showing a video animation of a prototype portable micronanobiosystem and instrument for ultra-fast analysis of pathogens in food.

A great big thank you to all our 2016 Geek-a-Palooza sponsors!

You are the wind beneath our wings, and we couldn't do it without you!

Join Team Geek in 2017!

2017 will be our biggest year yet, and now is the perfect time to get in on the action.

Become a sponsor

Geek-a-Palooza

We're ***stronger*** in numbers!


Prof. Manuel Quero

After lunch, Prof. Jose Manuel Quero of the SOLAR MEMS Technologies unit at the University of Seville, Spain explained that now was the right time for deployment of PCB technologies in lab-on-chip applications. He considered mature PCB technologies to be a natural partner to LoC development. Examples of devices, including a pressure sensor using capacitance changes in adjacent copper layers, a fluid impulsion device, a flow meter and nebuliser, were explained. The flow meter utilised a tiny wheel produced in copper with an opto coupler to detect and measure air or fluid flow. Flow focussing was the key feature of the nebuliser, using PCB technology to produce the flow focussing elements which can produce a very consistent bubble size for drug delivery. The fluid impulsion device was novel in that it used a fusible element formed in copper as a single-use microfluidic valve. This device demonstrated that a fully integrated microfluidic circuit can be implemented within a PCB substrate without the need of complex interfaces to external impulsion actuation. Quero explained that this technology also brings outstanding advantages of the possibility of integration with sensing and auxiliary electronics and a significant reduction in fabrication cost. A series of microvalves has been characterized varying their parameters of fabrication, leading to a device that requires 0.35 J of electrical energy and supports a range of differential pressures from 50 to 400 kPa.

Quero summed up by stating that PCB technology is a good candidate as a lab-on-chip substrate as its flexibility allows for a large diversity of devices and manufacturing techniques and was competitive as a mature technology for mass production of devices. In closing he emphasised the importance of technology transfer from academia to industry to take advantage of the synergies.


Prof. Stefen Gassmann

Next, we learnt about the requirements for fluidic PCB MEMS devices from Prof. Stefan Gassmann, of Jade University of Applied Sciences, Wilhelmshaven, Germany. Gassmann explained the route from the laboratory to full scale production and chose the examples of bubble detectors, active valves, analytical systems, micropumps, static mixers, pressure sensors and a water sample treatment system with which to whet our appetite. He considered the use of PCB technologies as a low-cost route to fabricating MEMS, often utilising non-standard properties. Gassmann explained that, to achieve success in novel application of PCB technology, it was essential to find the right PCB fabricator who was innovative enough to find solutions. A 5 cm x 5 cm monolithic chip system for a miniaturised flow injected analysis system for ferrite ion detection was the next example. The channel structures were formed from four PCBs with a polyimide film forming the pumps.

An example of the issues facing novel design was next expounded on a disposable device for genetic testing utilising 32 sensors for DNA detection on a 20μl sample. The device uses PCR for DNA amplification and it was very important that wetted parts should not inhibit the PCR process. It is known that many metals used in PCB fabrication can act as biocides and it was therefore decided to use gold-plated sensors which were known to be inert to the PCR process. However, after initial prototypes were built it was discovered that the standard gold plating was not pure enough with nickel and copper being detected at the

sensor surface. Gassmann explained that the solution eventually required a redesign of the sensor with a secondary solder mask defined gold-plated layer. The PCB fabricators in the audience were not at all surprised at this and an interesting discussion on precious metal plating technology ensued.

Gassmann closed by emphasising the need for innovative PCB fabricators to partner with technically minded researchers and commented that from "lab to fab" a special effort is needed.


Dr. Felismina Moreira

Dr. Felismina Moreira, post-doctoral researcher at BioMark Sensor Research in the School of Engineering of the Instituto Superior de Engenharia do Porto, Portugal, was next to address the audience. Moreira described a fabrication process for screen-printed electrodes (SPE) on conductive paper using a PVC, ceramic or PCB support. The biorecognition elements of the sensor used biomimetic techniques of molecular imprinting to make "plastic antibodies," the plastic being later extracted to form artificial antibodies. The technology was demonstrated with the example of a carcinogenic embryonic antigen detector using a silver electrode on a PCB support. Carcinoembryonic antigens are harmful substances (usually proteins) that are produced by some types of cancer; the test is used to check how well treatment is working in certain types of cancer. The electrochemical behaviour of the electrodes and the analytical response and selectivity of the detector were shown; this demonstrated the sensing materials stability and suitability for the task. Moreira closed by stating that PCB technology with silver tracks offers great advantages in terms of cost with real cost of each SPE in the range of a few Euro cents.


Prof. Frank Bier

The workshop then moved on to the subject of bioanalysis integration which was presented by Prof. Frank Bier of the Department of Biosystems Integration and Automation at the Fraunhofer Institute for Cell Therapy and Immunology, Germany. Bier explained that diagnostics are moving to where they are needed—the point of care. He stated that with an ageing society and better known biomarkers that diagnostics will be the pharma market of the future. He used an image of a "Star Trek" tricorder and went on to say that the best solution would be based on less infrastructure and miniaturisation but that diagnostic quality must equal that of a traditional laboratory. An integrated approach with new interfaces, perhaps expert systems and sensor ruled implants would form the necessary diagnostics as part of an early warning health system. Bier stated that it was critical to make the correct decision on technology early in the development cycle as this defines the ultimate cost of production and avoids falling into "Death Valley" on the product life cycle curve.

Bier ended his presentation with an introduction to the "Fraunhofer ivD-platform» which consists of a credit-card sized cartridge and a small read-out unit. By taking a small volume of sample and insertion into the Fraunhofer ivD-platform, assays based on a microarray are performed automatically. Within 10 to 15 minutes, a multitude of different parameters can simultaneously be measured and displayed. Bier explained that the platform minimises interfaces between the test cartridge and the measurement device and is an open platform for different sensor types including optical and electronic. Developments of the ivD platform are continuing and will cover new assay formats including nucleic acid based detection for antibody resistance, epigenetic patterns for transfusions and transplants, non-coding and circular RNA and liquid biopsy.


Steve Driver

Prior to the open panel discussion Steve Driver, the CEO of SCL PCB Solutions Group, addressed the delegates and thanked the speakers and participants in an enthusiastic address highlighting his passion for this technology and motivation to make products for an industry with a bright future. He echoed the sentiment around the room from those connected with

the PCB industry in wanting to be a part of this exciting future. Steve concluded by telling us that his Grandmother thought of a PCB as "that green thing in the back of a TV set." He explained that he now knew that it was a manifold for liquids!

The day ended with an open panel discussion led by Dr. Moschou where the interconnectivity between the technical and commercial aspects were further explored by an enlightened audience.

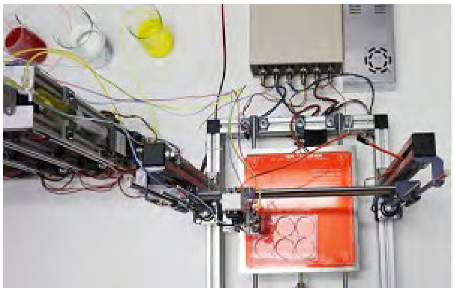
The event was attended by 25 delegates covering a wide spectrum of expertise from academia to industry. The organisers, EIPC, were very grateful to Dr. Despina Moschou of Bath University and Dr. Peter Hewkin of CfBI for bringing together such a knowledgeable and interesting group of delegates and speakers. PCB technology and medical advances rarely fail to surprise, this was especially true at this workshop where those from the PCB industry left excited about the role they could play in the advancement of technology that would transform medical diagnosis and much more besides! **PCB**

References

1. Centre for Business Innovation.

Alun Morgan is Chairman of EIPC.

