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June 2016

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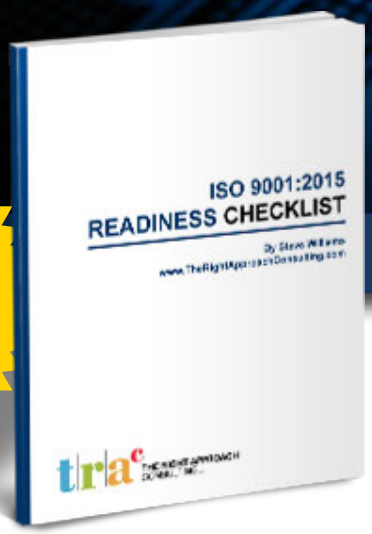

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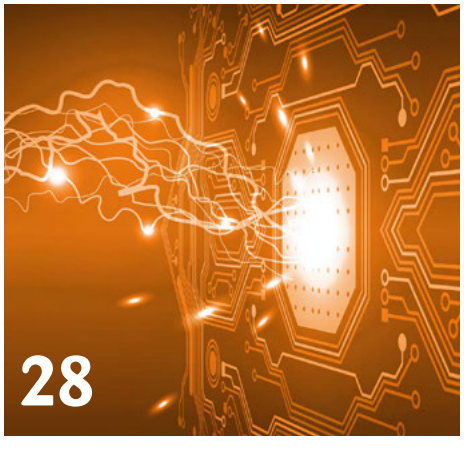

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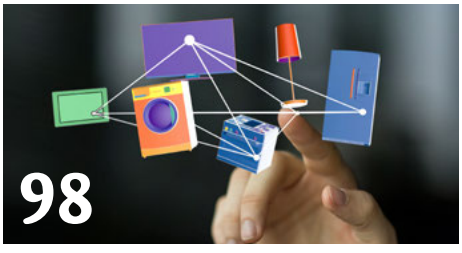

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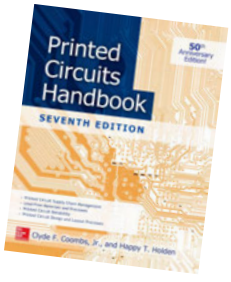

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Impacting the Industry–Literally

by Patty Goldman
I-CONNECT007

Unless you have been living under a rock or in a cave for the past six months or so, you should be aware (and perhaps astounded, astonished, amazed, dumbfounded, aghast…) at the presidential campaign goings-on. Dear heaven! But without going into detail or expressing an opinion, I thought I would share some highlights of my recent visit to our nation's capital. I attended IPC's IMPACT Washington, D.C. for the first time, though hopefully not for the last. It is a conference, an event, a seminar on the workings of our government, along with meetings with congresspersons and staff, all crammed into just a couple of days.

One afternoon I walked down to the National Mall, observing the numerous huge, very permanent stone buildings along the way. I walked past the EPA, OSHA, and IRS buildings, the Department of Justice and the FTC. There is the Capitol building on one end of the Mall, the Washington Monument on the other, and the White House just to the north, next to the Treasury Department. Congressional offices, the Library of Congress, the Supreme Court, other departments (Agriculture, Commerce, Transportation, Education, HUD, FDA, U.S. Postal Service and more) surround the Mall. This city definitely has the corner on white stone. And these departments with names engraved in huge letters are not going anywhere. They are here to stay; they will not be abolished, and they don't care a whole lot about you or your company.

Nevertheless I came away a believer, not so much in the workings of our government but in the need to participate, speak up, and have your voice heard. And the best way to do that is collectively, through an organization that has your best interests in mind. I feel so strongly about

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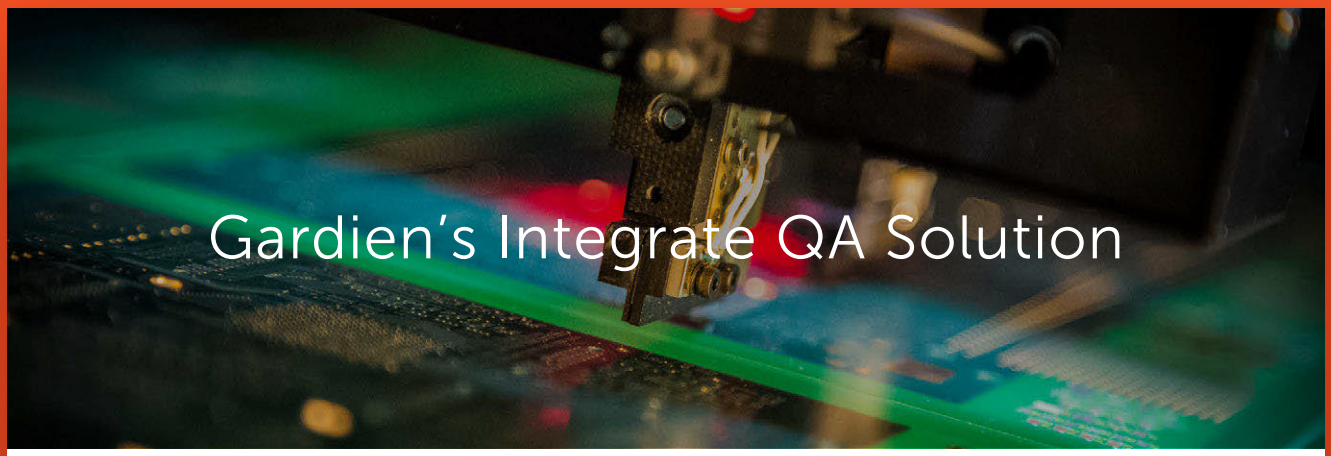

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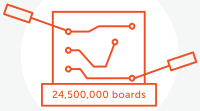

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this that I think I've become an IMPACT evangelist! To this end, we've created a special section in this month's magazine to help you learn more about IMPACT (which I don't believe is an acronym but just what you want to have—an impact). It mainly consists of a number of interviews I did with participants—possibly your customers, suppliers, and colleagues—plus an intro by me. Definitely worth a read. And I hope large numbers of you are inspired to do more than just read. Let me know!

Besides the IMPACT section, we do have much more for you this month. Your and my favorite author, Happy Holden, is back at it and full of info as usual—and this time his subject is landless vias. What finer feature is there than… none? As in no land, no pad. Doesn't that open up a bit of space on the circuit board? And the technology is there—for quite some time. Perhaps a feature whose time has come?

Next up is columnist Dave Becker of All Flex Flexible Circuits who gives us a short primer on laser direct imaging, especially as it applies to flex circuit processing. Direct imaging is pretty much a requirement for today's finest features.

We have a wonderful technical paper from Tobias Sponholz, et al., of Atotech Deutschland, which was originally presented at IPC APEX EXPO in March. It is a highly detailed paper on high-throw electroless copper processes specifically designed for very small holes and blind vias.

Right smack in the middle of everything are the IMPACT interviews.

We next have our troubleshooting columnist Mike Carano of RBP Chemical with a discourse on the developing process, which is a great follow-up to the earlier column on imaging. As always, Mike gives us plenty of helpful info and advice along with a better understanding of the process.

And now for an article that carries forward last month's topic of automation and reducing handling, and that is Alex Stepinski's detail on automating Whelen Engineering's new PCB fab operation. Alex gives plenty of detail and how-to in this paper that was originally presented at IPC APEX EXPO this year. It's a must-read for anyone thinking about handling and/or automating a process.

Finally, we are introducing a new columnist Barry Lee Cohen (BLC), of newly opened, Launch Communications. His inaugural column, *Launch Letters,* focuses on exceptional service, which he illustrates with an everyday example you will all relate to. Look for Barry's columns on marketing-related topics every month, with plenty of valuable tidbits.

Summer is upon us and wouldn't it be nice to take a week or two and forget about the shop and all the myriad issues, problems, deadlines and such? Ha, not in the electronics industry! I suppose we all wonder what it would be like to work in a different industry at a slower pace. Uh, how about boring? Because with the hectic schedules and headaches comes the adrenalin rush to meet that deadline and the satisfaction of solving a production problem to ship on time, not to mention just having made the most complicated, intricate PC board ever and isn't it beautiful? Who doesn't love the excitement, often lying just below the surface (perhaps pushed down by those pesky crises), of being in the fastest moving industry in the world, in fact the industry that is shaping and making the world we live in the most exciting ever.

So there's a little bit of inspiration for you. Let everyone else think we're crazy. Next month will be another issue filled with the practical stuff you need to do your job. The topic is inspection and test, and we'll try to bring you everything you need to know on that subject.

If you haven't already, subscribe now and be sure to make I-Connect007.com a "safe sender" so you will get it without delay. **PCB**

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

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Against the Density Wall:
Landless Vias Might be the Answer

by Happy Holden
PCB TECHNOLOGIST, RETIRED

You may not know about landless vias. This has been a well-kept secret for the last 30 years, possibly because it is not permitted on military boards, and therefore, discouraged in all IPC standards. Consequently, when our Japanese partner, OKI Electric, showed us their landless via boards, we said, "You can't do that; the vias have to have lands!" They replied, "You've been listening to IPC again! Try it out and test it!" So we created a test vehicle and tested thousands of vias with various diameters against numerous annular ring vias. Guess what? They were right! As the annular ring got smaller, the failures occurred earlier until we got to landless, and then they jumped to 10X fewer failures.

Not understanding this result, the PhDs of HP labs went to work and came up with an explanation (included in this paper). This was so radical a discovery that HP made the data, explanations and results proprietary and a company secret.

Introduction

I saw my first landless via multilayer while visiting NEC at Toyama, Japan back in 1985[1]. They were an enormous automated facility making Japanese telecom and mainframe computer boards, kind of like IBM and Western Electric rolled into one. NEC was using the liquid electrophoretic, positive-acting photoresist process with panel-plating. I wouldn't see another landless via multilayer until our Japanese partner (OKI) introduced it to us in 1988. OKI was using the landless vias to achieve higher density without having to pay the extra costs of finer lines. They knew about the higher reliability that resulted, and they had done their own testing (Figure 1), but were after the higher routing density (Figure 2) and it allowed them to route five traces between 0.100 inch PTH centers.

The Electrodeposited-Positive Acting Photoresist

My first introduction to the positive-acting photoresist (+PR) was at Hewlett-Packard's integrated circuit fabrication facility in Palo Alto, California in 1970. HP used this in the liquid form and it was spin-coated on wafers. The photoresist was supplied by Shipley Company of Newton, Massachusetts. I was further exposed to the +PR after moving to the printed circuit fabrication facility. It was not being used on PCBs, but on metal photo-chemically machined

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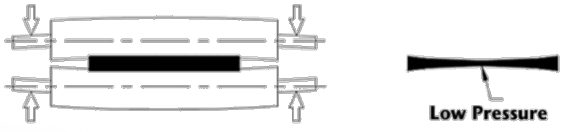

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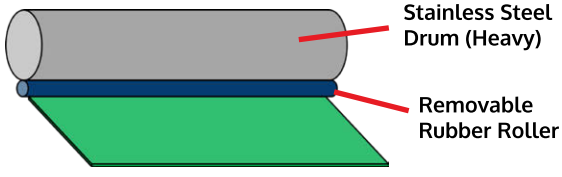

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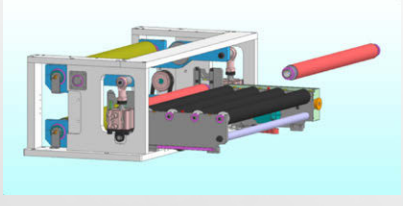

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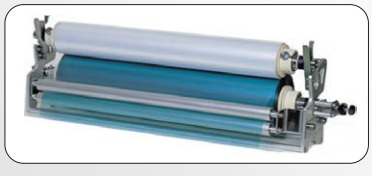

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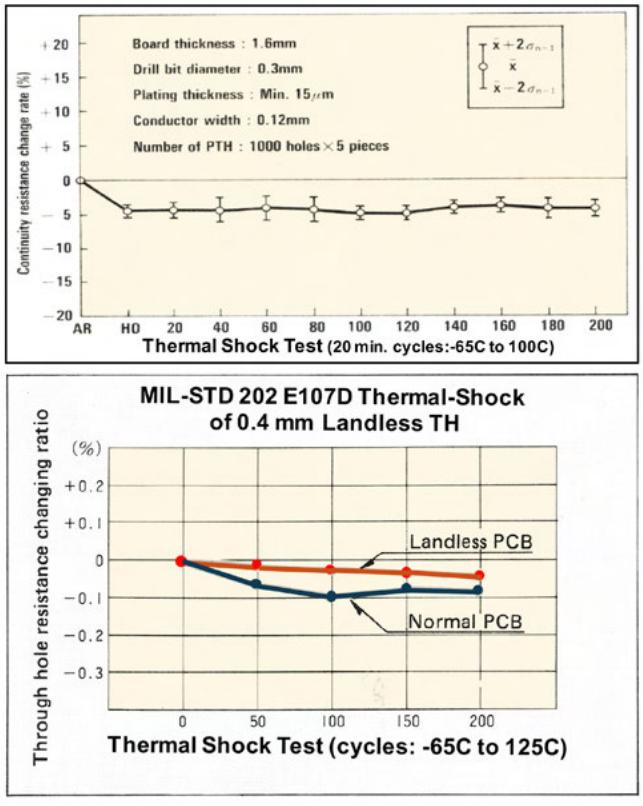

Figure 1: Reliability data from NEC on their landless via fabrication process[1].

parts that were also made in that facility. The advantage of the +PR was that it was extremely resistant to the ferric chloride etchant and it could be used in 'progressive' exposure and etching. That is, the metals could be etched, then new artwork would expose additional metal that could be etched, etc. In this manner, 3D features could be etched in the various metals. (Technical details on this type of photoresist, the electrodeposition process, machinery and applications can be found in the technical papers in the *Reference* section, 2–5.)

Getting Over the Density Wall

When it comes to getting higher routing density, you only have five degrees of freedom:

- Smaller traces
- Traces closer together (spaces)
- Smaller vias (down to microvias)
- Smaller annular ring for the vias
- Higher layout efficiency when routing (definition in column #10-DFM/A)[6]

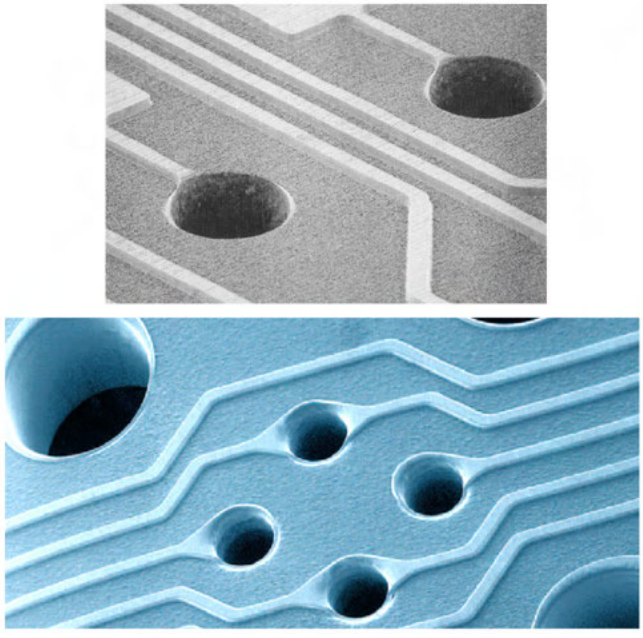

Figure 2: Typical landless vias on a Japanese multilayer from ~1985.