Spanish Scientists Create a 3D Bioprinter to Print Human Skin



Scientists from the Universidad Carlos III de Madrid (UC3M), CIEMAT (Center for Energy, Environmental and Technological Research), Hospital General Universitario Gregorio Marañón, in collaboration with the firm BioDan Group, have presented a prototype for a 3D bioprinter that can create totally functional human skin. This skin is adequate for transplanting to patients or for use in research or the testing of cosmetic, chemical, and pharmaceutical products.

This research has recently been published in the electronic version of the scientific journal Biofabrication. In the article, the team of researchers has demonstrated, for the first time, that using the new 3D printing technology can produce proper human skin. One of the authors, Professor José Luis from UC3M's department of Bioengineering and Aerospace Engineering and head of the Mixed Unit CIEMAT/UC3M in Biomedical Engineering, points out that this skin "can be transplanted to patients or used in business settings to test chemical products, cosmetics or pharmaceutical products in quantities and with timetables and prices that are compatible with these uses."

This new skin is one of the first living human organs created using bioprinting to be introduced to the marketplace. It replicates skin's natural structure, with an epidermis and stratum corneum, which acts as protection against the external environment, together with another thicker, deeper layer, the dermis.

MilAero007 Highlights

Supplier Spotlight: American Standard Circuit's AS9100 Journey

I had the privilege of working with American Standard Circuits (ASC) over the past year with their successful pursuit of AS9100 quality management system certification. The company has chosen to share their approach, lessons learned and benefits gained by going through this formidable process.

Aerospace Robotics Market to Hit $4.54B by 2022

The market is projected to grow from $1.81 billion in 2016 to $4.54 billion by 2022, at a CAGR of 16.55% during the forecast period.

Sparton and Ultra Electronics JV Inks $30.3M US Navy Sonobuoy Contract

Sparton Corp. and Ultra Electronics Holdings plc have been awarded subcontracts valued at $30.3 million to their ERAPSCO joint venture, for the manufacture of sonobuoys for the United States Navy.

Tim's Takeaways: 'Sparks' to the Rescue in RF Design

Just like the early days of radio where Sparks the radio specialist was in demand to get the job done, we now need RF specialists to work together with electrical engineers to create the intricate designs required for RF circuits. You are now Sparks, the go-to specialist who will take care of RF design business.

FTG Receives New Long Term Agreement Worth Over $12M

Firan Technology Group Corporation has been awarded a new three-year long-term agreement (LTA) from one of the leading global OEMs supporting the aerospace market.

NASA Aeronautics in 2016: This is the Story

We are in the midst of an historic new era of X-planes research, including the continuing development of trailblazing green aviation technologies, and ever-expanding base testing of new air traffic management technologies.

PCi Purchases Keyence IM-6225 Instant Dimensional Measurement System

Rigid-flex circuit board manufacturer Printed Circuits Inc. has purchased an IM-6225 instant measurement system from Keyence.

Aviation Industry to go Faster with Real-time Data Analytics

The intensity of competition within the global commercial avionics systems market is expected to increase strongly over the coming years. Improvements in economy and the growing appeal and ease of air travel have generated a high buzz for all players in the global commercial avionics systems market and they are expected to ramp up development rates to match the demand.

Declining Defense Spending by Developed Economies Emerged as Major Cause of Concern

Only a handful of players dominated the global thermal imaging market in 2012, finds Transparency Market Research (TMR) in its latest report. Prominent companies such as DRS Technologies Inc., BAE Systems Inc., Raytheon Company, and FLIR Systems Inc., held dominance in the global market with a share of 75% in 2012.

Global Nanosatellite and Microsatellite Market Report

"The U.S. has continued offering lucrative opportunities for players operating in the global nanosatellites and microsatellites market. With an increasing number of companies looking to expand their footprint in the nation, the U.S. is likely to remain at the fore of the global market through forecast period," said a lead TMR analyst.

Why Trump Will Be Good for Our Industry

by Steve Williams
THE RIGHT APPROACH CONSULTING

Introduction

Regardless of which side of the political fence you fall on, what matters most around any election are the policy implications. Taking the partisanship out of politics and looking strictly at the Trump policy promises, there is cause for optimism in business.

What Will it Look Like?

As I craft this edition of the column, we are still three weeks from Trump's inauguration, however, by the time you read this we will all have a few weeks under our belts of what a Trump presidency is going to look like. Personally, I would not be surprised if we see changes on Day 1, and I have great expectations for the first 100 days. Of course, any changes to the fundamental macro outlook will take time to materialize as we navigate through the near-term uncertainty of political transition, but early moves by the Trump transition team offer some strategic direction of things to come. On paper, if I were to list the issues and policy objectives each candidate ran under for U.S. President, Trump's campaign scorecard appears to be more in line with a pro-business and pro-growth outlook.

A Look Back

Before we look forward, it is instructive to look at the "business state-of-the-union" since the start of the millennium. The past 16 years have not been kind to business, and the last eight have been absolutely crushing. A little more than a year ago, 2015 closed with the first 10-year period in U.S. history where the annual growth rate of real GDP did not reach 3% (Bureau of Economic Analysis). The prior longest stretch was the four-year stretch from 1930 to 1933 during the Great Depression (Figure 1). The data coming from the Bureau of Labor Statistics shows the Labor Force Participation Rate is the lowest in more than 40 years, which means that companies are just not hiring (Figure 2). To add salt to the wound, while the unemployment rate for October 2016 was report-

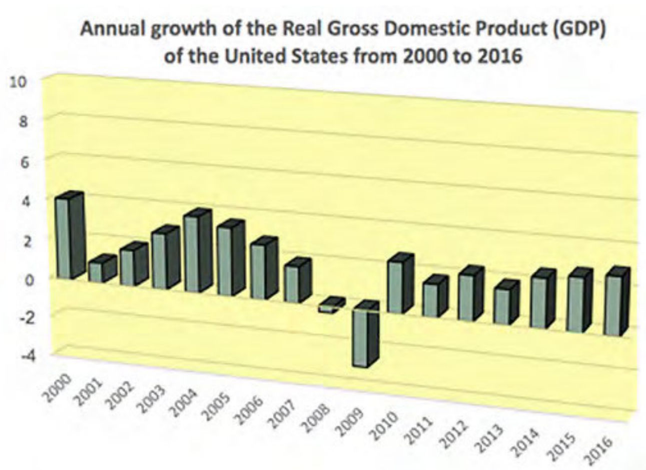


Figure 1: GDP annual growth rate. (Source: Bureau of Economic Analysis)

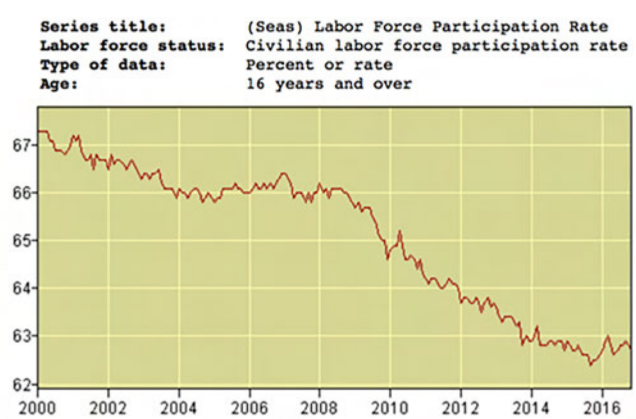


Figure 2: Labor participation rate. (Source: Bureau of Labor Statistics)


APEX EXPO IPC 2017
FEBRUARY 14-16
SAN DIEGO, CA
Visit us at
BOOTH # 3701
The very best in
PCB supplies
and equipment
MATRIX
CIRCUIT BOARD MATERIALS
Panasonic
Multilayer & Flex
Laminates
MADE EXCLUSIVELY
WITH
CIRCUIT FOIL
ADVANCED COPPER FOIL
High Quality ED
Copper Foils
JINZHOU
Drills, Routers & Endmills
KB
KINGBOARD
Rigid CCL
Hakuto
Film Laminators
1-800-668-5447 • www.matrixusa.us
TORONTO • SANTA ANA • SANTA CLARA • CHICAGO • MINNESOTA • OSAKA