I'm talking about 'routing density' on a single layer; more signal layers will result in more total routing distance on a board. The equation for routing density is:

$$N = \left[\frac{G - (D_v + 2D_a) - C_s}{2C_w}\right]_{INT} \quad \text{(Eq. 1)}$$

Where:
N = number of traces in the channel
G = routing channel dimension
Dv = via diameter (FHS)
Da = via's annular ring
Cs = conductor spacing
Cw = conductor width

If you reduce some of the variables in this equation (Eq.1), then the resulting routing density will go up by the percent indicated in Table 1. Figure 3 shows the opportunity for maximum density routing using 0.004 inch traces with 0.004 inch spacing and landless vias. The largest effect on density is reducing the trace width, but this can come with electrical issues; the second best way to increase density is to reduce the via's annular ring (AR), but a very small AR will signifi-

Trace width (in)	Trace spacing (in.)	Finished hole size (in)	Finished hole land (in)	Routing density (traces/in)	Increase in density (%)
0.003	0.004	0.010	0.018	80 traces per inch	25 %
0.004	0.003	0.010	0.018	60 traces per inch	0 %
0.004	0.004	0.008	0.016	80 traces per inch	25 %
0.004	0.004	0.010	0.016	60 traces per inch	0 %
0.004	0.004	0.010	0.010 (ldls)	80 traces per inch	25 %
BASIS: channel=0.05 in; trace=0.004 in; spacing=0.004 in; FHS=0.010 in; annular ring=0.004 in					

Table 1: PCB design rules effect on routing density on one layer.

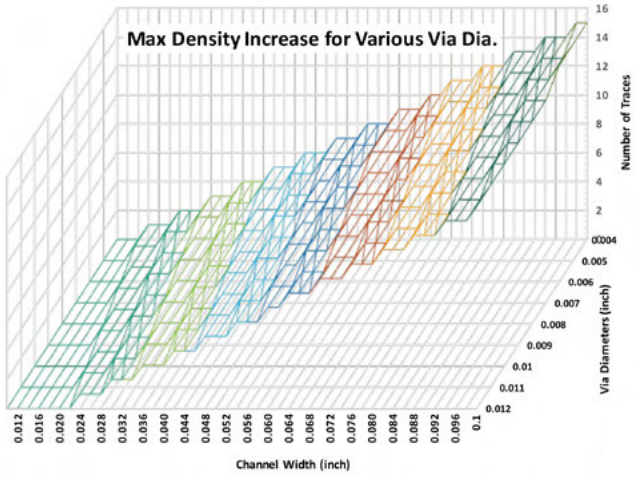

Figure 3: The maximum number of traces available for various routing channel widths as a function of via diameters when all the vias are landless.

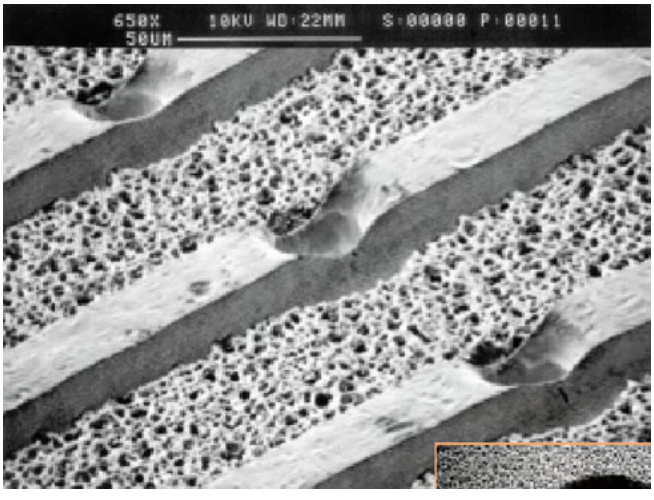

Figure 4: Landless via supplemented with the same diameter as the trace width, in this case 0.004 in. (0.1 mm). These are referred to as invisible vias.

cantly reduce the via's reliability. Therefore, landless is an excellent way to achieve higher density without reducing trace widths or spacings.

Because the number of through-holes on a multilayer block numerous routing channels all through the board, the use of blind and buried vias can significantly increase a layer's routing density, on the order of 2X to 4X without their use. This is also measured by layout efficiency (L.E.), the amount of space used for routing as compared to the entire area on the signal layer. L.E. is also enhanced by blind and buried vias, to the order of 2X to 4X. The L.E. for a through-hole multilayer is 8% to 10%; 16% with TH and blind-vias; to 24% for TH/with two-sided blind vias and multiple build-up layers. Some of the landless vias are seen in Figures 4, 5 and 6.

Landless Via Processes

There are numerous patent applications about landless vias. All require laser sculpting of the via or pinpoint laser exposure for the imaging. None of these have ever entered production. The two that have been used in high-volume production are listed here, with two additional techniques that appear to be very practical.

HP Process Learned from the Japanese

The Japanese process for making landless vias is very simple, but anyone I talked to never figured it out until I explained the process. It is a true example of thinking outside the box:

Whatever your registration tolerances are, then reduce the artwork land opening size by

that amount. When using dry film photoresist. The DF will now extend beyond the wall of the drilled hole.

1. Two things will happen with this arrangement: 1) the plating bath will be forced to throw into the hole, improving the distribution; 2) There will be no land except where the trace enters the hole.

2. After stripping and etching, there will be landless vias with the trace dropping into the barrel of the PTH or blind via.

3. This process does not work for panel plating. Then you have to use the next process like NEC.

Positive Liquid Electrophoretic Photoresist

When I first saw this process in Japan in 1985, they were using a positive-acting electrophoretic photoresist from Nippon Paint that evolved from the electrophoretic paints used on automobiles. A similar photoresist was available in the USA and Europe from Shipley. A more recent photoresist and process came from PPG Industries and is documented in a paper by Patricia Goldman (formerly of PPG) and Tim Schmidt of Compunetics[4]. The positive-acting photoresists have many properties that can be very useful. The most useful is multiple

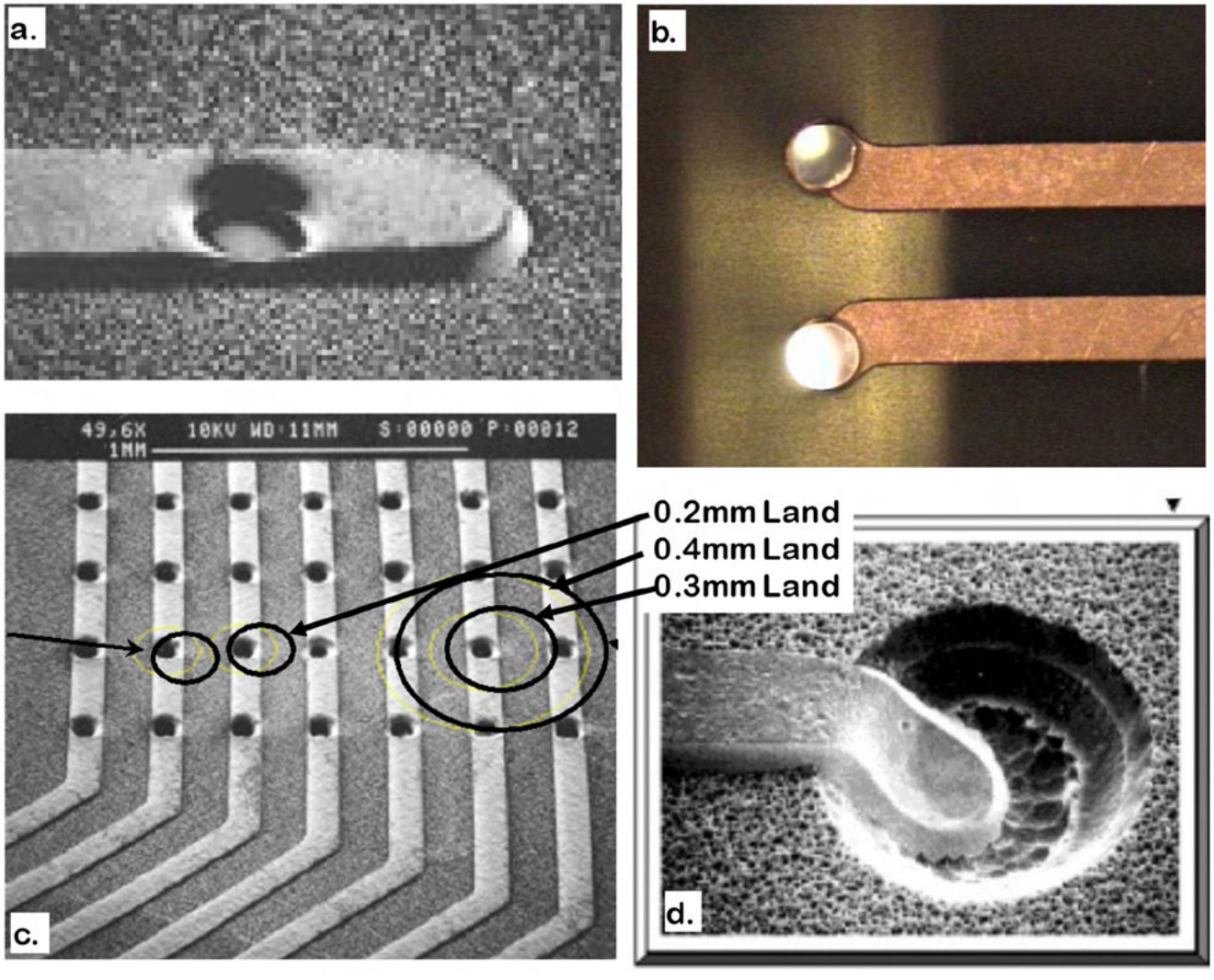

Figure 5: More landless vias including three more examples of invisible vias. a) Laser drilled 0.1 mm blind via in a 0.1 mm trace; b) two landless vias on a 0.008 in (0.2 mm) TH; c) The one view shows 0.2 mm pitch traces with 0.1 mm landless vias and the proportional size if there were 0.2 mm, 0.4 mm or 0.35 mm lands on the vias; d) 0.1 mm trace in a plasma-etched, 0.2 mm blind via.

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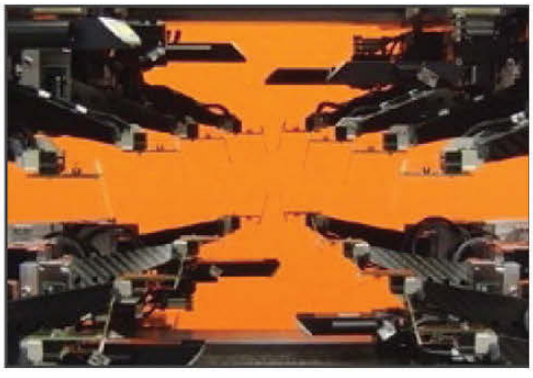

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- Bake dry

The panels are now ready for exposure or transportation. A finished via and trace are shown in Figure 6.

Perfect Registration

Now with the advent of direct digital imaging (DDI) and board scanning, it is possible to have perfect registration on both sides of a board. The DDI unit seen in Figure 7 has nine cameras that scan a panel as it enters the machine from both sides. Then, as it starts to expose each side, the artwork is modified on-the-fly so that each land is perfectly registered to its hole. Without high-speed computers, scanners and the new software, this was impossible before.

Novel Russian Technique

At a recent PCB West conference, I had a conversation with a Russian PCB fabricator. It seems the Russians also used landless vias after they saw it on Japanese computers. The Russian process was novel and I wish I had thought it up! They used the property of dry film photoresist's sensitivity to oxygen. When they laminate the dry film to the panel, they have a shroud around the unit filled with oxygen. Thus oxygen is trapped in the holes by the dry film. They expose the panel to their normal artwork (but there are no lands for traces that will interconnect to the landless vias). They then do a short 100°C bake of the panels, remove the cover sheet on the dry film and develop normally. The oxygen and heat has polymerized the dry film from the inside at exactly the same diameter as the hole. Thus when developed, the via has perfect dry film registration and is landless.

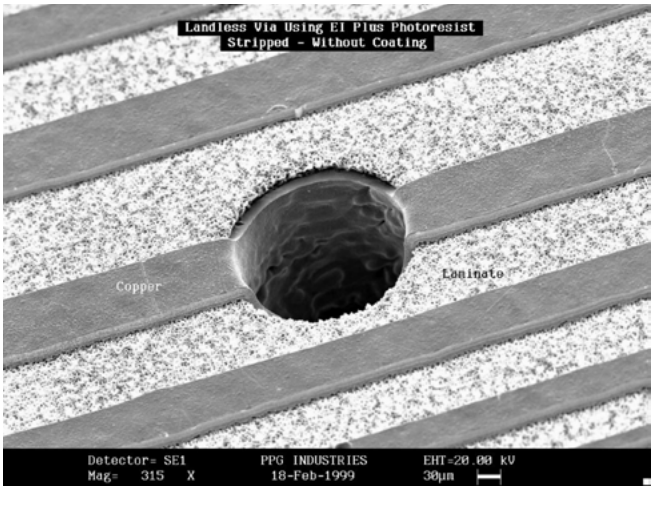

Figure 6: Landless via (0.010 in [0.25 mm] and .004 in [0.1 mm] traces) created with the liquid, electrophoretic, positive photoresist from PPG.

Issues with Smaller Traces and Annular Rings

Very small traces and spaces are very much alive in the IC packaging arena. When the line length is under the critical length created by the rise-time of the signals, transmission lines

Figure 7: The new generation of DDI production exposure units using DLP, solid-state LEDs and computer scanners to insure registration and high productivity.

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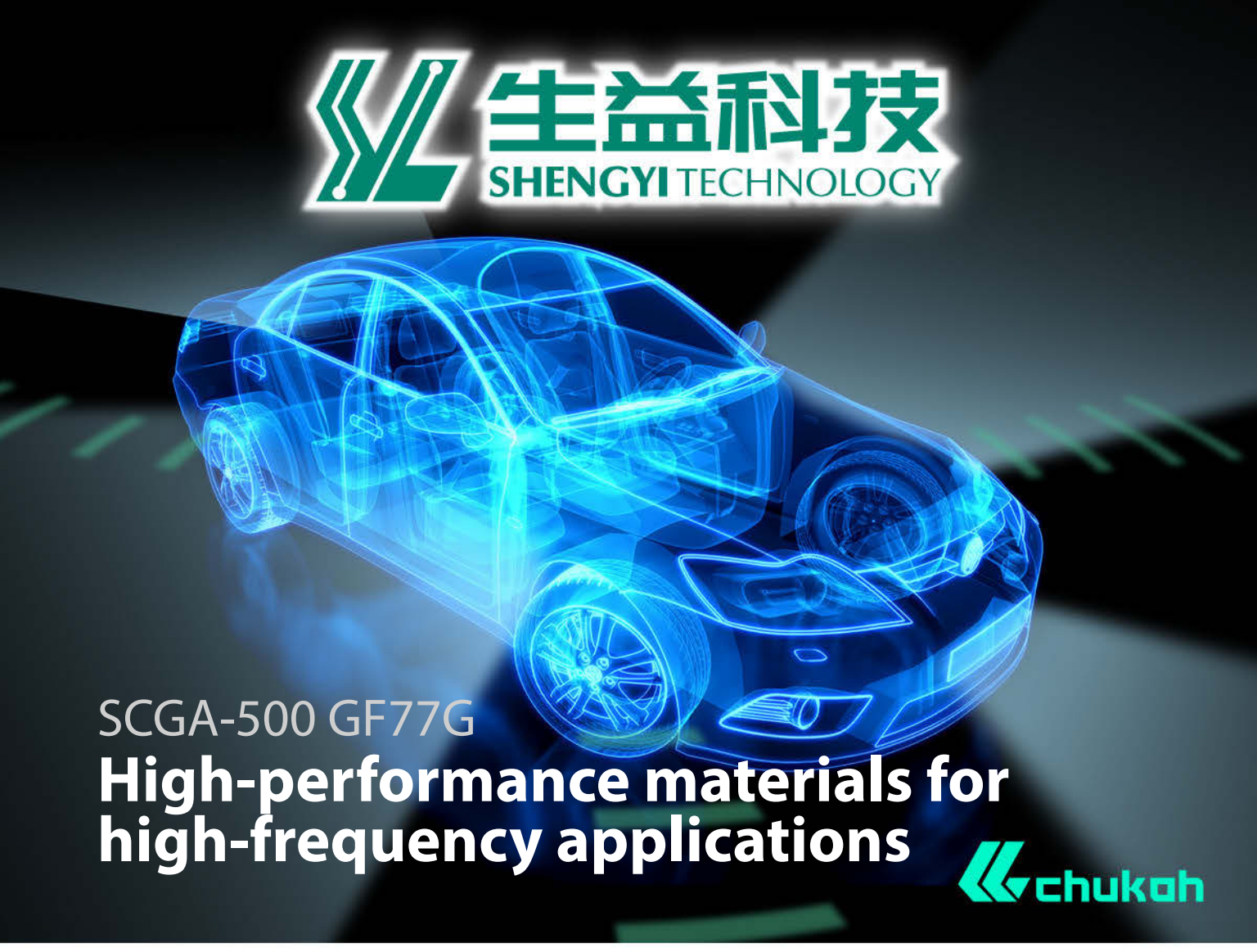