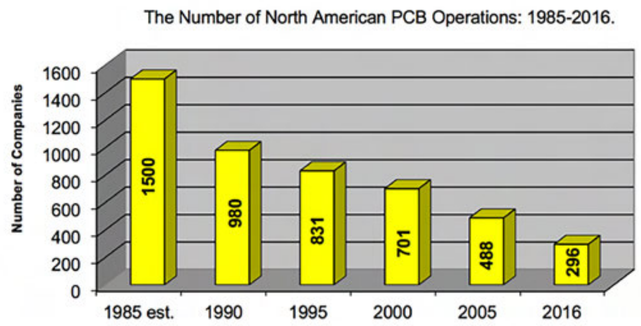


Figure 3: North American PCB operations. (Source: Harvey Miller, Fabfile Online)

Figure 4: U.S. trade deficit with China. (Source: Supply Chain Digest)

ed as 4.6%, according to the U.S. Department of Labor the Real Unemployment Rate (U-6) for October was 9.5%. This disparity is because the tens of millions of people that have quit looking for work are not counted.

The news specific to our PCB fabrication industry is even worse; the number of board fabricators has declined 55% over the past 16 years (Figure 3).

Trade Policy

One of the foundational messages of Trump's campaign was the destructive U.S. trade policies that, ironically, seem to favor everyone but the U.S. While I disagree that this is the major cause of the loss of U.S. manufacturing, it is certainly a contributor. This country was founded on the free market system, but looking objectively at the facts of the past 16 years is eye opening. While no one is saying "life is fair," the deck should not be so heavily stacked against U.S. success, and something needs to change. A trade deficit reflects the difference between U.S. exports to a country and the imports into the U.S. from that country. The deficit with China increased $22.6 billion to $365.7 billion in 2015, due to a combination of a $7.5 billion decrease in U.S. exports and a $15.1 billion increase in imports.

Figure 4 shows the annual trade deficit in goods between the U.S. and China with the cumulative deficit since 2000.

Renegotiation of existing trade agreements with the intent of benefiting the U.S. first should stimulate the economy, increase U.S. imports and work toward gaining a level-playing field for U.S. manufacturing. The collateral benefits may include a return of some lost jobs and an increase in U.S. manufacturing output.

Immigration Policy

We are the only country in the world whose immigration system puts the needs of other nations ahead of our own. The facts: According to the Heritage Foundation[1], there are currently over 11 million illegal immigrants in the U.S., with almost 8 million of them working. Out of the 8 million working, roughly 50% of them do not pay any taxes. The demographics show roughly half of all illegal immigrants are Mexican, with most of the other half coming from Central and South American countries. The costs for the United States have been extraordinary: U.S. taxpayers have been asked to pick up hundreds of billions in healthcare costs, housing costs, education costs, welfare costs, etc. Businesses share in the cost of supporting social programs, health care costs and other tax related burdens that are being used by a growing illegal population that is not paying for the benefits, a double-whammy.

The Trump Immigration Reform Plan consists of several actions, including:

- Securing the border
- Tripling the number of ICE officers
- E-verify businesses nationwide
- Deporting all criminal illegal immigrants
- Defunding sanctuary cities
- Enhancing penalties for overstaying a visa
- Ending welfare abuse
- Hiring American Workers First program

Implementation of any of the actions should provide an incremental benefit to business across the board.

Healthcare Policy

The Affordable Care Act (ACA, or Obamacare) enacted into law in March of 2010 has proved to be anything but affordable to the average worker and business. The ACA imposes fees and taxes on businesses of all sizes, but is particularly crippling to small business. Since the Small Business Administration reports that 65% of net new jobs are created by small businesses, this is a major issue for the U.S. economy. One of the many legislative mandates is the employer mandate, which requires employers with greater than 50 full time equivalents to provide insurance to their full-time employees or pay a per month penalty. This mandate has forced employers to look at their business practices on hiring in total, but specifically when to hire full-time employees or part-time employees. The ACA further pushes businesses up against the wall by changing the definition of full-time as only 30 hours per week. As Figure 5 shows the impact of rising healthcare costs on business is staggering. While the annual cost of employee contributions to healthcare premiums have increased $3,950 over the past 16 years, employer contributions have increased $8,614, per employee.

The proposed Trump administration healthcare reform looks to include:

- Completely repealing Obamacare
- Making healthcare plans available nationally instead of regionally
- Creating full tax deduction for health insurance premium payments
- Improving Health Savings Accounts (HSAs)
- Requiring price transparency from all healthcare providers

The reforms outlined above will lower healthcare costs for all Americans, and businesses, allowing that money to go back into business growth and the economy.

Financial Policy

Markets are focusing on Trump's promise for tax reform, deregulation and investment. The stock market typically shows a bump after any election, regardless of party, however, as of this writing the Dow came within a single point of reaching the historic 20,000. Since the election, 17 Dow record closings have been set, which

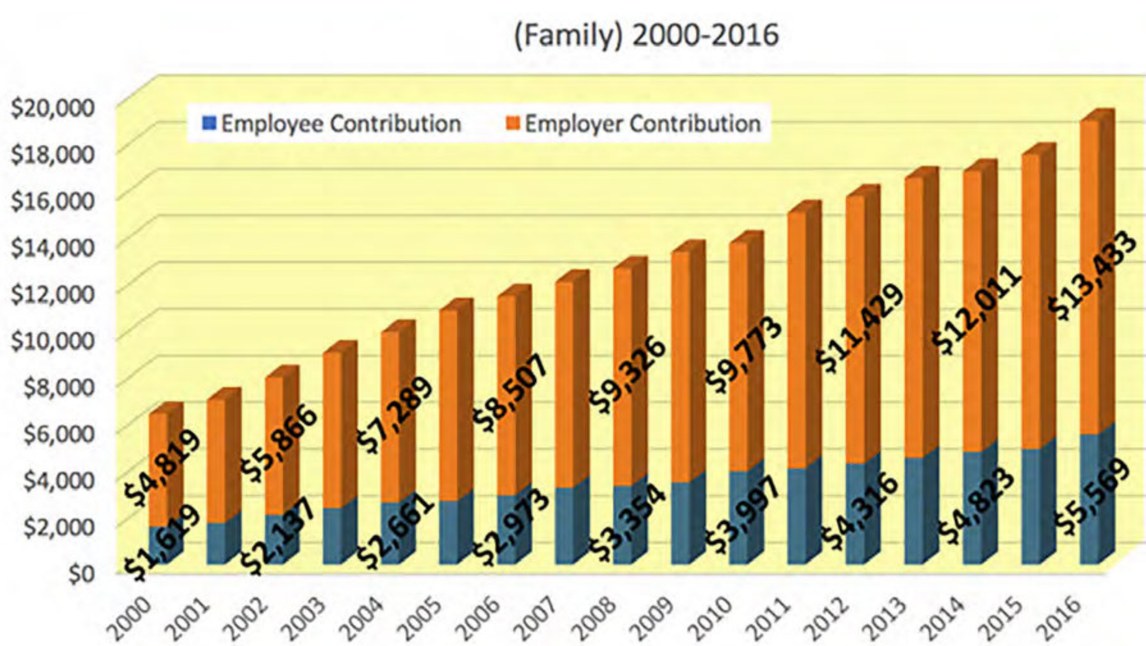


Figure 5: Healthcare premium contributions. (Source: Kaiser Family Foundation)

Figure 6: Dow Approaches 20,000. (Source: Reuters)

may be more than a mere bump. Businesses are excited about the upcoming potential to shed the restrictive tax and legislation constraints that have suppressed growth for a decade. If these campaign promise are kept, markets should continue to support this policy change of the guard. A sweep of government is generally embraced by markets, as it gives more ability to provide policy clarity and affect change. A pro-growth and pro-investment agenda, accompanied by the ability of Congress to break years of gridlock, should drive business growth, which will stimulate the economy.

Tax Policy

The United States has the highest corporate income tax rate among the 35 industrialized nations of the Organization for Economic Cooperation and Development (OECD). The combination of federal and state corporate taxes put the U.S. at 39%, which is tied with Puerto Rico for second highest rate in the world with only the United Arab Emirates (55%) higher. The low wages of low cost countries are mostly blamed for U.S. companies leaving to set-up shop on foreign land, but, in my humble opinion, the tax rate is the biggest factor. The other side of this coin is that our corporate tax rate make it cost-prohibitive for foreign organizations to put up plants in the U.S. The personal income tax situation is even worse; per the Pew Research Center, the top 20% of income earners pay 65% of all taxes, while the bottom 20% have negative tax rates, meaning they pay no taxes but receive tax refunds and/or benefits. While one-percenters take a lot of heat for "not paying their fair share," the fact is that they pay roughly 40% of all taxes. Why is this important to business? Because a majority of the high-earners are entrepreneurs and small business owners, which as discussed earlier, are the creators of a majority of net new jobs in the U.S.

The Trump tax reform vision currently looks like this:

- Reduce taxes across-the-board, especially for working and middle-income Americans who will receive a massive tax reduction
- Ensure the rich will pay their fair share, but no one will pay so much that it destroys jobs or undermines America's ability to compete
- Eliminate special interest loopholes, make our business tax rate more competitive to keep jobs in America, create new opportunities and revitalize our economy
- Reduce the cost of childcare by allowing families to fully deduct the average cost of childcare from their taxes, including stay-at-home parents

How will this be accomplished? Some of the key actions of the Trump Plan are:

- Collapse the current seven tax brackets to three with ~20% tax cut
- Repeal the death tax with provisions to protect against abuse
- Above-the-line childcare deduction for children under age 13
- Allow individuals to establish Dependent Care Savings Accounts (DCSAs)
- Lower the business corporate tax rate from 35% to 15%, and eliminate the corporate alternative minimum tax

Economic & Deregulation Policy

The electronics industry, and specifically printed circuit fabrication, is one of the most heavily regulated business segments. The EPA, RoHS, REACH, Dodd-Frank, Sarbanes–Oxley, Conflict Minerals, ad nauseam, are overburdening our industry, adding cost while not adding value.

The bureaucratic tide of red tape that threatens to drown U.S. consumers and businesses hit unprecedented record levels during the past eight years per a Heritage Foundation study[2] released in 2016. More than $22 billion per year in new regulatory costs were imposed on Americans in 2015, pushing the total burden for the Obama years to exceed $100 billion annually. Over the past two administrations, 16 years, over 1.1 million pages of new regulations have been put into law, with over 82,000 pages added during 2015 alone (2016 numbers are not published yet).

The Top Ten Ways the Trump Administration can roll back bureaucracy:

10. Boost regulatory review resources
9. Professionalize review, revision, repeal and sunsetting of regulations
8. Expand the number of rules requiring cost analysis
7. Scrutinize all agency decrees that affect the public
6. Enhance rule disclosure in the Unified Agenda of Federal Regulations
5. Track the accumulation of federal regulations as businesses sectors grow
4. Analyze and recognize deadweight and waste in Government
3. Freeze regulations
2. Develop and regularly publish a Regulatory Transparency Report Card
1. Establish the "Office of No"

A recent survey by The Wall Street Journal[3] states that business leaders say all Americans stand to benefit from a lighter regulatory touch that would boost profits, growth and hiring, particularly for small and midsize businesses.

Conclusion

In the wake of the November 8 election of Donald J. Trump as the next president of the United States, the country is battered and bruised, but from an economic standpoint, there's real reason for optimism. President-elect Trump has promised a lot, starting on Day 1. But now the rhetoric ends and the hard work begins. For the sake of our industry, I hope Trump is wildly successful as president.

Full Disclosure

I have studied Donald Trump for over a dozen years while teaching in the MBA program through case studies I created from his show The Apprentice. My business students analyzed, scrutinized and dissected the strategy and tactical execution of the tasks, and Trump's decision making skills. From a personal standpoint, I believe he will do what he said he will do: make America great again. **PCB**

References

1. The Heritage Foundation
2. Red Tape Rising 2016: Obama Regs Top100 Billion Annually, The Heritage Foundation.
3. Donald Trump Cabinet Picks Signal Deregulation Moves Are Coming, The Wall Street Journal.

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

Help Wanted! Our 2017 Industry Hiring Survey

In January, we conducted an industry-wide survey of our readers about their plans for hiring during the coming year. Included here is a summary of the results, which brought some surprising, along with not so surprising results. One result that we saw as a good sign for the industry was prompted by the very first question, which was, "Do you plan to hire additional people this year?" More than half of the respondents answered yes while about one-third said no. We take this as an optimistic sign that our industry plans to expand in 2017. For more information click here.

Metalizing Difficult-to-Plate Substrates

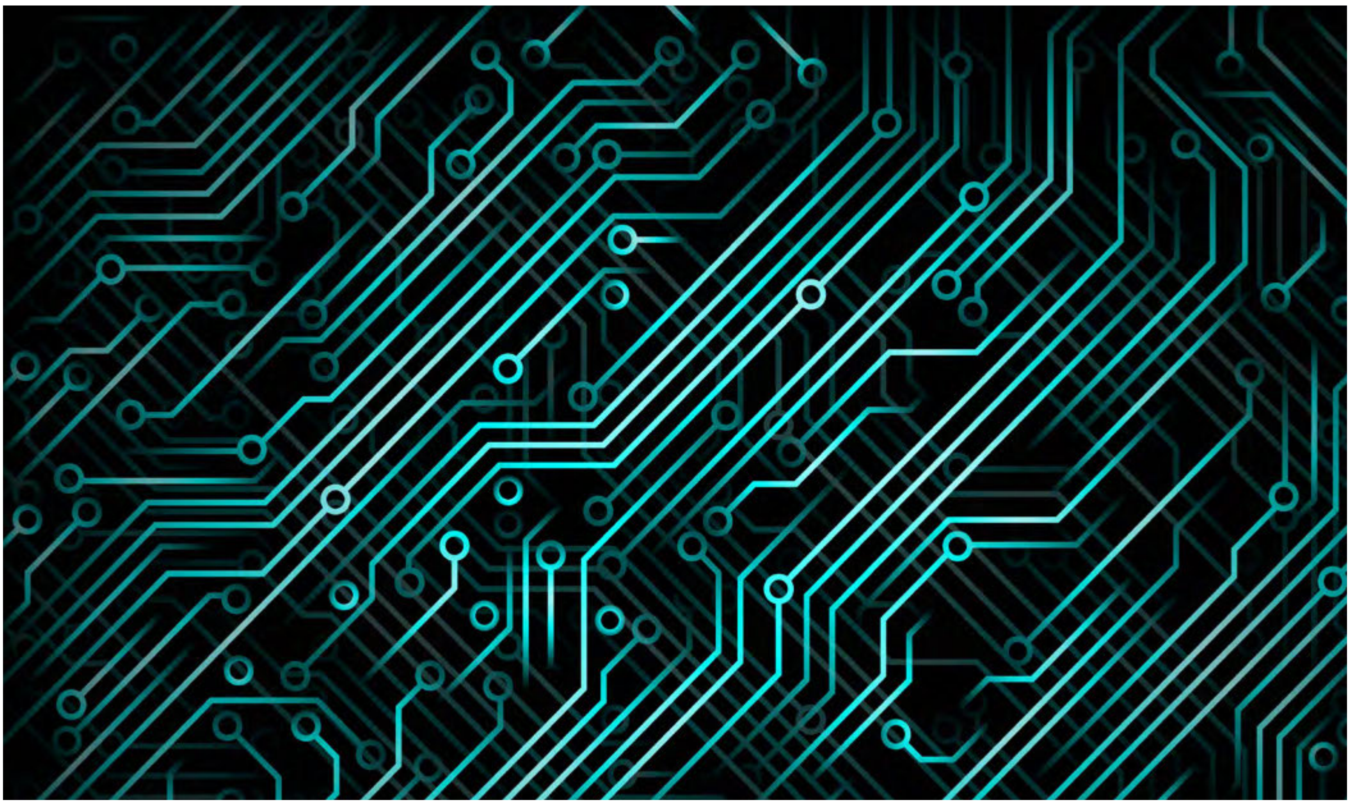
by Michael Carano
RBP CHEMICAL TECHNOLOGY