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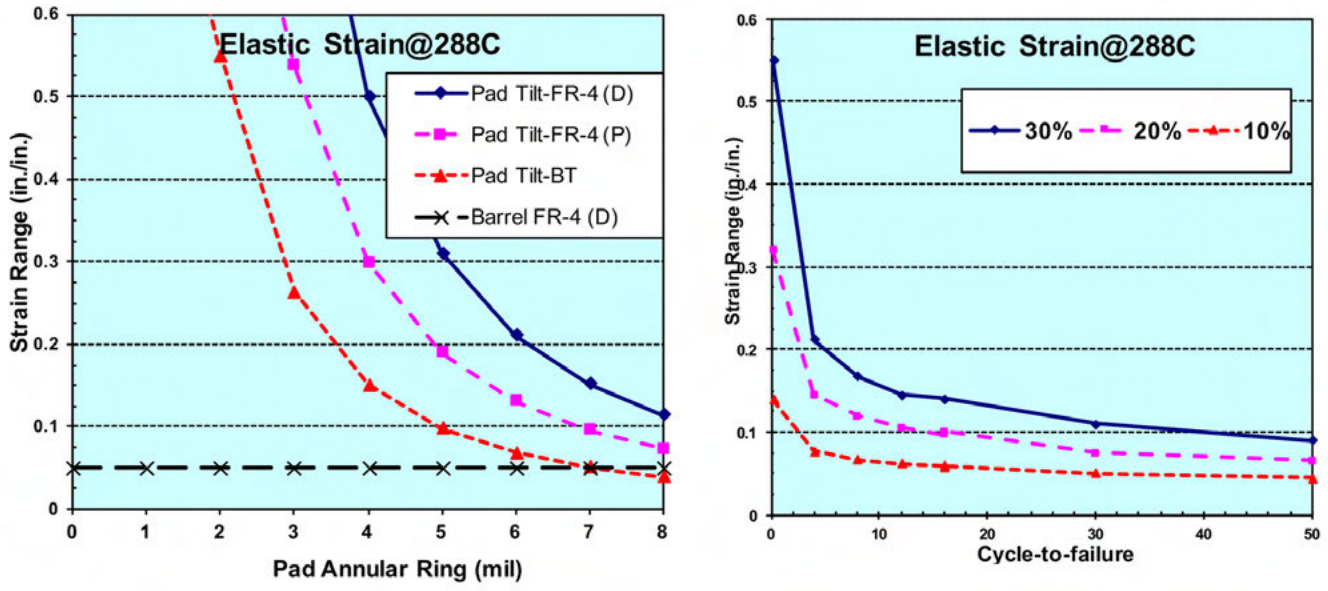

Figure 8: On temperature elevation to lead-free reflow temperatures, a via pad will tilt. a) The angle is a function of the annular ring diameter—stresses introduced will create a crack failure in the corner. b) The number of these cycles-to-failure as a function of the copper ductility. The horizontal line is the barrel and also a landless via pad.[7].

are not required. This is the ideal case for trace width of 5–10 microns or larger. But in general board routing, there are a number of issues with reducing trace widths and annular rings on multilayers. Here are four:

1. Reliability of Very Small Annular Rings

HP Lab's scientist discovered the reason that landless vias were so reliable. As the laminate expands when it is heated, the copper hole does not expand as much. This creates stress on the copper plating in the hole and is concentrated in the corners. Depending on the ductility of the copper plating, the resulting land rise will initiate a crack in the corner (called corner cracking). The smaller the annular ring, the higher the angle of the land edge, and this results in increased corner cracking with the smaller annular rings. When there is no annular ring (landless), then there is no corner crack. This is different from the barrel cracking defect that is related to the total thickness of copper in the barrel of the via. Figure 8a and 8b show this phenomena. An excellent explanation is written by Dr. Reza Ghaffarian from the JPL in Chapter 60 in the new *PCB Handbook, 7th edition*[7].

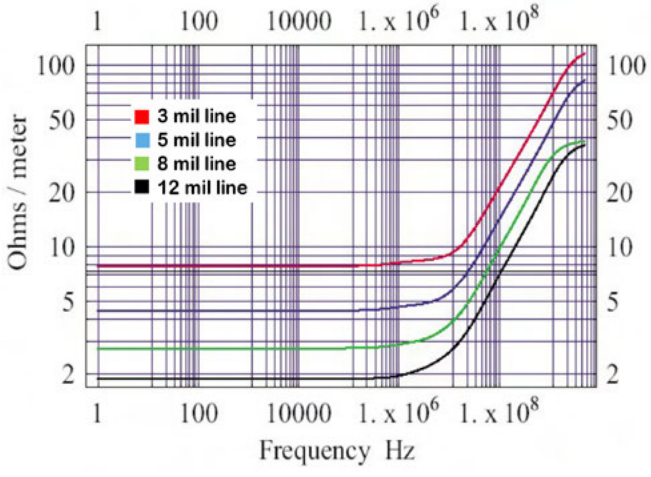

Figure 9: Copper losses for 1 oz. copper foil as a function of frequency for different trace widths.

2. Copper Losses

The energy loss in copper is fairly constant until you start to get above 2 MHz signals. As seen in Figure 9, the copper losses at 1 GHz for a 0.004 inch (0.10 mm) trace are around 30 ohms per meter or about 6 db/m. But at 0.003 inch (0.075 mm) the losses are above 60 ohms/m or a loss of 8 db/m.

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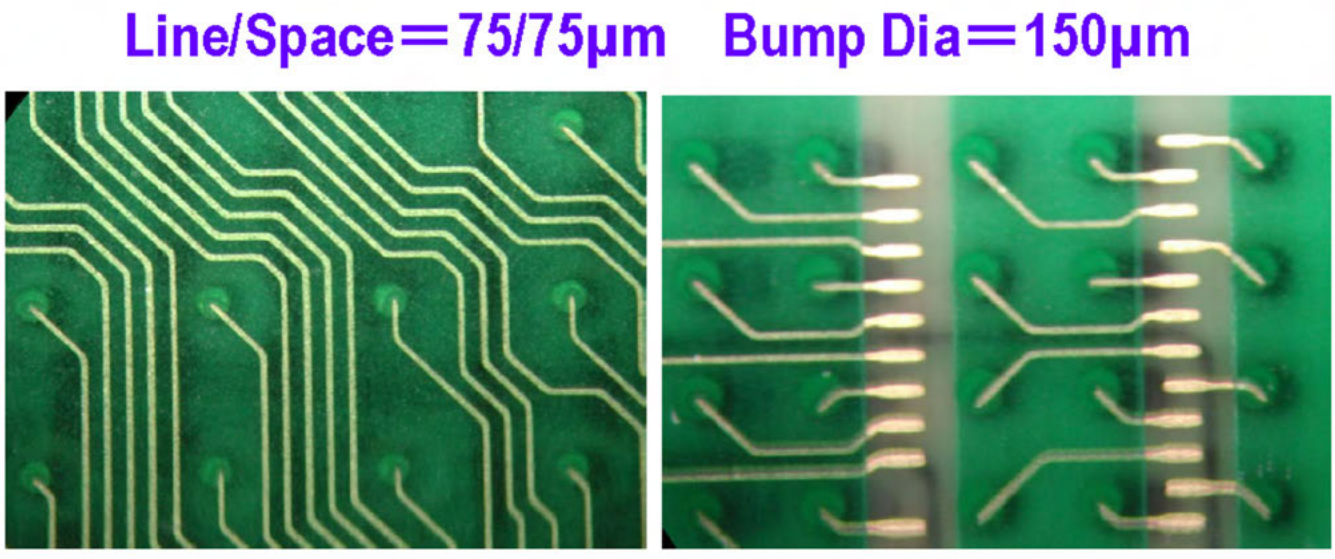

Figure 10: Landless via technology in Japan, circa 2002. Further publications have not been found.

3. Transmission Line Control

To hold a characteristic impedance as the line width gets smaller requires thinner dielectrics to the reference plane. For a 50 ohm transmission line, a 0.004 inch (.10 mm) trace on FR-4 needs a 0.00315 inch dielectric, but at 0.003 inch (.075 mm) the thickness is only 0.0027 inch (0.069 mm). The dimensional stability of <0.003 inch material is significantly reduced.

4. Impedance Tolerances

It may be more difficult for a fabricator to hold a +/- 10% tolerance on a transmission line when the trace width is reduced to 0.003 inch (0.075 mm) or smaller. A +/- 10% tolerance on 50 ohms with a 0.004 inch trace is +/- 0.0008 inch (0.0203 mm), but at 0.003 inch trace, it is +/- 0.0006 inch (0.0152 mm).

Landless vias have all but dropped out of sight. The last publication showing landless vias was in 2002 (Figure 10). But since the technology is real and has been used for many years, there is nothing holding it back from a reappearance and renaissance. **PCB**

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

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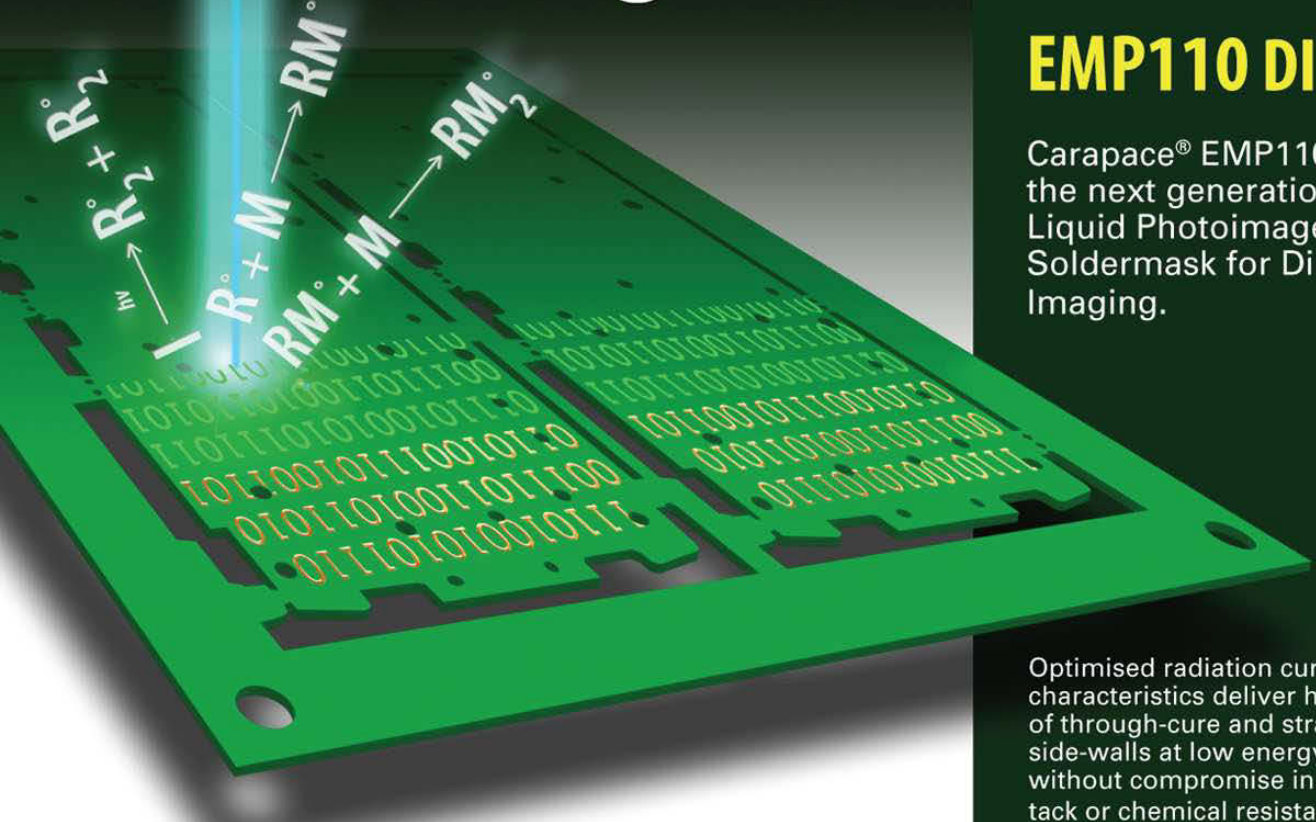

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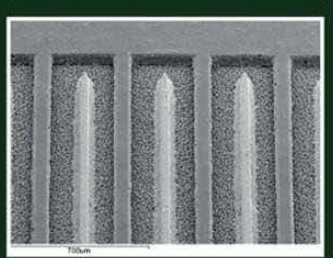

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Imaging Methods for Etch Resist, Part 3: LDI

by Dave Becker
ALL FLEX FLEXIBLE CIRCUITS LLC

This column is the third and final part on methods for imaging etch resist. Part 1 discussed screen printing and Part 2 discussed traditional photo exposing.

The basic process sequence for LDI is similar to photo exposing:

- The flexible substrate is coated with photosensitive resist
- The resist coated substrate is positioned in the LDI exposing unit
- LDI digitally exposes the desired pattern
- The photoresist is developed and the unwanted resist is washed away
- The copper pattern exposed by removed resist is chemically removed (i.e., etched)
- The resist is stripped off; only the copper pattern remains

Unlike photo exposing, LDI does not use a phototool, but directly exposes a digitally saved artwork pattern onto the resist. Photoresist is selectively exposed as the laser beam increments across the substrate in a rastering fashion. The image formation can be likened to the image formation on a CRT screen, which is formed from thousands of horizontal lines across the screen. Like photo exposing, LDI requires a photoresist, but the resist is normally specially formulated for laser printing; LDI resist is much faster-acting than traditional photoresist. Like photo exposing, resist for LDI comes in liquid or dry film options and the resist application methods are identical to those employed when using an artwork phototool.

The post-exposing processing of an LDI-processed flexible circuit is exactly the same as photo exposing.

Chris Ryder, ESI

The Quiet Mainstreaming of HDI Manufacturing

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

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

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While technically an LDI digital process does not have the same resolution capability as contact printing, LDI is actually superior for high-density flexible circuit fabrication. The LDI imaging process is capable of reproducing feature sizes down to 1 mil. This may be an issue for integrated circuit (IC) fabrication where features are much smaller, but for most PCB fabricators this resolution is acceptable. LDI has become the standard used in the printed circuit industry for high density interconnect (HDI) circuit boards.

The main reason LDI has gained favor in the industry, especially for high density circuit fabrication, is it eliminates the phototool. Consider the following issues associated with a phototool:

- There is an expense associated with the storage, preservation, tracking and constant inspection of a phototool that LDI does not have
- As the phototool is used, dirt, fibers, smears and scratches can degrade the phototool and reduce its ability to re-create the desired pattern
- Even under ideal conditions, a phototool will allow some diffraction of light
- Phototools are susceptible to temperature and humidity variations that can distort the original image
- There are limitations in phototool alignment to the substrate. Flexible circuit substrates may change dimensionally through normal processing. While a static phototool can be adjusted to a "best fit," LDI computer algorithms use optics technology to stretch or shrink the image pattern to precisely accommodate dimensional changes. This is particularly important for double-sided and multilayer circuit fabrication, where registration to vias and other features are critical.

There are two main disadvantages of LDI: capital cost and maintenance expense. The purchase price for an LDI unit is significantly higher than that of the traditional photoimaging lines. Soft demand in a highly capitalized factory can have a pretty dramatic effect on profitability. Maintenance service contracts add an additional annual cost.

As with photoimaging and screen printing, to avoid compromising yields LDI should be in a near particle-free environment. Each resist-coated panel goes through a cleaner immediately before inserting into the LDI chamber to remove any particles. Particles and fibers can block the UV light and create a short or open in the circuit pattern. Class 10,000 cleanroom conditions are recommended with tight temperature and humidity controls.

"Particles and fibers can block the UV light and create a short or open in the circuit pattern. Class 10,000 cleanroom conditions are recommended with tight temperature and humidity controls."

When LDI technology was first introduced around 20 years ago, throughput was an issue. LDI was often restricted to low volume or prototype runs. Subsequent advances in equipment as well as faster acting photoresist have made it practical for high volume circuit fabrication. When one considers the improved yields, enhanced capability, reduced set-up time, and lower costs associated with eliminating the phototool, investments in LDI technology can result in acceptable ROIs for many circuit fabricators. **PCB**

Dave Becker is the V.P. of sales and marketing at All Flex Flexible Circuits and Heaters. To contact Becker, or read past columns, click here.

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High-Throw Electroless Copper—New Opportunities for IC Substrates and HDI Manufacturing

by Tobias Sponholz, Lars-Eric Pribyl, Frank Brüning, and Robin Taylor
ATOTECH DEUTSCHLAND GMBH

Originally presented at IPC APEX EXPO 2016 and published in the proceedings.

Introduction

The one constant in electronics manufacturing is change. Moore's Law, which successfully predicted a rate of change at which transistor counts doubled on integrated circuits (ICs) at lower cost for decades, is ceding to be an appropriate prediction tool. Increasing technical and economic requirements, deriving from the semiconductor environment, are cascaded down to the printed circuit and in particular to the IC substrate manufacturers. This is both a challenge and an opportunity for IC substrate manufacturers, when dealing with the demands of the packaging market.

As a consequence, miniaturization of lines and spaces (L/S) down to 5/5 µm and even below to 2/2 µm in conjunction with smaller blind micro vias (BMV) is required to meet the very challenging wiring densities for new technologies. However, implications of the 'faster, smaller, and cheaper' mindset also affect high-end HDI printed circuit board manufacturers. The existing production infrastructure based on panel plating is not capable of 20/20 µm L/S—as required by OEMs for high-end mobile devices. As a consequence of this, production technology needs to change to pattern plating.

Miniaturization leads to increased requirements for all process steps involved in the value-added-chain. This paper discusses the corresponding challenges for metallization based on electroless copper processes. In order to minimize the effect of the differential etch process, which is one of the major factors determining surface feature resolution, the thickness of the deposited electroless copper layer on the surface of the substrate must be reduced. Moreover, the thickness at the sidewalls and bottom of the BMV must be improved to ensure excellent via filling performance. These contradicting re-

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quirements can only be fulfilled by increasing the throwing power (TP) of the applied electroless copper bath.

This paper introduces two new electroless copper baths developed for IC substrate manufacturing based on semi-additive process (SAP) technology (hereafter referred to as e'less copper IC) and HDI production (hereafter referred to as e'less copper HDI) and optimized for high throw into BMVs. An introduction to reliable throwing power measurement methods based on scanning electron microscope (SEM) is given, followed by a compilation and discussion of key performance criteria for each application, namely throwing power, copper adhesion on the substrate, dry film adhesion and reliability.

State of the Art Technologies and Future Challenges

The state-of-the-art production technology for high-end IC substrates—characterized by the smallest L/S at the outer redistribution layer (RDL)—is the SAP technology in vertical application mode. Contrary to the intuitive meaning of the expression 'semi-additive process,' the technology is in fact still a subtractive build-up technology and the L/S resolution is limited by the differential etch process step that is applied to form the desired pattern and that comes along with an inherent line width reduction.

However, the differential etch is reduced by the usage of bare laminates (base materials without a copper clad) resulting in a reduced copper thickness that needs to be etched. Leading IC substrate manufacturers are etching approximately 1.0 µm electroless copper plus additional 1.0–2.0 µm safety margin because of the rough surface (R_z ~ 2.0 µm) and achieve 9/12 µm L/S with acceptable yield in mass production. A further reduction in L/S requirements below this 21 µm track pitch could be theoretically fulfilled in different ways:

Firstly, a fully additive process (FAP) would make the differential etch step superfluous because the pattern is created before copper is plated. Unfortunately, there is no mass production proven FAP technology established yet in the industry. Secondly, new manufacturing approaches in development like laser embedded conductors (LEC) could contribute to increased wiring densities. Thirdly—and closest to mass production—the state of the art subtractive SAP technology and all involved process steps could be optimized for minimized differential etch.

> **"These contradicting requirements of the layer thickness on the surface and in the BMV can only be solved by an increased throwing power of the electroless copper bath."**

Imperative for this capability extension of the SAP technology is a further reduction of the electroless copper layer thickness on the surface of the build-up layer. The electroless copper layer thickness in the wedge of the BMV on the other hand is limited to a certain minimum because of conductivity and process safety requirements of the following development and via filling process steps. These contradicting requirements of the layer thickness on the surface and in the BMV can only be solved by an increased throwing power of the electroless copper bath. In this context, throwing power is generally defined as the ratio between the deposited electroless copper thickness in the BMV compared to that on the surface. The impact on L/S resolution of a reduced electroless copper surface thickness is illustrated in Figure 1. As can be seen in the upper part of the schematic drawing, the state of the art technology, simulated for targeted 5/5 µm L/S, faces an inevitable line reduction due to the differential etch of about 3 µm (1 µm electroless copper plus an additional safety margin of 2 µm due to the roughness of the surface). In order to increase the actual line width all relevant process steps need to be pushed to the limits. The electroless copper thickness must be reduced and new base materials, characterized by a lower surface roughness compared to standard materials like ABF GX-92, are required.

All measures sum up to an actual line width increase of 75% from 2.0 µm to 3.5 µm.

Throwing power is an essential requirement for electroless copper processes for enhanced fine line capability, but not the only one. Other relevant performance characteristics are the adhesion of dry films onto the electroless copper deposits and the adhesion of the deposited layer itself to the increasingly flattening bare laminates. Both factors directly affect the overall process yield rate.

The picture changes for HDI board manufacturing. The contemporary manufacturing technique for high-end HDI PCBs is panel plating in horizontal application mode. Leading manufacturers achieve approximately 35/35 µm L/S by applying standard 17 µm copper clad base materials and about 18–20 µm electrolytic copper plating. In order to reduce the etch depth required for the pattern formation and thus elevate the L/S resolution significantly down to 20/20 µm, manufacturers intend to change their current production process from panel to pattern plating and more precisely to the advanced modified semi additive process (AMSAP) technology (Figure 2). As a consequence, the existing manufacturing equipment and processes needs to be modified to cope with the new challenges that come along with this approach. The alternative, to push the panel plating technology to its limit by applying a thin copper clad base material—similar to the one used for AMSAP—and by the reduction of the electrolytic copper layer, is still limited in L/S resolution of above 20/20 µm and therefore no viable option.

As can be seen in Figure 3, the dry film lamination and development steps within the AMSAP process are located directly after the electroless copper deposition in contrast to the panel plating process where the dry film is applied after the final electrolytic copper build-up. This difference in the process sequence has an

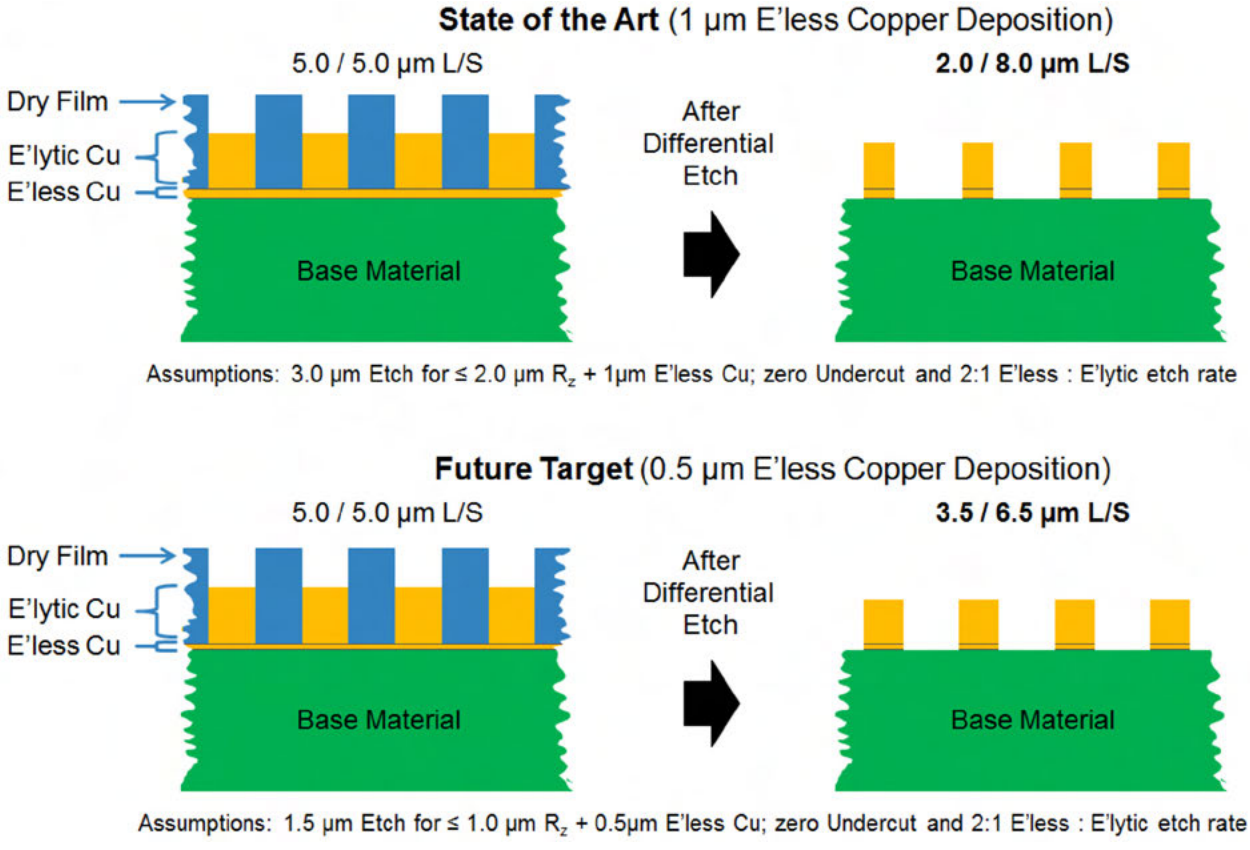

Figure 1: Impact of the electroless copper thickness on L/S resolution for IC substrates based on SAP technology.

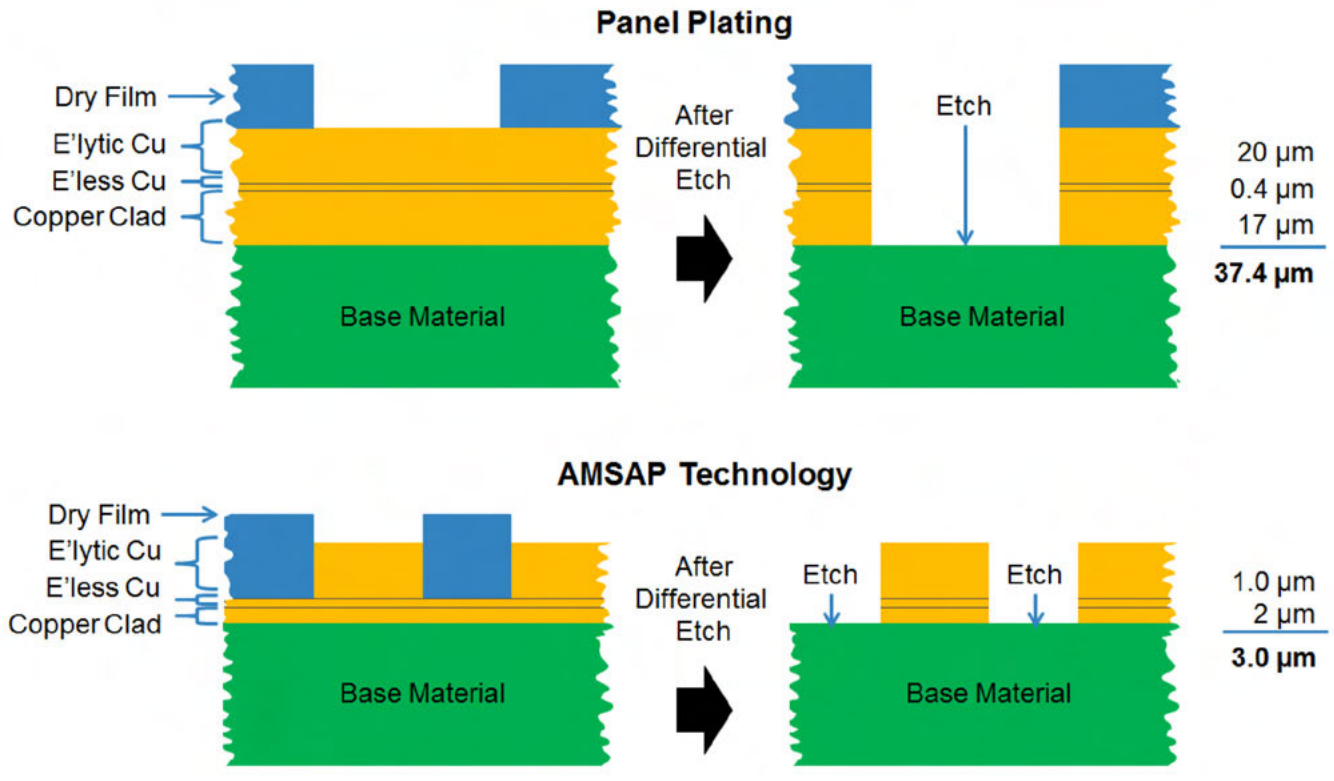

Figure 2: Comparison of the differential etch of panel plating versus AMSAP technology.

Figure 3: Process flow comparison of panel plating and AMSAP technologies.

impact to the required electroless copper deposition thickness.

In case of a pattern plating scenario (AMSAP), 0.35 µm to 0.5 µm deposited on the panel surface are not sufficient to ensure a high production yield due to several copper etching steps prior to the via filling. The risk attached is voiding primarily at the bottom of the BMVs due to a thin electroless copper layer that might be completely etched away by the acid pre-treatment during the electrolytic plating process. To prevent this, manufacturers tend to increase the deposition thickness on the surface up to 1.0 µm or even more to increase the process safety, but to the disadvantage of a thicker copper layer that needs to be (differentially) etched.

Another, more cost-effective way is an electroless copper process with increased throwing power for process safety especially at the bottom of the BMVs, the most critical area for voiding. The required absolute electroless copper thickness in the BMV could be achieved while increasing the thickness at the surface only marginally compared to current copper thicknesses targeted in panel plating. As a result, the fine line resolution is improved.

Table 1 summarizes the main process requirements for electroless copper processes targeting the high-end IC substrate manufacturing as well as HDI application by AMSAP technology.