Introduction

Metalizing materials such as polyimide used for flexible circuitry provides a significant challenge for process engineers. Conventional electroless copper systems often required pre-treatments with hazardous chemicals or have a small process window to achieve a uniform coverage without blistering. It all boils down to enhancing the adhesion of the thin film of electroless copper to these smooth surfaces. In addition, internal stress in the copper deposit is a significant factor with respect to adhesion of the plated metal to the substrate. This process of plating on polyimide flexible materials is very much POP (plating on plastics). Electroless copper has been adapted for metalization of difficult to plate substrates and materials such as polyimide, POP and molded interconnect devices (MID). The author will present MID in a future column.

The Challenge of Metalizing Smooth Surfaces

One significant concern with metaliizing thin films over substrates is the concept of deposit stress. Hydrogen gas is a by-product of the electroless copper deposition process. Consequently, hydrogen may be incorporated into the thin deposit with a negative influence on internal stress. The hydrogen gas issue has been attributed to blister formation in the copper deposit. In addition, a challenge typically encountered on smooth surfaces such as polyimide-based flexible circuit materials is ensuring good adhesion of the electroless copper to the substrate. Adhesion of a thin film deposit to a substrate that lacks sufficient microroughness is compromised. To mitigate this issue, one solution is to reduce the internal stress of the copper deposit as much as possible.



Now, one remedy to minimize hydrogen gas effects on the deposit is to lower the surface tension of the electroless copper electrolyte. By lowering surface tension using specific wetting agents, the hydrogen gas bubbles are less likely to remain on the plated surface. The hydrogen gas issue not withstanding, one must also be concerned with electroless copper deposit stress. Excessive deposit stress will cause the copper plated deposit to blister or pull away from the substrate. Essentially this is a stress relief phenomenon.

It is well known that polyimide materials for flexible circuit fabrication have a rather smooth texture even after plasma desmear. Unlike most of the epoxy-based resin systems, polyimide for flex remains void of the micro-roughened surface texture generally experienced with alkaline permanganate chemical desmear. With these "anchoring" sites (Figure 1), one can see that there is ample surface area for which the thin film of electroless copper can adhere to epoxy-based resin systems.

Another limiting factor with respect to adhesion of copper to flexible polyimide is the low surface energy of polyimide films. Surfaces with low surface energy tend to repel chemical interactions, making it more difficult for process chemistry to effect good adhesion properties. In addition, flexible circuits are by design flexed and bent during their useful service life. Therefore, creating excellent adhesion of the plated copper to the substrate is critical to the functioning of the circuit. Certainly, plasma treatment of the polyimide material provides an improvement to the low surface energy of polyimide. However, such treatments often do not go far enough to insure long-term adhesion by relieving internal stress.

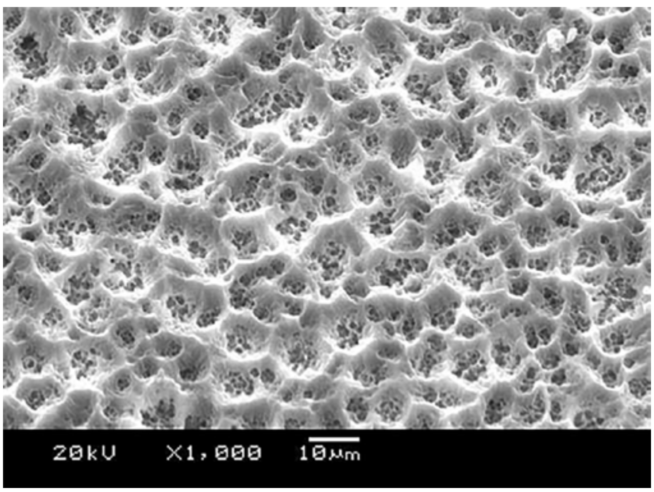


Figure 1: Hole wall after desmear with alkaline permanganate (rigid circuit board with epoxy resin-high Tg 170°C material).
Source: RBP Chemical Technology

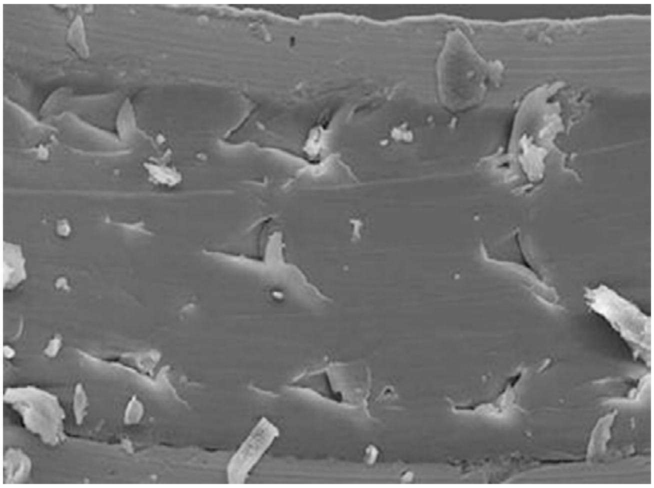


Figure 2: Polyimide flexible circuit after plasma desmear—note the smooth topography.
(Source IPC 9121 Process Effects Handbook)

The Influence of Stress

Stress in the electroless copper deposit can be either compressive or tensile. The copper deposit can be thought of as a spring that is either under tension (stretched), which is tensile stress, or compressed, which is compressive stress. Compressively stressed copper deposits lift or blister off smooth surfaces that lack anchoring sites such as adhesive-less polyimide flexible materials.

The spiral contractometer as shown in Figure 3 utilizes a strip of metal wound into a coil or helix. The unit is attached to the plating cell and the metal is then deposited on one side of the coil only. Depending on the type and extent of the internal stress, the coil will either expand or contract. If the deposit is compressively stressed, the coil will tighten. If the stress is tensile, the coil will expand. The contractometer is equipped with a gauge to measure quantitatively whether the stress is compressive or tensile.

Figure 3: Spiral contractometer for measuring internal stress in the plated deposit.

So it is somewhat obvious that excellent plating adhesion to the substrate is necessary for a circuit that will experience potentially many flexures over the course of its life. In addition, low to no stress in the copper deposit is preferred. It is important to keep in mind that adhesion of a thin film to a substrate is a complex mechanism. Internal deposit stress is just one factor. Additional factors affecting adhesion are:

- Ionic bonding between two surfaces
- Adsorption: adhesion is based on interatomic and intermolecular interactions such as van der Waals and perhaps Lewis Acid interactions
- Mechanical interlocking

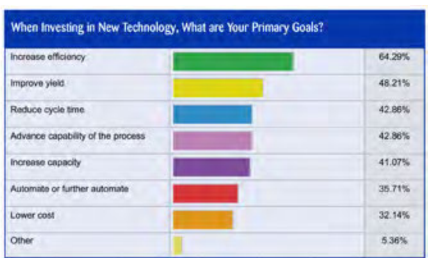
The last bullet point depends on the contribution from a roughened surface. In the case of flexible polyimide, a roughened topography is not achievable.