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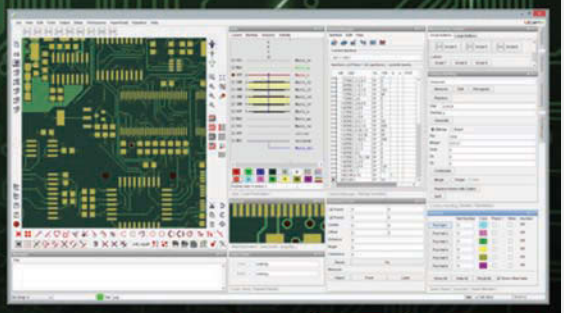

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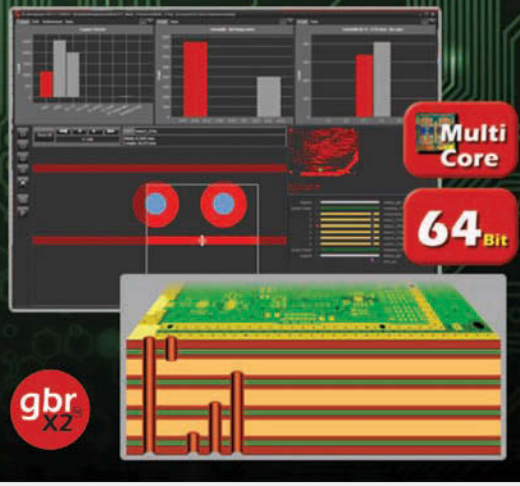

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Selected Performance Criteria	Impact on IC Substrates (SAP)	Impact on HDI PCB (AMSAP)
Throwing Power	**Fine line capability, yield**	**Fine line capability, yield**
Dry Film Adhesion	Fine line capability, yield	Fine line capability, yield
Copper Adhesion on the Substrate (Internal Stress and Peel Strength)	Yield	-
Reliability	Yield	Yield

Table 1: Impact of selected electroless copper performance criteria on IC Substrates and HDI PCB.

Throwing Power Measurement Methods

A reliable throwing power measurement method is essential for throwing power comparisons as performance criteria of different electroless copper baths. There is currently no industry standard available, which is why throwing power measurements and performance values of different players in the PCB industry are typically not comparable. To overcome this issue two reliable and standardized measurement methods based on cross sections and SEM evaluation are proposed which have been applied for all measurements shown in this paper. These two methods are required to measure the electroless copper thickness in different areas, namely on base materials respectively laminates (*method A*) and directly on copper (capture pad or copper clad on the surface; *method B*).

For the measurement of the electroless copper deposit thickness directly on the base material several factors need to be considered. Conventional throwing power measurement methods—as applied in the area of thick electrolytic copper—are not applicable for electroless copper. Etching and polishing for example potentially reduce the electroless copper thickness and a protection layer could form an intermetallic phase with the electroless copper, both leading to significant measurement errors of the actual layer thicknesses for deposits below 1.0 µm thickness. As a consequence, the sample preparation for the throwing power measurement *method A* excludes any etching or grinding and protection layer and the embedding resin must not induce any heat into the system during curing to avoid any smear of the electroless copper layer. After sample preparation, the throwing power can be calculated by thickness measurement of several different exposed spots in the BMV (Figure 4).

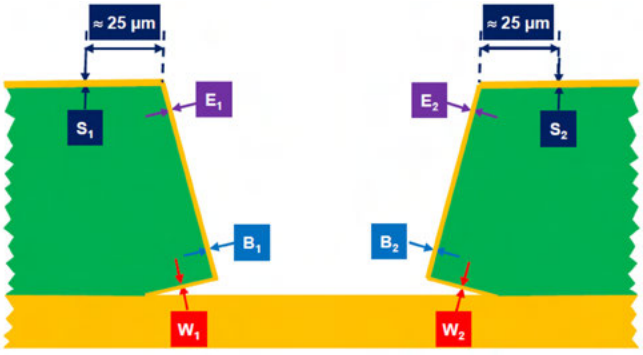

Figure 4: Throwing power measurement (method A).

The average electroless copper thickness per location and per image is calculated with i = 1,2 and N = 3:

$$\overline{S_i} = \frac{1}{N} \cdot \sum_{n=1}^{N} S_{i,n} \qquad \overline{E_i} = \frac{1}{N} \cdot \sum_{n=1}^{N} E_{i,n}$$

$$\overline{B_i} = \frac{1}{N} \cdot \sum_{n=1}^{N} B_{i,n} \qquad \overline{W_i} = \frac{1}{N} \cdot \sum_{n=1}^{N} W_{i,n}$$

$$i \in \{1;2\} \qquad N = 3$$

Equation 1: Thickness measurement at different areas in the BMV.

According to the required measurement points, the throwing power is calculated as follows:

$$TPW_S = \frac{\overline{W}_1 + \overline{W}_2}{\overline{S}_1 + \overline{S}_2} \cdot 100\% \qquad TPB_S = \frac{\overline{B}_1 + \overline{B}_2}{\overline{S}_1 + \overline{S}_2} \cdot 100\%$$

$$TPW_E = \frac{\overline{W}_1 + \overline{W}_2}{\overline{E}_1 + \overline{E}_2} \cdot 100\% \qquad TPB_E = \frac{\overline{B}_1 + \overline{B}_2}{\overline{E}_1 + \overline{E}_2} \cdot 100\%$$

Equation 2: Throwing power measurement at different areas in the BMV.

In order to achieve a sufficient measurement resolution, it is mandatory to apply SEM for evaluation of the cross sections. The SEM settings used for the thickness measurement are standardized to increase the comparability between different locations and SEM types. Nevertheless, the measurement is still operator dependent but according to intensive testing of the method and statistical evaluations, the expected error is in an acceptable range. The application of focused ion beam (FIB) cutting would be a potential alternative to SEM, but due to the immense cost and throughput constraints for the measurement it is not a viable option.

The presented *method A* is suited to measure the throwing power directly on the base material but not on copper because etching or electro polishing is required in order to distinguish between different copper layers (e.g., electroless copper vs. the capture pad) and the method does not allow these preparation techniques. As described, etching or electro polishing attacks the electroless copper layer quite strongly, that is why two copper protection layers are electrolytically plated in *method B* before and after the electroless copper deposit to be measured (Figure 5). This build-up enables a stable electroless copper thickness even after etching and electro polishing and therefore provides an accurate method of electroless copper thickness measurement on the capture pad or on the copper clad surface.

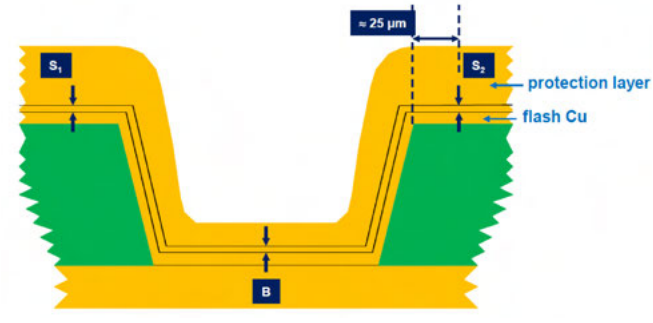

Figure 5: Throwing power measurement (method B).

The measurement of the throwing power is performed analogue to *method A* by cross sections and SEM images.

Throwing Power Performance

As discussed, throwing power is one of the most important performance criteria for next-generation electroless copper baths for both, IC substrates as well as HDI panels. On the one hand, a minimized electroless copper layer thickness on the surface of the laminate is required in order to reduce the differential etch and increase the achievable resolution. The electroless copper thickness in the wedge of the BMV on the other hand is limited to a certain thickness because of conductivity requirements of the subsequent via filling process step. A solution for these contradicting requirements is a high throwing power electroless copper process. Currently, throwing power values of approx. 30% in the wedge and 70% on the capture pad of the BMV represent the typical performance in the industry for vertical IC substrate manufacturing whereas future design rules will require minimum 70% throwing power in the wedge and 100% on the capture pad. For horizontally produced HDI boards in panel plating, the throwing power on the capture pad is approximately 30% and the requirements will increase due to the postulated technology shift to AMSAP.

The throwing power performance is not only a function of the electroless copper bath, but also of the solution exchange influenced by the type of plating equipment, the aspect ratio (AR) of the BMV and the wedge formation respectively the AR of the wedge. Nevertheless, the chemical formulation and the process parameters of an electroless copper bath significantly influence the throwing power performance.

Figure 6 shows a typical BMV (60 µm width × 40 µm depth) on ABF GX-92 processed with

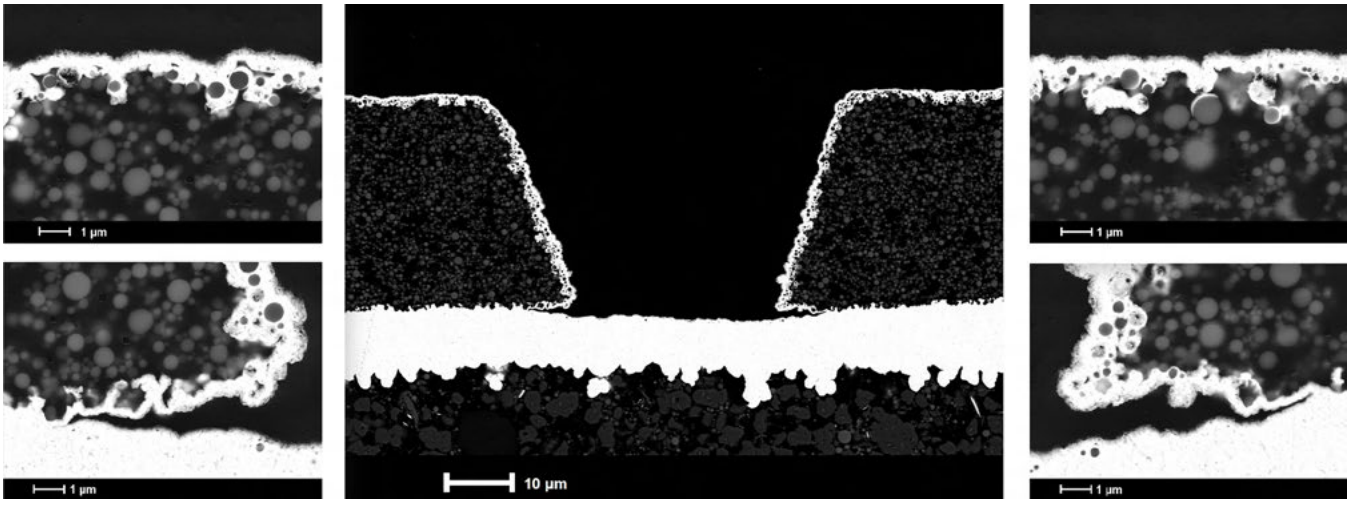

Figure 6: SEM Images of a BMV (60 × 40 µm) on ABF GX-92 treated with e'less copper IC.

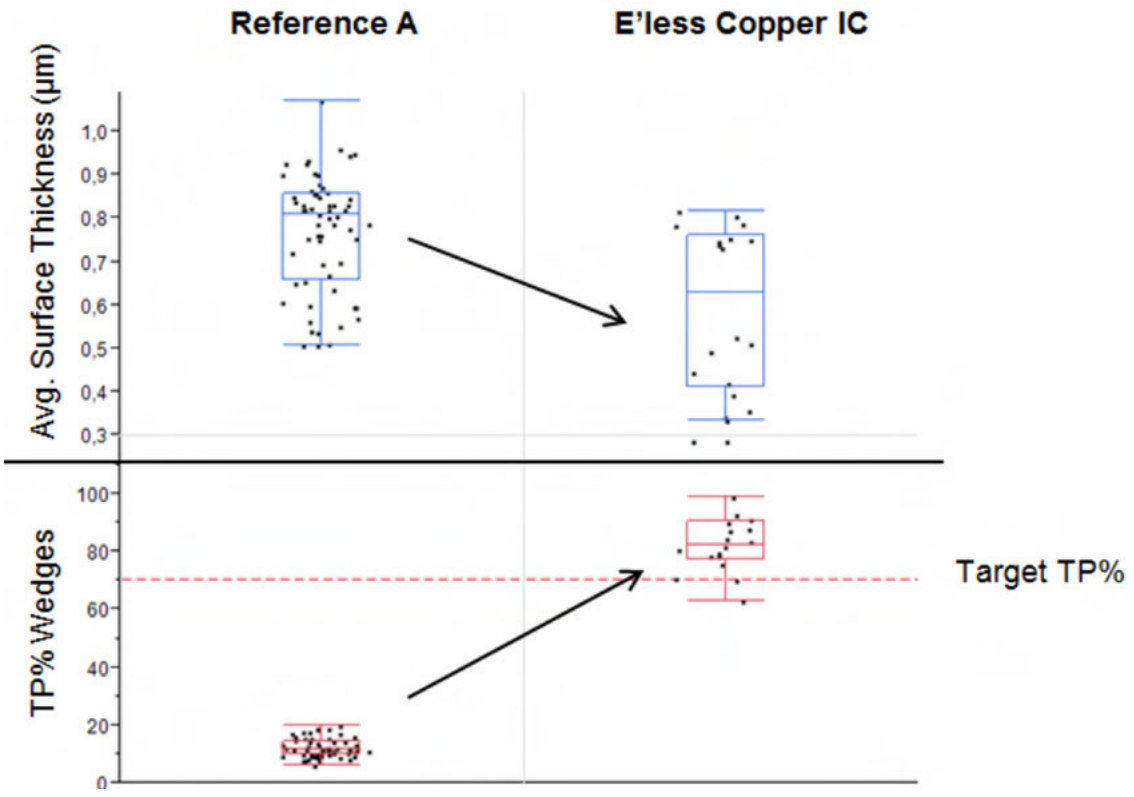

Figure 7: Statistical evaluation of a comparison line test of e'less copper IC and the reference bath.

e'less copper IC—a new, vertical electroless copper bath developed for high-end IC substrate manufacturing—in a mass production environment in Japan. The aspect ratios of the wedges are 1:0.3 (8 µm width × 2 µm depth). By applying the measurement *method A* as described above, the throwing power is approximately 80% in the wedges.

Figure 7 illustrates a statistical evaluation of a throwing power comparison line test of the new *e'less copper IC* and a reference bath established in mass production at several major IC

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substrate manufacturers. The throwing power was evaluated using *method A* according to TPW_S. As can be seen in the lower part of the chart, the new electroless copper bath outperforms the reference system in terms of throwing power. The new electroless bath achieved a significantly higher absolute and relative deposition in the BMV wedges which leads to a throwing power of approx. 70–80 %, whereas the reference achieves a throwing power of about 20%.

Throwing power measurements and comparison tests for the recently developed horizontal *e'less copper HDI* are shown in Figures 8 and 9. The new electrolyte was compared with two horizontal reference systems using analysis *method A* with throwing power evaluation TPB_E in horizontal mass production equipment, which is the standard production environment for high-end HDI manufacturing. Reasons for this are the constant process conditions for each panel and the excellent fluid exchange especially in BMVs. During the test, the electroless copper thickness at the top or entrance of the BMVs was comparable for all three candidates thereby fluctuating around 350 nm whereas the absolute thickness at the bottom of the BMVs was significantly higher for the new bath *e'less copper HDI* compared to the reference systems. As a consequence, the calculated throwing power (approx. 73%) is higher for the new bath.

In another test throwing power measurement *method B* was applied to evaluate the throwing power directly on the capture pad. The electroless copper layer of *e'less copper HDI* in between the electrolytic copper protection layers becomes visible after electro polishing (see Figure 10). A similar throwing power (approx. 74%) compared to the result using *method A* at the bottom of the BMV was achieved.

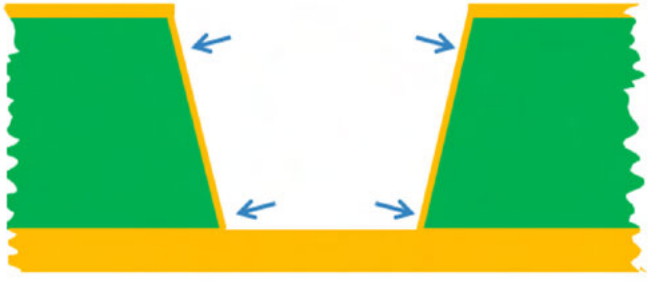

Figure 8: Throwing power measurement method A according to TPB_E and the test vehicle.

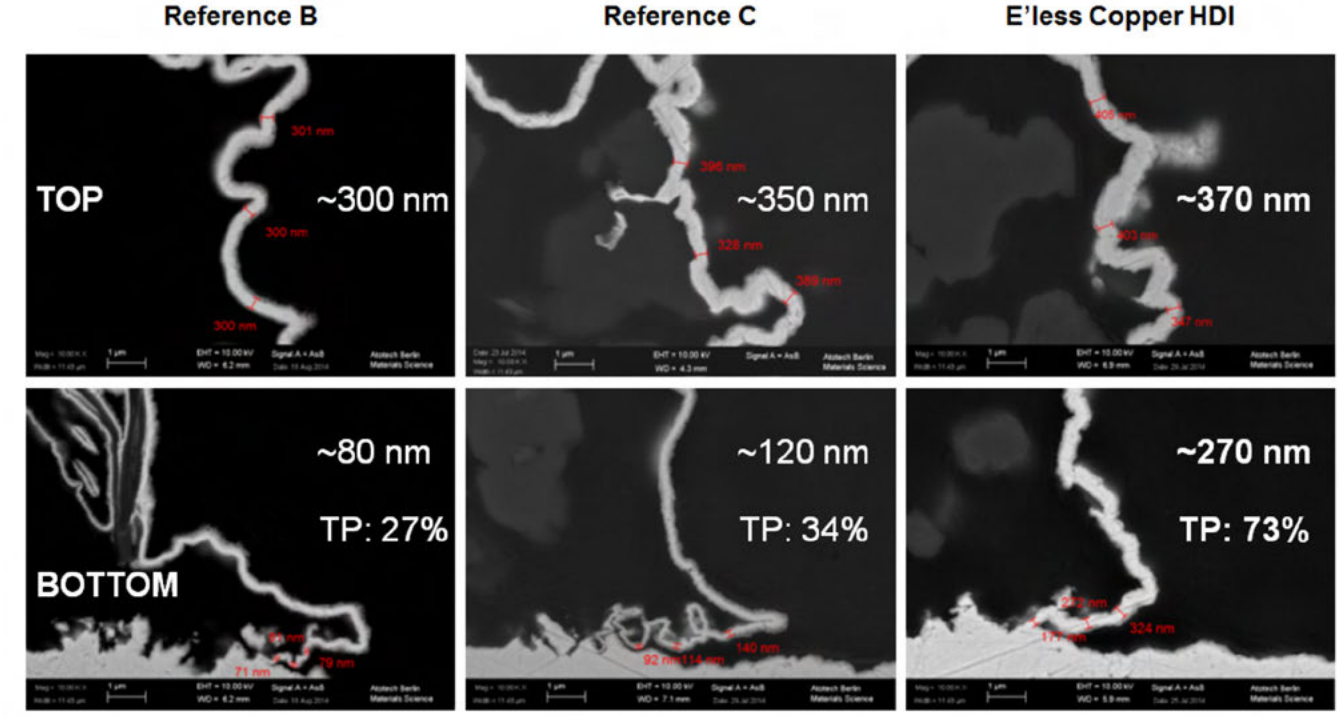

Figure 9: Throwing power comparison of e'less copper HDI and two reference systems.

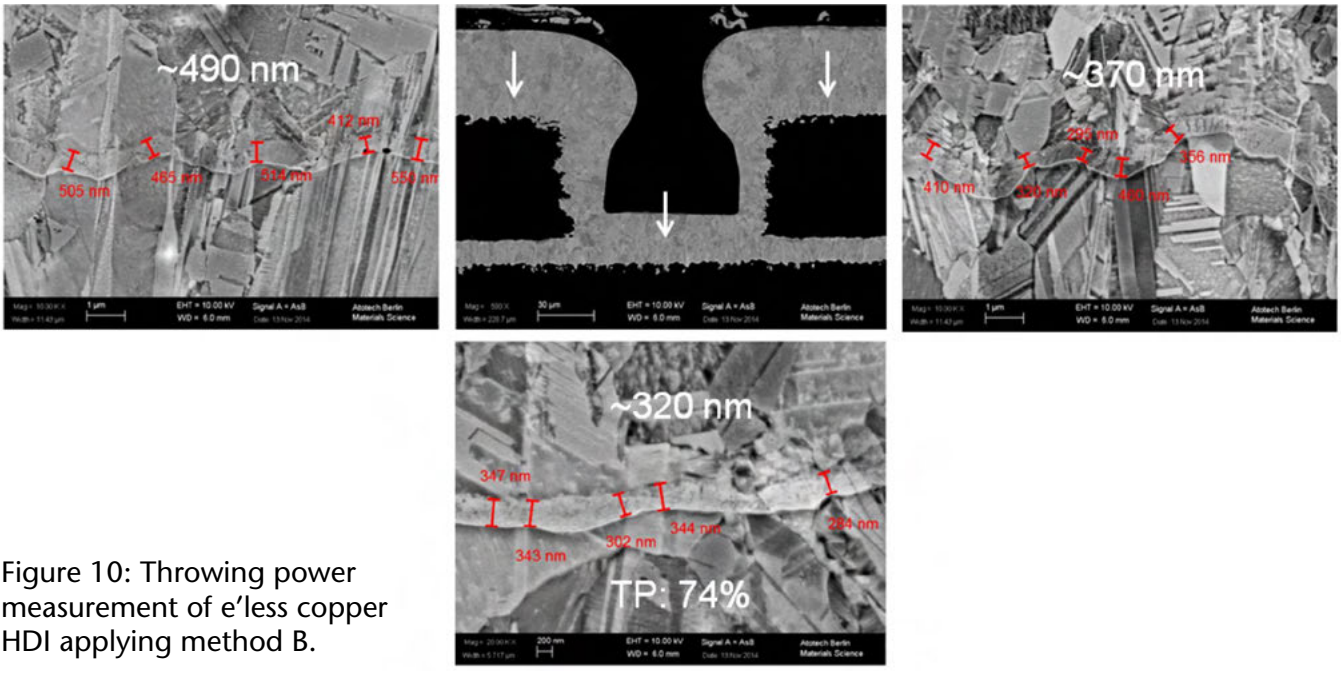

Figure 10: Throwing power measurement of e'less copper HDI applying method B.

Dry Film Adhesion Performance

The application of the dry film during pattern plating is a critical factor for the overall yield of the manufacturing process. In order to ensure an acceptable yield, the adhesion of the dry film on the electroless copper layer needs to be sufficient to survive the subsequent process steps of the pattern plating. Insufficient adhesion could otherwise lead to opens and shorts resulting in yield loss. Several parameters are influencing the dry film adhesion and need to be considered. Two of the most important factors are firstly the lamination conditions of the dry film and secondly, the surface morphology of the electroless copper layer. For an optimal result, the lamination parameters need to be optimized to the specific electroless copper deposit.

Dry film adhesion on the new *e'less copper IC* bath is demonstrated by using the "line adhesion test" on electroless copper deposits plated on ABF GX-T31 laminate. After copper surface treatment with H_2SO_4, production series dry film line structures with a width of 6 µm respectively 8 µm are evaluated after exposure and development by a UV microscope. The percentage of dry film lines that survived the development process is an indicator for the adhesion on the tested electroless copper deposits. As illustrated in Figure 11, the new electroless copper process outperforms the reference system in dry film adhesion for both repetitions of the test. Nearly all 8 µm dry film tracks are in good shape after the development process whereas the 8 µm dry film lines for the reference process are visibly damaged. The result for the 6 µm dry film tracks with *e'less copper IC* in this test set-up is not perfect, but still significantly better than the reference that failed completely in both test runs.

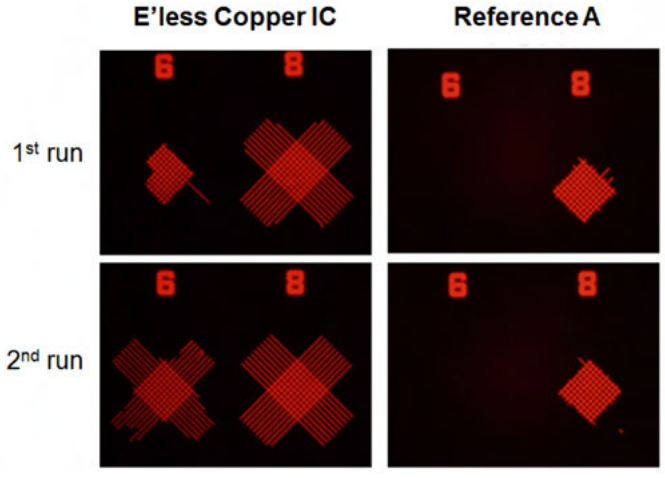

Figure 11: Production series dry film adhesion test of two different electroless copper deposits on ABF GX-T31.

Dry film adhesion tests for *e'less copper HDI* generated in mass production equipment are currently in progress and therefore cannot be discussed in this paper. However, all initial results showed similar excellent performance as for *e'less copper IC*.

Electroless Copper Adhesion on the Substrate

New substrates introduced to the market for application with SAP technology are becoming increasingly smoother because of the demand for higher circuitry densities and signal frequencies. The influence of the substrate surface constitution on the adhesion of the electroless copper layer via mechanical anchoring and chemical interface bonding is significant. Weak adhesion of the copper layer could lead to spontaneous delamination failures (blistering) and line peel-offs that are not acceptable for customers in mass production. Internal stress characteristics of the electroless copper layer have been shown to significantly impact the tendency of a copper layer to delaminate from the substrate [1, 2]. The occurrence of compressive stress in the layer correlates to the probability of buckle driven delamination, namely blistering, whereas tensile stress suppresses the likelihood of blistering. The internal stress characteristics of the copper layer deriving from *e'less copper IC* have been analyzed using the in situ X-ray diffraction method (XRD). As can be seen in figure 12 the internal stress is slightly more tensile compared to the reference electroless copper bath, one of the current standards in the market. The copper layer is therefore perfectly suited to adhere on the substrate surface without any blistering issues for a representative deposition thickness range.

The blistering tendency of the copper layer is not only related to the internal stress characteristics but also to the peel strength of the layer. The peel strength is a well-known performance criterion in the industry and can be described as the clamp force of the copper layer to the substrate. Broadly speaking, blistering occurs when the delamination force due to the internal stress characteristics exceeds the clamp force of the layer. The peel strength is dependent on the chemical bonding of the copper layer on the surface and the mechanical anchoring via the surface roughness. The latter is highly influenced by the conditions that are applied in prior process steps especially in the desmear and the

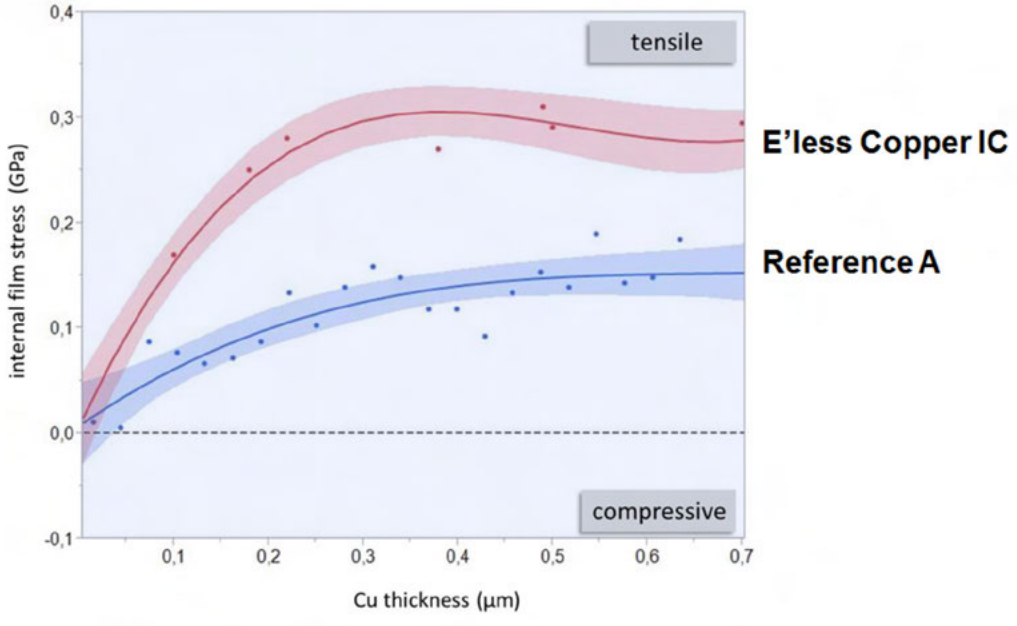

Figure 12: Plot of the internal stress of copper films deposited from two different electroless copper baths against deposit thickness, as measured by in situ XRD. (Measurements in cooperation with Mt. Allison University, Canada.)

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lamination process of the film. Mass production comparison tests of e'less copper IC with the reference system on ABF GX-92 showed that the peel strength performance of the new bath is on the same very good level as the reference bath (cf. Figure 13). This result could be confirmed also on several other relevant laminates including ABF GX-T31 and ABF GY-series.

Reliability

During the development and mass production qualification, both new electroless copper baths have been intensively tested with all standard reliability tests established in the market (see Table 2 below).

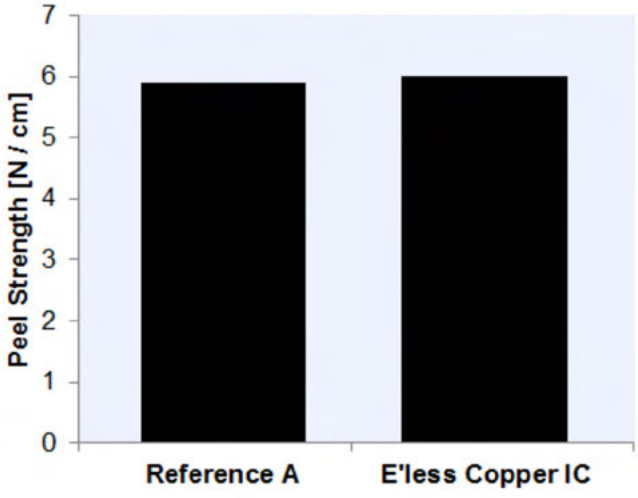


Figure 13: Peel strength results after acid copper plating on ABF GX-92; Annealing Parameter.: 1h at 130°C after e'less copper, 1h at 180°C after electrolytic copper.

The following figure illustrates the detailed IST and TCT test results for *e'less copper HDI* as achieved at a mass production test in Korea.

Summary

Two new electroless copper baths have been developed to cope with upcoming miniaturization challenges in the high-end IC substrate segment as well as in the evolving HDI board market. The main challenge to be overcome is the reduction of the differential etch in the pattern plating process by decreased electroless copper thickness on the surface of the build-up layer. To this end, several requirements need to be fulfilled to ensure a safe and high yield production. First of all, the throwing power performance of e'less copper IC and e'less copper HDI[3] especially in the wedges respectively at the bottom of the BMVs is crucial for the via-filling performance due to conductivity requirements. Two reliable throwing power measurement methods have been introduced and throwing power results presented in this paper show that the new electroless copper baths constantly achieve significantly better throwing power performance compared to the reference systems that are industry standards in the respective markets. A minimum target thickness of the electroless copper layer in the BMV (wedges) is therefore ensured while the thickness on the surface can be reduced for improved L/S resolution. Secondly, the adhesion of the copper layer on the bare laminate (typically ABF material) is a basic requirement for the high-end IC substrates manufacturing process. Favorable internal stress characteristics of the copper layer of the e'less copper

Test	Conditions	Result
Solder shock test (SST)	6 × 288° C solder float	Passed
Interconnect stress test (IST)	From RT up to 150° C, resistance increase in the power circuit < 3%	2000 cycles passed
"Comfort 40" online temperature cycle test (TCT)	-40° C / 125 ° C, 15 min / 15 min, resistance increase in the power circuit < 3 %	1000 cycles passed
Quick Via Pull (QVP)	75, 100, 125 and 150 µm diameter BMVs	Passed

Table 2: Summary of reliability tests for e'less copper IC and e'less copper HDI.