With respect to flexible polyimide, optimum adhesion of the electroless copper deposit is heavily dependent on internal deposit stress and adsorption of the palladium catalyst to a plasma desmear treated surface. Please keep these factors in mind when troubleshooting an adhesion issue. **PCB**

Michael Carano is VP of Technology and Business Development at RBP Chemical Technology. To read past columns or to contact Carano, click here.

I-Connect007 Survey: Investing in New Technologies

Manufacturing is undergoing the fourth industrial revolution (Industry 4.0), an era where we see new technologies and techniques transforming the systems and processes of our factories. Automation, IoT, analytics, and robotics, to name a few, are among the advances and strategies that electronics assemblers must embrace to improve their manufacturing performance, lower labor costs and create smarter factories. Electronics manufacturers are beginning to consider investing in new systems to take their processes to the next level.



In a recent I-Connect007 survey on the topic of new technology, the top reasons cited by manufacturers to invest in new technologies are to increase efficiency, improve yield, reduce cycle time, and the advance capability of the process. Adopting new technologies involves a heavy capital investment, but surprisingly, the majority of the respondents considered the capabilities of these systems as the most important factor when buying new equipment. Read more here.

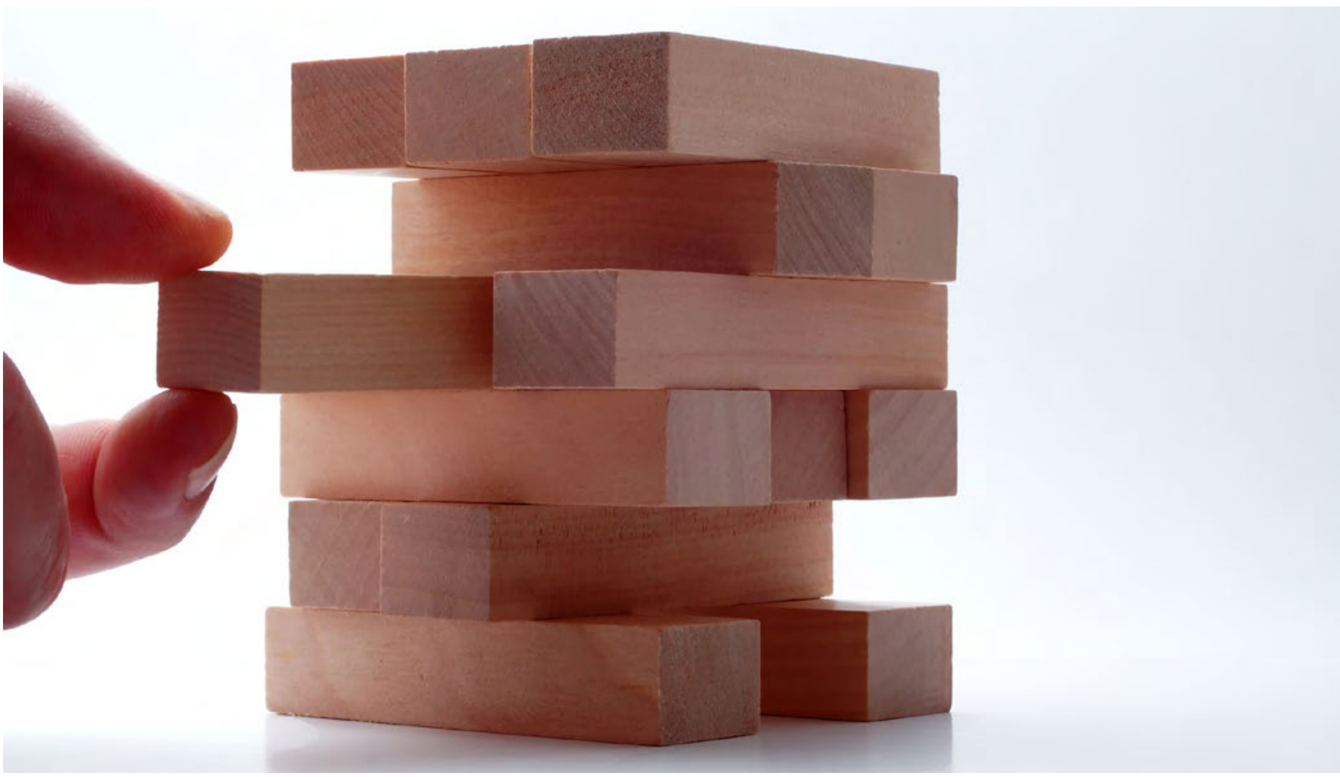
How Strong is Your Foundation?

by Keith M. Sellers
NTS-BALTIMORE

In my December 2016 column, we discussed the idea of supplier surveillance and that one should put into place some type of double-check to ensure that you are getting exactly what you've asked for, designed, ordered, etc. To take that idea a step further and to circle it back to the main industry we are discussing here, let's look at some of the testing that one might do under a supplier surveillance program as it relates to a standard printed circuit board—the foundation of most electronics in today's world.

The most obvious and commonly performed first steps in testing on bare printed circuit boards are a combination of as-received visual examinations and cross-sectional evaluations via microsection analysis. From an equipment standpoint, the as-received visual examination needs only a simple stereomicroscope with magnification up to around 100x. In the as-received state, the printed circuit board can be inspected for various anomalies, such as those pertaining to conductor widths/spacings, plated through-hole/via hole construction, and surface contamination, just to name a few.

A more in-depth inspection can be accomplished through microsection analysis, whereas the printed circuit board will need to be diced, potted in an epoxy resin, and then ground and polished to specific vertical and/or horizontal planes of interest. For this inspection, internal board structures can be intimately inspected and measured to ensure that the board has been constructed as you've designed or specified. Potential anomalies that could affect reliability down the road could also be identified. Of course, the sample preparation and inspection techniques needed for this type of analysis are a bit more involved as microsection analysis is as much art as it is science and then some type of metallurgical scope will be needed for the



actual inspection. For reference, to help guide you, documents such as IPC-A-600: Acceptability of Printed Boards[1] and IPC-6012: Qualification and Performance Specification for Rigid Printed Boards[2], are good guides for the good and the bad associated with printed circuit board constructions. Definitions of various industry terms are contained within, along with visual examples of acceptable and unacceptable structures.

> **A few additional tests that can be performed on incoming printed circuit board product include solderability and thermal stress analyses.**

A few additional tests that can be performed on incoming printed circuit board product include solderability and thermal stress analyses.

Solderability testing is just as it sounds and is performed to ensure that the metallic surfaces on a printed circuit board will wet with molten solder under standard test conditions. The test involves a commonly available soldering flux and a molten solder pot. A simple confirmation of whether the board can pass a solderability test, such as one called out in IPC-J-STD-003: Solderability Tests for Printed Boards[3], is a good place to start.

Thermal stress testing is also just as it sounds. A printed circuit board specimen is exposed to heat cycles via a molten solder pot to determine whether the board (and all its connections) can withstand the potential solder reflow cycles that the board might see during the assembly process yet to come. After exposure of the test sample to the solder reflow cycles, cross-sectional samples are prepared, as described above when we discussed microsection analysis, for another evaluation of the internal board structures—this one after a stress event. For a guideline, IPC-TM-650, method 2.6.8: Thermal Stress, Plated-Through Holes[4] is a commonly utilized test for thermal stress analysis.

So far, the testing mentioned in this column has dealt mostly with the "structures" associated with printed circuit boards—traces, plated through-holes, via holes, etc. Although these aspects of printed circuit boards are clearly important and relevant, there is another aspect of the board's construction that is equally as important, yet commonly overlooked. That aspect relates to the material which is used to physically construct the board, and its "structures"—the laminate. When designing and developing a printed circuit board, a laminate material is called out on the board's drawing. The material is chosen for various reasons, such as glass transition temperature, thermal expansion capabilities, and delamination (or more specifically, lack-of-delamination) properties, just to name a few. To investigate these types of properties, one must call upon the use of thermal analysis test equipment. Of specific interest would be a differential scanning calorimeter (DSC) and a thermomechanical analyzer (TMA).

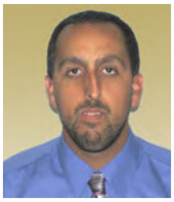
A DSC measures heat flow in or out of a test specimen as a function of time or temperature. Determining the glass transition temperature (Tg) of a board's laminate material is a commonly monitored material parameter, as the Tg value is an important factor when selecting the laminate material for the board's construction, due to the reflow profile that will be used during the board's assembly process. At the same time, degree of cure—a property which sheds light on whether a printed circuit board was cured properly—is also commonly investigated as an incompletely cured board can lead to board population issues during the assembly process. As a guideline, one can use IPC-TM-650, method 2.4.25: Glass Transition Temperature and Cure Factor by DSC[5] if interested in these properties.

A TMA measures distance change of a test specimen as a function of time or temperature. Although TMA can also be used to determine Tg, like DSC, it's more generally used to measure thermal expansion-related properties. Like the DSC testing described above, board designers also use thermal expansion properties of the board when designing the board's layout and when choosing the materials for the board's construction. A commonly used test method for measuring these properties is IPC-TM-650, method 2.4.24: Glass Transition Temperature and Z-Axis Thermal Expansion by TMA[6]. In addition to measuring the specific thermal expansion values, obtaining information about the board's ability to withstand delamination of its layers at elevated temperature can also be investigated via TMA. There is a group of test methods for this type of delamination testing, with IPC-TM-650, method 2.4.24.1: Time to Delamination (TMA Method)[7] the most commonly used.

Clearly, a variety of steps that can be taken to help ensure you're getting what you paid for…and doing any testing is honestly better than doing none at all. **PCB**

References

1. IPC-A-600
2. IPC-6012
3. J-STD-003B
4. IPC-TM-650, method 2.6.8E
5. IPC-TM-650, method 2.4.25c
6. IPC-TM-650, method 2.4.24c
7. IPC-TM-650, 2.4.24.1



Keith M. Sellers is operations manager with NTS in Baltimore, Maryland. To read past columns or to contact Sellers, click here.

NASA Selects Two Missions to Explore the Early Solar System

NASA has selected two missions that have the potential to open new windows on one of the earliest eras in the history of our solar system—a time less than 10 million years after the birth of our sun. The missions, known as Lucy and Psyche, were chosen from among five finalists and will proceed to mission formulation, with the goal of launching in 2021 and 2023, respectively.

"Lucy will visit a target-rich environment of Jupiter's mysterious Trojan asteroids, while Psyche will study a unique metal asteroid that has never been visited before," said Thomas Zurbuchen, associate administrator for NASA's Science Mission Directorate in Washington. "This is what Discovery Program missions are all about—boldly going to places we have never been, to enable groundbreaking science."

Lucy, a robotic spacecraft, is scheduled to launch in 2021. It's slated to arrive at its first destination, a main belt asteroid, in 2025. From 2027 to 2033, Lucy will explore six Jupiter Trojan asteroids trapped by Jupiter's gravity in two swarms sharing the planet's orbit, one leading and one trailing Jupiter in its 12-year solar circuit. The Trojans are thought to be relics of an earlier era in the history of the solar system, and may have formed far beyond Jupiter's current orbit.

The Psyche mission will explore a giant metal asteroid, known as 16 Psyche, about three times farther away from the sun than is the Earth. This asteroid measures about 130 miles in diameter and, unlike most other asteroids that are rocky or icy bodies, is thought to be comprised mostly of metallic iron and nickel, similar to Earth's core. Scientists wonder whether Psyche could be an exposed core of an early planet that could have been as large as Mars.

E-Newsletter Magic

by Barry Lee Cohen
LAUNCH COMMUNICATIONS

"Welcome to Our Newsletter!" How many times have your current or past employers welcomed customers to the first of what was touted to be a monthly or quarterly issue of your company's premiere digital publication? It's not a trick question, but it does make some of us think, "Oh yeah, whatever happened to it?"

You may recall there were promises made with expectations to deliver "news you can use," that would make your customers' lives easier and more profitable. However, just like the optimism and excitement of a first date, the second date often led to dashed hopes and disappointment. If published at all, subsequent issues were deployed whenever time permitted and communicated disappointing drumbeats of sell, sell, sell. To quote the legendary B.B. King, "The thrill is gone." The promise to deliver value was squashed. Opportunity for engagement was one and done—badly.

Please don't fret. Most assumed you would fail. Furthermore, they expected your pomposity. Your company's gallant attempts to communicate value were relegated to the dumpster of broken promises, low expectations and "me too" follow-through as witnessed by the many competitive organs that came before yours.

Don't be a victim of the dumpster. This column highlights ways to create e-newsletter magic.

Blast-off

• **Set Objectives.** Why do you wish to publish an e-newsletter? If the word "competitors" followed by the words "do it" is your reason, please stop reading. Dive into the dumpster now. You will fail. However, if any of your objectives include raising brand awareness, generating qualified leads, communicating expertise, as well as informing and educating on topics relevant to your customers, then read on!

• **Commit to an Editorial Schedule.** Even before you write the first syllable, you need to develop a plan that outlines the editorial focus with assigned articles for at least the first three (and preferably six) issues. It's like developing a marketing and sales plan or a technology roadmap. Determine an established frequency and resolve to keep to it for at least 18 months.

New ON IPC EDGE

IPC Essentials & IPC ESD Certification

IPC ESSENTIALS

IPC EDGE

- Simple to use online portal
- Convenient for you, open 24/7
- Keeps track of your training transcripts

IPC ESD Certification for Trainers (CET), and IPC ESD Certification for Operators (ECO)

ESD certification control for your company

- Fills a gap in the industry, developed by IPC and EOS/ESD Association Inc.
- Operators are trained by certified ESD trainers
- Certification complies with ANSI/ESD S20.20
- Verifiable and trackable certification record

IPC Essentials

IPC Essentials delivers

- Enhanced knowledge of IPC Standards and their applications
- Modules covered — standards development, impact on the electronics industry, standards training
- Increases knowledge and improves productivity for line operators, managers, executives and all those impacted by IPC standards
- Improvement to the certification programs
- A program requirement for CIT and MIT professionals

Visit www.ipc.org/edge for more details.

IPC EDGE Online Education and Training for the Electronics Industry

IPC EDGE

Note: Special events such as trade show participation and technical conference presentations, as well as product campaign launches, can and most often should be given a separate forum, whereas the e-newsletter should be employed as a support—not the primary—tactic to communicate your initiative. The e-newsletter should be considered a part of a more robust marketing plan.

• **Measure.** What does success look like? Set benchmarks that make sense for your business or promotion. Based on industry averages for your category, such measurements as increasing qualified leads by a certain percentage or driving targeted customers to your website to download a technical guide may be relevant. With today's diversity of e-newsletter platforms readily available, measurement of the effectiveness of the e-newsletter itself, as well as individual content can be measured by "opens" and "click throughs," as well as other coding and tracking methods.

• **TMI.** Too much information quite often sabotages the best e-newsletters. Remember, it's a newsletter, not a newspaper or a technical presentation. Structure content for each article so that it clearly communicates the most relevant details in the first paragraph, while eliciting curiosity that entices readers to click for more information. Furthermore, limit the number of articles per issue. Drive and track qualified visitors to your website or blog. Allow them to read the complete details and explore your site for further content. This exploration will enable conversions via blog comments, submission forms/landing pages, and other engagements.

• **Keep Above the Fold.** For most B2B markets in which I've been privileged to participate, approximately a third of customers will view e-newsletters via a mobile device, whereby scrolling through to find content can be tiresome. Even when linking the article titles below the masthead, not all content can be programed "back to top." Furthermore, the majority that will be viewing your e-newsletter via laptop or desktop will dedicate limited time to reading your masterpiece. Therefore, content placement "above the fold" ensures your most important communications appears on the screen with little or no scrolling.