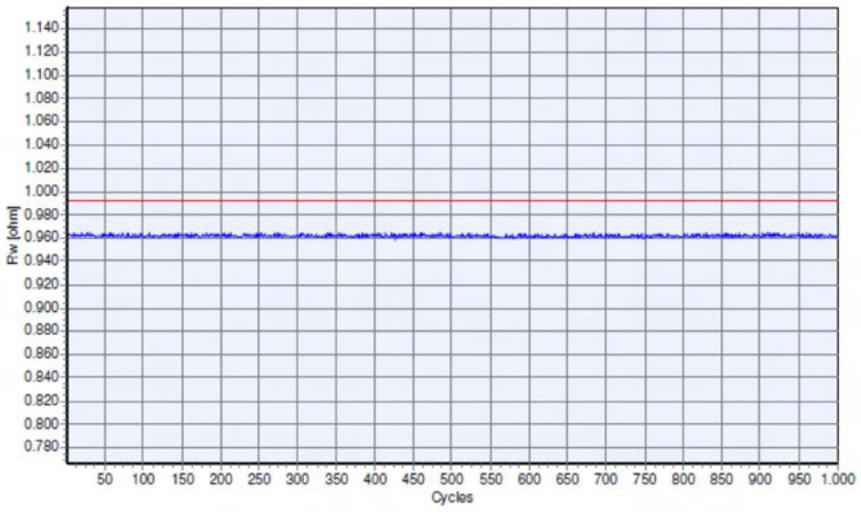


Figure 14: TCT result (1000 cycles passed) of e'less copper HDI.

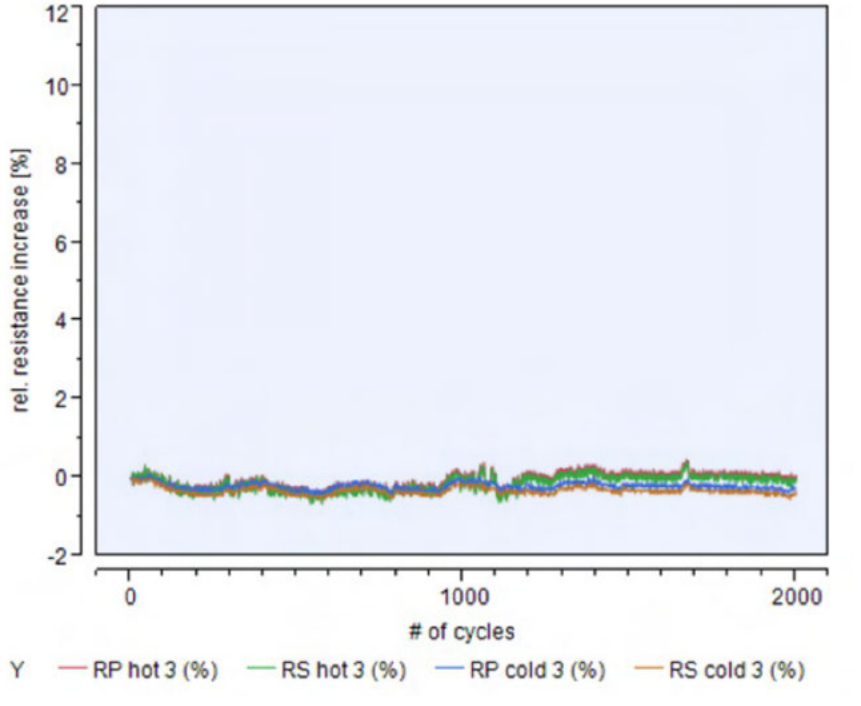


Figure 15: IST result (2000 cycles passed) of e'less copper HDI.

IC bath combined with excellent peel strength results ensure a reliable and strong adhesion of the copper layer on the resin surface. Thirdly, dry film adhesion and differential etching are key process steps for high yield manufacturing. The surface morphology of the e'less copper IC layer enables improved mechanical anchoring of the dry film compared to the reference system and dry film adhesion data for e'less copper HDI is under evaluation. Both electroless copper baths were thoroughly tested for industry standard reliability requirements and achieved excellent results. **PCB**

References

1. Simon Bamberg et al., "Stress/strain in electroless copper films: analysis by in-situ X-ray diffraction and curvature methods," 9th International Conference on Device Packaging, Arizona, 2013.

2. Tobias Bernhard, Simon Bamberg, Frank Brüning, Ralf Brüning, Laurence J. Gregoriades, Tanu Sharma, Delilah Brown, M. Klaus, Christian Genzel, "Analysis of stress/strain in electroless copper films", 46th International Symposium of Microelectronics, Orlando, Florida, 2013.

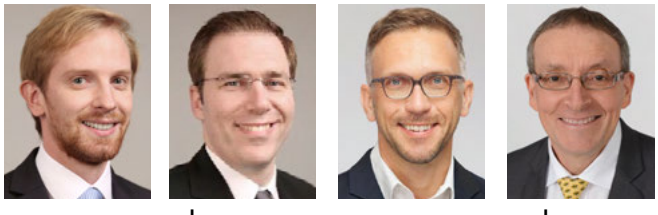
3. For further information on E'less copper IC (Printoganth MV TP1) and E'less copper HDI (Printoganth T1) please click here.

a) Tobias Sponholz is assistant product manager PTH.

b) Lars-Eric Pribyl is global product manager PTH.

c) Dr. Frank Brüning is global business manager PTH.

d) Robin Taylor is marketing and sales manager—electronics.



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Supply Lines
Highlights

Ventec International Group Expands North American Focus

Ventec International Group is looking to expand their U.S. operations, and they've begun this process by bringing Chris Alessio on board as VP of sales and operations of Ventec USA. I met with Chris and Ventec USA President Jack Pattie at IPC APEX EXPO 2016 to discuss their approach and possible opportunities for the North American laminate market.

Koen Hollevoet Explains Rogers' New PEEK-based Material for Extreme Temps

Rogers has been developing a new material called XT/duroid laminate, which is based on polyether ether ketone (PEEK) material and can withstand some of the harshest temperatures and environments. I met with Koen Hollevoet, Business Development Manager at Rogers Corporation, at IPC APEX EXPO 2016 to further discuss this material and learn how it might benefit the PCB market.

Orbotech's Latest Technology at IPC APEX EXPO

Orbotech presented their latest new technologies at IPC APEX EXPO 2016. The Nuvogo 1000 is a higher power version of their multi wavelength direct imaging machine, as well as their new automated optical shaping technology which can add copper deposition to an otherwise defective PCB.

IEC: Celebrating 50 Years in Business

I caught up with Shawn Stone of IEC recently, to discuss plating, laminates, printed electronics and IEC's many strategic alliances, including their most recent agreement with ITEQ to distribute their copper-clad laminate line throughout North America. This alliance will give IEC, a company his father started more than 50 years ago, its first North American footprint.

Oak-Mitsui Expands Partnership with Insulectro

Oak-Mitsui and Insulectro are proud to announce an expanded strategic partnership adding Oak Mitsui's proprietary ABC (aluminum bonded copper) to Insulectro's premier product portfolio including CAC (copper aluminum copper).

American Standard Circuits Augments Capabilities by Installing GenFlex from Orbotech

GenFlex provides state-of-the-art analysis and editing capability for flex and rigid-flex boards. The GenFlex System compensates for material bending and possible distortion and allows quick global revision via dedicated Design for Manufacture (DFM) tools, pattern optimization, optimal operator efficiency and speed with minimum revisions and maximum yield/quality.

Frontline Launches InCAM Flex

Frontline PCB Solutions, an Orbotech-Mentor Graphics company, today announced the launch of InCAM Flex, a dedicated new CAM solution for flex and rigid-flex PCB makers.

ESI Advances HDI Via Drilling Solutions Portfolio in APAC

Electro Scientific Industries Inc.'s nViant laser processing system has secured multiple customer placements in the high-density interconnect (HDI) and substrate processing segments.

MuTracx Appoints Jeroen de Groot as New CEO

Jeroen de Groot has been appointed CEO of MuTracx International BV—full subsidiary of innovative technology partner Sioux—as of 1 May 2016. Strengthening MuTracx with the addition of De Groot fits perfectly within the growth aspirations of the manufacturer of digital inkjet PCB printers.

Testing Todd: Quality Management and the Hidden "I" in Team

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

SPECIAL SECTION

IPC IMPACT WASHINGTON, D.C 2016

IPC's IMPACT Washington, D.C. 2016: Who, What, Where, and Why

All photos in this section courtesy of IPC

by Patty Goldman
EDITOR

CEOs, CTOs, VPs, presidents, upper management, even engineers and worker bees: I call out to you to read this message. Your very life, at least your working life, may depend on it and I am truly not being dramatic.

I had the opportunity in mid-April to attend IPC's IMPACT 2016 conference in Washington, D.C., and it was quite a learning experience—and I didn't even get to most of the meetings. I'm not big on government, politics, our Congress, or probably 99% of the things that go on in our nation's capital (but I do love the museums). However, I learned that we have to work with what we have. So in this special IMPACT Washington, D.C. section, I have included nine interviews I conducted with people in our industry who can tell you in their own words what it was like to be involved and what they think of IMPACT—and whether it's worthwhile for you to attend.

A very serious and determined group of your peers—top management from IPC member companies representing PCB, EMS, equipment and materials suppliers—listened carefully to IPC's staff experts on the immediate, most pressing concerns of our industry. This year, three hot issues were chosen to follow up on with members of Congress and their staff. (It is best to limit the agenda to just a few items so as to not dilute the message nor distract the intended audience.)

The three major issues addressed at this IMPACT were:

- TSCA—The EPA's interpretation of the Toxic Substances Control Act makes it more difficult to recycle chemicals like copper etchant than to simply treat and dispose. IPC's argument: "We want to do the right thing and recycle as much as possible. Do you really want to discourage this?"
- Dept. of Labor—New proposed regulations would significantly raise the baseline salary of those who can be considered exempt from federal overtime pay regulations, effectively making more people eligible for overtime pay. Plus a formula is being proposed that would continue to raise this baseline on a yearly basis, pushing many salaried employees to become hourly, with attendant time card requirements.
- NNMI—the National Network for Manufacturing Innovation is a public-private partnership that draws on the resources of the federal government, local governments, universities, research institutes and industry to accelerate manufacturing innovation. IPC is urging full funding and long-term planning for the network.

Attendees were also asked to extend thanks for passing the now permanent R&D tax credit.

Since this time it appears that the DOL has issued the new regs affecting overtime pay, not the best of news for business. However, IPC is part of a coalition to continue to educate mem-

bers of Congress on the impact this will have on our industry.

On the other hand, as of May 23, IPC's language on by-products (TSCA item) has been included in the compromise being worked out between the House and Senate. This will indeed be a benefit to (mainly) PCB fabricators, keeping recycling practical and sensible. A vote is expected in House this week and the Senate possibly next week. This is a big win for our industry and is a direct result of efforts at IMPACT.

And now to the "Why." I think I'm like most of you—I abhor politics, politicians and all things that smack of them, which of course includes at least half the population of Washington, D.C. However, ya gotta do what ya gotta do, as they say. And as John Hasselmann says, "You are either at the table or on the menu," meaning that if we don't speak up and let Washington know what is important and vital to our industry, then we are at the mercy of whatever regulations suit their fancy—or are on the agenda of the myriad government agencies and/or special interest groups (think EPA, OSHA, Greenpeace, etc.).

It became obvious to me through conversations with the attendees that some of the congresspersons and their staff viewed corporations as the enemy, though others were more open-minded. It's so easy to look the other way (or vote the other way…) when a corporation or business is far away and seen as a big blob full of greedy people who don't want to share their wealth (magically produced, apparently). But when actually sitting down face to face, suddenly that abstract enemy entity becomes real, the company president becomes a real person and then he mentions the 10,000 or 1,000 or even 50–60 people that work for him (duh, voters!), and perspectives change.

And so it was and is. One thing I heard time and again was the importance, the criticality of a face-to-face meeting with one's representatives in Congress and/or a member of their staff. More than one attendee mentioned visits to their facilities by their representative and the very positive impression it made on some. A bonus for the CEO was that the tours sometimes became a town meeting for their employees, which is definitely a win-win.

All of this happens and happened at IMPACT Washington, D.C. 2016. Many of the participants had been to IMPACT several times before but some were newcomers. IPC's Washington staff carefully prepared the agenda, the talking points, so to speak, and thoroughly coached participants on how to approach various representatives. In one case, specific "hot buttons" were to be carefully avoided. This was serious, important business. I can't stress that enough—as important as that next piece of equipment or facility upgrade, in fact probably more important, considering the number of things in Washington working against staying in business.

So don't sit back and wait for someone else to go. Start thinking about and planning for IMPACT 2017, next April. There will be a new administration, new members in Congress, and more educating to be done. New bills will be proposed. Will they be pro-business? Will they help or hinder your business?

In the meantime, contact IPC's John Hasselmann and ask him to help set up a visit or tour with your representatives at your company. Bookmark and regularly check IPC's Government Relations page for updates on legislation and other info that could affect your company, along with the latest issue of the Global Advocacy Report. Do be proactive and take part. It's good for you, good for your business and good for our industry.

I hope you find this special section enlightening and inspiring. And thank you. **PCB**

Veteran IMPACT Washington, D.C. Attendee Matt Turpin on the Event's Benefits

I made contact with Matt Turpin, CEO of Zentech, before the first evening's dinner. We sat down to discuss what he hoped to gain by attending the event.

Patty Goldman: *Matt, I'd like to know what your expectations are of this meeting.*

Matt Turpin: The IPC does this every year, and I've been here the last five years for IPC. It's a great opportunity for the IPC and members of the IPC to meet with their local officials on Capitol Hill as well as other people on Capitol Hill and kind of deliver the message of what's important to IPC and the IPC vendor, whether it's in terms of RoHS compliance or conflict minerals, etc. This year it's Defense Department labor regulations and things like that. It's a good way for IPC to get its point across and to influence what happens on Capitol Hill.

Goldman: *How has that worked in the past?*

Turpin: It's worked out well. Some of the issues in the past have been the R&D tax credit and it looks like that is permanent at this point. I think some of the things relative to changing the narrative with conflict minerals is going slow, but it keeps the issue alive and shows that it's not the slam dunk that Dodd-Frank thought it was going to be. There are other issues where they have had some success, like the NNMI (Na-

Zentech's CEO Matt Turpin and VP John Vaughan during a preliminary meeting.

tional Network for Manufacturing Innovation) that the White House was big on, getting that properly funded and through Congress. That was a big push and it's been a big success.

Goldman: *Do you think this is directly attributed to IPC and its members being here in Washington?*

Turpin: Absolutely, yes. The IPC are tying up and spending member dollars doing this and they've got a local lobbying group that helps them with setting up. As part of that, they're making sure that they're getting back their bucks. Every year we talk about what are we going for, and what progress to aim for. The Government Affairs Committee orders routine board calls and committee calls to find out what we're working on, what outcomes to expect and what kind of progress.

"Every year we talk about what are we going for, and what progress to aim for. The Government Affairs Committee orders routine board calls and committee calls to find out what we're working on, what outcomes to expect and what kind of progress."

Goldman: *You've seen real progress?*

Turpin: There has been real progress. Absolutely. There's always something new.

Goldman: *I assume there is always something you have to worry about and work on.*

Turpin: Congress is always trying to come up with new ways…

Goldman: *New ways to mess it up [Laughs]. What do you particularly want to get out of this session?*

Turpin: The sessions have a number of different purposes. One is that it's good to get IPC members together. They tend to bring in CEOs for this event. It's good to do the networking and to find out what other people are faced with separate from the regulatory issues. It's also good for the CEOs that come to this to understand what the regulatory climate is like and what those issues are. Because I know when I first started coming, I really didn't understand all the issues that IPC was going to bat to Congress for in terms of representing their constituents within the IPC. I enjoy that aspect of it.

For me personally this year, I'm taking a more active role in helping get across the message in terms of the new Department of Labor regulations that are being proposed—as related to exempt and non-exempt status and raising the baseline salary level of those who can be considered non-exempt.