• **Mobile-friendly is a Must.** As noted in the preceding section, viewings via a mobile device are significant and continue to grow. If it's been a while since you've updated your e-newsletter template, you're most likely losing readership and gaining opt-outs (unsubscribes).

• **Spam me! Spam Me!** A fatal sin is when your company uses one standard contact list to distribute their communications. Segregating and regularly updating distributions by industry, market, product, customer, prospect—or whatever is applicable for your business—is critical. Otherwise, you will upset (I'm being politically correct) those who feel you are invading their inboxes with frivolous information. Instead of maintaining or attempting to establish credibility, the e-newsletter may be rejected as spam or the contact will opt-out/unsubscribe from the e-newsletter and all future digital communications from your company. Ouch!

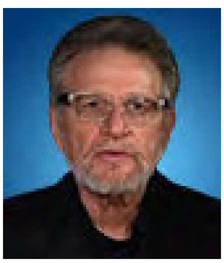
• **Be Respectful.** There's a delicate balance between imparting credible information about your company's product or service and distributing an all-out, chest-beating commercial. Even a single sentence buried within a well-crafted article can be a poison pill. Instead, subtly remind readers why they are or should be doing business with you. This is best demonstrated through the article content itself—that should include the publication of case studies, white papers, and technical articles, as well as award recognitions and industry certifications, to mention a few.

Let's be real. An e-newsletter is not going to make the sale. However, when published regularly with compelling content, it will create awareness and interest, thereby feeding the first stages of the sales funnel. I call this "e-newsletter magic." This magic opens the door to subsequent purchasing discussions and customer capture. **PCB**

Barry Lee Cohen is president and managing director of Launch Communications. To read past columns or to contact Cohen, click here.

Recent Highlights from PCB007

1 CES 2017: Disruptive Technologies



Those of you that have read my previous columns covering CES 2017 know that at recent CES shows I have seen many drones, autonomous cars, IoT devices, robots, and other items ranging from robots who stand in for your doctor to smart trash cans who tell you via Alexa, Google, or soon, Cortana, on your own computer, that since you have thrown away two empty milk cartons in the last few days it may be time to order more milk.

2 CES 2017: Press Day, Launch.It and Showstoppers

Before the show opens, CES provides two days and evenings not open to the general attendees, to enable companies, large and small, an opportunity to present their new offerings to the press. These opportunities range from small meetings with individual members of the trade press to huge events.

3 Flex Talk: A Glimpse into PCB Sales

Summarizing the feedback from both customers and manufacturers, the most successful PCB salespeople are organized, take a genuine interest in their customers' needs and business challenges, and have a better than average understanding of the PCB industry.

4 Weiner's World

Here are a few thoughts for the New Year and beyond from a long-term colleague and friend of the past half century, Harvey Miller, electronics market researcher, consultant and founder of Fabfile Online.

5 Emmy Ross Discusses the New I-Connect007 E-Book Series

One thing that is long overdue in our industry is a series of guidebooks focused on helping companies with all their needs, from qualifications like AS9100 and Mil-P-31032 to various technologies, heavy copper, rigid-flex and microvias. I-Connect007 is now providing our industry with an entire series of these guidebooks, starting with the first, "The Printed Circuits Buyers Guide to... AS9100 Certification."

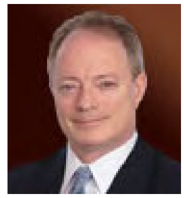
6 On Location at HKPCA: IPC's Mitchell and Carmichael on Asia, the Global Industry Outlook, and Trump

While in Shenzhen, China, recently, with the PCB industry's biggest trade show as a backdrop, Publisher Barry Matties sat down once again to interview IPC President John Mitchell and IPC Asia President Phil Carmichael. This time they discussed trends they're seeing in the Asia-Pacific region and what a Trump presidency means to the industry.

7 Top 10 Most-Read PCB News Stories of 2016

As the year ends, look back at the industry's highs and lows. The editors at I-Connect007 have compiled a list of the top 10 most-read news stories from the pages of PCB007. Join us for a look back at the most popular news highlights of 2016.

8 Punching Out! Types of Company Buyers in the PCB and EMS Sectors



Mergers and acquisitions in the U.S. PCB sector have been in the news recently, with at least 12 deals completed over the past year, and several more in the works. In contrast, the EMS sector has been relatively quiet, but that may change now that the presidential election is over.

9 PCB Maker Unimicron Developing SLP Products

Unimicron

Unimicron Technology has set aside a capex budget of NT$4.946 billion ($153.19 million) for 2017 to finance the development of substrate-like PCB (SLP) products and ramp up the production capacity of HDI boards and automobile boards.

10 All About Flex: Are Manufacturing Companies Susceptible to Ransomware?

Every business (and every individual) needs to pay attention to cyber security. There are many sophisticated hackers throughout the world looking for ways to access or corrupt systems. While manufacturing companies have not been a common target, there are certainly risks that need to be considered.

For the latest PCB news and information, visit: PCB007.com

Events

For IPC Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar of Events, click here.

For the complete PCB007 Calendar of Events, click here.

MD&M West
February 7–9, 2017
Anaheim, California, USA

IPC APEX EXPO 2017 Conference and Exhibition
February 14–15, 2017
San Diego, California, USA

China International PCB & Assembly Show (CPCA)
March 7–9, 2017
Shanghai, China

14th Electronic Circuits World Convention
April 25–27, 2017
Goyang City, South Korea

IPC Reliability Forum: Manufacturing High Performance Products
April 26–27, 2017
Chicago, Illinois, USA

KPCA Show 2017
April 25–27, 2017
Goyang City, South Korea

IMPACT Washington D.C. 2017
May 2–3, 2017
Washington, D.C. USA

Thailand PCB Expo 2017
May 11–13, 2017
Bangkok, Thailand

JPCA Show 2017
June 7–9, 2017
Tokyo, Japan

IPC Reliability Forum: Emerging Technologies
June 27–28, 2017
Düsseldorf, Germany

SMTA International 2017 Conference and Exhibition
September 17–21, 2017
Rosemont, Illinois, USA

electronicAsia
October 13–16, 2017
Hong Kong

IPC Flexible Circuits: HDI Forum
October 17–19, 2017
Minneapolis, Minnesota, USA

TPCA Show
October 25–27, 2017
Taipei, Taiwan

PUBLISHER: **BARRY MATTIES**
barry@iconnect007.com

SALES: **ANGELA ALEXANDER**
(408) 489-8389; angela@iconnect007.com

MARKETING SERVICES: **TOBEY MARSICOVETERE**
(916) 266-9160; tobey@iconnect007.com

EDITORIAL:
MANAGING EDITOR: **PATRICIA GOLDMAN**
(724) 299-8633; patty@iconnect007.com

TECHNICAL EDITOR: **PETE STARKEY**
+44 (0) 1455 293333; pete@iconnect007.com

MAGAZINE PRODUCTION CREW:
PRODUCTION MANAGER: **MIKE RADOGNA**
mike@iconnect007.com

MAGAZINE LAYOUT: **RON MEOGROSSI**

AD DESIGN: **MIKE RADOGNA, SHELLY STEIN, TOBEY MARSICOVETERE**

INNOVATIVE TECHNOLOGY: **BRYSON MATTIES**

COVER: **SHELLY STEIN**

COVER IMAGE: **© AGSANDREW, ADOBE STOCK**

I-Connect007 Presents
the pcb magazine

The PCB Magazine® is published by BR Publishing, Inc., PO Box 50, Seaside, OR 97138

February 2017, Volume 7, Number 2 • The PCB Magazine© is published monthly, by BR Publishing, Inc.

ADVERTISER INDEX

Coming Soon to *The PCB Magazine:*

MARCH:
The Wide World of Flex:
Materials, handling and the varied types of flex circuitry.

APRIL:
High Performance Materials

MAY:
Help Wanted!