Goldman: *Anything else you would like to say about this?*

Turpin: I would say the only other thing is that anybody who is reading this article and is aware of the IPC, or some of the events the IPC does, whether it's APEX or whether it's IMPACT or another event, if they're a CEO, it's worthwhile to get involved and to help out. It helps them personally and it helps the industry as a whole.

Goldman: *Some people would probably say it's expensive to come here, like paying for the hotel, travel and that kind of stuff. How do you feel about the money end of that?*

Turpin: Everything has a cost. You could certainly argue that not participating also has a cost. I personally think that it's worthwhile and that on the whole the cost is definitely worth the benefit to people individually and to members as a whole.

Goldman: *Thank you, it's nice to talk with you.*

Turpin: Thank you. **PCB**

IPC's Hasselmann on IMPACT Washington, D.C. 2016: Why it Matters

I spoke with IPC's VP of Government Relations, John Hasselmann, immediately following the welcome dinner at IMPACT Washington, D.C. 2016. Among the topics we discussed was the importance of industry executives coming to Washington to present a collective message to policymakers.

Patty Goldman: *John, how was the dinner discussion tonight?*

John Hasselmann: Thank you, Patty, it was good. This was an opportunity for those who have been here before, and those who haven't, to network and get acquainted. We also had two speakers, Republican senior strategist Charlie Black and Democratic senior strategist Scott Pastrick, to talk about the current state of politics, not just in Washington but nationally. When you go into a meeting with a member of Congress or a policymaker, it's important to remember there are other things happening in the headlines, and they may be distracted by that. We need to be the advocate and say, "We need to talk to you about this even though there's a lot of other stuff going on out there."

Goldman: *Right, your goal is to keep them focused on your issues, and of course they've got a million other issues that they are also focused on.*

Hasselmann: Exactly. But the collective group here is a very powerful voice. When you have these executives coming into town, representing the electronics industry, and they are here together on the same page, not necessarily as competitors, that makes an impact.

IPC's John Hasselmann(L) and John Mitchell (R) pose with Congressman Bill Johnson (R-OH) with the capitol building in the background.

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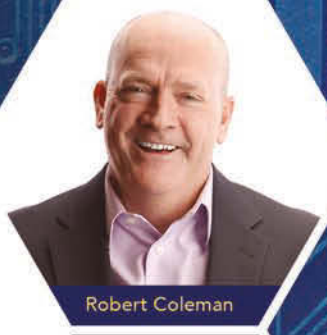
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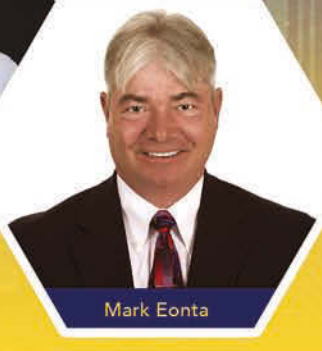
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Goldman: *I think a lot of people don't understand that it can make a difference. They think, 'I'm just one little person, what can I possibly accomplish? The policymakers have a million other things on their minds. How do you make a difference?*

Hasselmann: Well, your voice as an individual is important, but when there is a collective voice that is unified, it's very important. I always point out that firefighters, nurses, policemen, teachers, etc., all have representation here.

Goldman: *Tremendous representation.*

Hasselmann: Exactly, and so should manufacturers and the electronics industry. We're just using the tools in our toolbox to represent the industry and be that collective voice. You mentioned that these members of Congress and their staff have all these issues to think about, and they're all over the map meeting with tons of people. IPC represents the whole supply chain. IPC members are in every continental state, and IPC represents almost a million workers. So when you tell that story to members of Congress, they'll listen. We're their constituents in almost every district. So if we come in and we're organized, if we have a succinct message and we have credible data, we can have a real impact.

"IPC members are in every continental state, and IPC represents almost a million workers. So when you tell that story to members of Congress, they'll listen."

Goldman: *What do you expect to accomplish over the next two days? What's the mission?*

Hasselmann: This year is a little different because we're in a presidential election year. Congress has very few legislative days this year, so we have a small window of opportunity to educate these policymakers, and to lay the groundwork for the coming year with a new President and a new Congress. A lot of our goals here are focused on meeting policymakers that may be even more influential next year. So we're meeting with surrogates from the presidential campaigns tomorrow; some are current members of Congress, others are former high-ranking officials who now represent these campaigns. But we're also solidifying and still educating a lot of these policymakers about IPC and who we are and what we stand for as an industry.

Goldman: *I can imagine what happens is you get some of them educated and then they move on. You've got to keep on educating.*

Hasselmann: That's why we're here, for the industry. The 48 hours that these executives come to town for IMPACT help us do our job for the rest of the year. That's not just in the U.S.—we're focused globally—but this particular event in D.C. is very important. It's exciting and I love doing it.

Goldman: *One of the things that I hope to accomplish is to get across to a lot of people that aren't here why there's good reason to be here.*

Hasselmann: Well, thank you for that. When I started here three years ago, one of my goals was to make sure that we had a stronger communications effort. What's that cliché? If a tree falls in the woods, and no one is around to hear it, does it make a sound? I think that is what happened in the past, like there was a small segment of the industry that knew the importance of what we were doing on the advocacy front, but it wasn't enough.

Now the industry is getting more involved—through the board of directors, through our government relations steering committee, and through various other groups. This is a good thing; we need to be at the table. You know, the other cliché is: If you're not at the table, you're on the menu!

I think because our industry is so connected to government, whether it's here or in the EU or

(L-R) John Hasselmann, Nilesh Naik and Bhawnesh Mathur on the terrace during a cocktail hour.

in China, the decisions really affect our members.

***Goldman:** We all know that from RoHS, right? Everybody got blindsided by that.*

Hasselmann: Yes. RoHS, conflict minerals, and there are others. When something is coming across a policymaker or regulator's desk, or there's some sort of proposed rule or a piece of legislation, I want someone to say, "Have we called IPC?" Because that's my goal: to be at the table. There are a lot of other trade associations, but we represent the whole supply chain, we're global, we do standards with a lot of professional development and educational training around these standards, and we do trade shows. That's very unique compared to some of the traditional trade associations that are based here in Washington, D.C. who just focus on advocacy. We've got a lot of real-world experience to back up our advocacy.

***Goldman:** A lot of people probably think, and I'm just trying to be the devil's advocate here, why not let IPC do all that? Why do I need to come to town? What is the importance of having companies or company executives come? What difference does it make?*

Hasselmann: The congressional staff see us all the time, but it's much different when a CEO takes the time to call a member of Congress, or to come to Washington or Brussels.

If a CEO comes in who's on the front line every day—making decisions that affect their employees, making decisions about whether they need to have a factory here or there, who is looking at their bottom line in terms of keeping revenues up and keeping their employees and customers happy—then members of Congress and policymakers are going to understand how important it is when they make a decision, and that they're going to impact us.

If CEOs take the time to be advocates, policymakers are going to listen because they have to make those decisions, too. We're always trying to get the decision makers together in the same room to come up with a plan and make it work. And that's the goal.

***Goldman:** And if your members are not there?*

Hasselmann: Then you can't complain.

***Goldman:** That is also true; how do you complain about something if you didn't engage or take part?*

Hasselmann: That is the beauty of this. I'm a firm believer in petitioning the government, and under our Constitution, we have the ability to do that. Without their trade associations, the nurses, firefighters, engineers and CEOs aren't going to come to D.C. all the time, so we try to bring that opportunity to our members.

Let me give you another example. We instituted a program called "Meet the Policymakers," in which we bring them into the factories and facilities and let them see all the innovation that is happening and to meet the workers. In the last few years, we have done over 30 or 40 site visits with members of Congress and our member companies around the U.S., and we have done some with our members in China with Chinese officials as well.

***Goldman:** So they get to meet the voters.*

Hasselmann: And the workers are their voters, exactly. It's a two-way street. When they see the factories they're just like, "Wow."

***Goldman:** They probably can't even conceive of what goes on in there either.*

Hasselmann: They're usually very interested, and when we get the employees together, they are thrilled to be able to engage with them. We'll set up meet-and-greets or town hall meetings and just let them ask whatever they want, and that brings the advocacy opportunity to the employees, too.

***Goldman:** If any IPC members called up and said, "Hey, can you arrange something with my congressman and help me get them into our factory?" That can actually happen?*

Hasselmann: Yes, we will do our best, no question. That's why we're here. But it's not all happening here, it's really happening out there—all the work, the innovation, the R&D, and the jobs. We're just trying to make sure that policymakers are educated and that the legal, regulatory and legislative environment is conducive to continuing to grow our industry.

We want to be at the table. We want to be able to debate the pros and cons of anything that may have a negative or positive impact on the industry. We want to be a stakeholder, and we're going to be that voice. We're making a lot of strides, and this event is really helping us to do that.

"We're making a lot of strides, and this event is really helping us to do that."

***Goldman:** How many congressmen will you guys be seeing over the next few days?*

Hasselmann: It's a two-track approach. As a group, we have about ten key meetings with members of Congress and administration officials. But then we also arrange individual meetings for our attendees with their representatives where they have facilities. So they can go in and establish those relationships and we facilitate that, and that allows us to spread the word even more.

We probably have 30 to 40 of those individual meetings, where it's an opportunity for that CEO or that executive to talk about very specific issues of concern to them and whatever they want to raise. The policymaker wants to know, "What's keeping them up at night? What can I do to be helpful? What do you need? What can I do to cut some red tape for you?" They want to do that in a heartbeat for businesses in their district.

This is the opportunity for our members to talk about those very local issues, but also we're there to talk about some of the broader issues where we can come back and work with them

because it's an opportunity to help their constituents. That's where we're trying to connect dots.

***Goldman:** Connecting dots is a good way of saying it.*

Hasselmann: I get excited about this, as you can tell. [Laughs]

***Goldman:** Well, like you said, this event is only one part of your job overall, but it's going to make your job easier.*

John Vaughan of Zentech told me he's been coming for six years, and in the first few years he didn't really notice much, and then he started seeing stuff happen, like the things that you guys were advocating becoming some real success stories. Things don't happen right away though, it takes time. These guys can't just come here and then expect next month that something's going to happen as a direct result. It doesn't happen that fast.

> "We try to help facilitate that conversation and try to offer policy solutions that help the industry."

Hasselmann: I think they get it. For the most part it is like long-term planning, like when these CEOs have to look ahead with a five-year plan. There's a new Congress here every two years, they roll out an agenda, and we have an agenda, too. Where do they mesh? We try to help facilitate that conversation and try to offer policy solutions that help the industry.

***Goldman:** I was just thinking there are some very loud voices here in Washington these days. You probably can't get louder than them, so you just have to be that voice of reason in there.*

Hasselmann: Oh yes, and I think that's what we are. Our issues are bipartisan. We have great market research on the industry, we have data, and we have information that backs up what we are advocating for. For example, when we're talking about some of these environmental issues, we have data that explains why we think this approach is better than that approach. Policymakers and their staff thrive on all that. Instead of just rhetoric that people get so wrapped up in, we try to be that voice of reason because we can bring in the data that supports our message, and that's my role: To make sure it's bipartisan and that we have the meat behind our message.

***Goldman:** And does that get through?*

Hasselmann: It does. The serious policymakers appreciate it, and they'll come back to us. With all the engineers and the technical and compliance people involved with IPC, we can go and ask them, 'How would this regulation affect you?' Then we have the execs and CEOs to weigh in and say, 'Okay, we think this will be good for the industry, let's go.' I like that we can draw on the expertise of all segments of a company.

***Goldman:** I noticed, too, that a lot of the issues on your agenda, like conflict minerals, are not just challenges in our industry. It's not like we're saying do this for me, me, me. IPC's agenda is good for business, for the industry, and for the country.*

Hasselmann: Exactly, it's even more powerful than just us. We're working to be seen as a leader among the various industry groups. It's very important to form and be part of broader coalitions of industry groups to bring more voices to the table. Coalition building is critical, and we have a lot of organizations that we work with, here and abroad, depending on the issue. We have members of IPC that are members of other organizations, and they want us to work together and achieve more synergy. They understand that the collective voice among different industries is just as important for getting something done.

***Goldman:** John, I really appreciate you taking time to speak with me today. I wish you the best in the next 48 hours.*

Hasselmann: Thank you, Patty. **PCB**

STI Electronics Participating in IPC's IMPACT Washington, D.C.

Dave Raby is president and CEO of STI Electronics and an eager participant at this year's IMPACT Washington, D.C. event. We talked early on the first day of the event, before a heavily scheduled day for the attendees.

Patty Goldman: *Dave, what are your thoughts about this year's IMPACT event, overall?*

Dave Raby: I'm excited. I came to this event for the first time last year and have been looking forward all year to coming back. It's really great to meet the other people in here. It's all senior executives from companies in our industry from all over the country. Whenever senior executives from the same industry get together, we usually find out we share many of the same concerns and that is true with this group. Washington, D.C. is also a foreign world to most of us, and it's great to get up here and see what's going on here and see what our representatives are thinking. What is even better is, through the efforts of IPC, we can actually have an influence on some things and can give them our opinions. As Americans, it is what we're supposed to do but I don't think most of us do anything unless there's a group like this supporting it and organizing it.

Dave Raby

Goldman: *Yeah, there's some reluctance.*

Raby: It's hard to come up here as a lone wolf and just say, "Hey, I want to support this bill."

Goldman: *First of all, how would you get to see anybody?*

Raby: That's a good question but also how would you even know what bill was out there? IPC does a great job of scheduling visits with key people from all over the country and also with the representatives from my states. STI has employees in four states and tomorrow I'll be visiting both senators from one of the states and our U.S. representative from two others. IPC staff does a great job of keeping us informed on the legislation that is at various levels of the process and gives us a very good idea on where the people we are meeting with stand. We can then express our views and let them know we appreciate their support and encourage more support, or let them know why we see their particular stance as a problem. My opinion may or may not change their opinion but I've been impressed with how they really will listen and consider how a certain piece of legislation will affect my company and their constituents. It was fascinating to me when I came last year just to see how the government works. We often complain about how it doesn't work, but in re

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ality, it has done a pretty good job over the last 240 years or so.

Most of the legislation starts for a good reason. I compare it to my shower thoughts at home. I've come up with what seemed like some of the world's greatest solution or idea as I'm getting ready to go to work in the morning. I'm so excited when I can get to the office and tell my staff about them. Most of the time, as soon as I start saying them out loud I realize that it may actually be the dumbest idea I've ever had. The legislation starts for a good reason and seems like a good idea at the time and, by the time you get through the process that they go through, there's hopefully people like us that have come in to say, "Yeah, this really is a good idea but could you add this to it?" Or, "We really don't like this. Have you thought of what this would do to business? While it seems like a good idea overall, maybe if you took out this line, then it really would do what you want." Right now, you've got the unintended consequences that are going to happen.

***Goldman:** You really have to think about the consequences.*

Raby: Exactly, and no offense to the lawmakers but they are trying to improve our lives and businesses but usually have no idea how they work and some of the unintended side effects some of their laws can have. Just making up an example here but there could be something that will save my company $10,000 but causes me to have to hire a full time person just to fill out the paperwork. That didn't save me $10,000. That put a productive person out of work. That's a big reason for being here this week.

Just as a citizen, it's frustrating to watch the democrats versus the republicans, republicans versus democrats. If I have an idea, no matter how good it is, you're not going to like it, and vice versa. It's nice to get up here and see they actually do talk to each other (or at least many of them do), and there are some things that they cooperate on.

***Goldman:** There are things behind the news that happen.*

Raby: Right. Apparently, talking to each other doesn't make the news.

***Goldman:** That's for sure; it's not as exciting. Do you think you'll come next year? Do you see this as a good event to attend?*

Raby: Yes I do. If it's anything like last year—and from the schedule we have, it looks like it will be—I'll be back next year. I also want to encourage other business leaders and owners to do the same. It costs two or three days of time plus your travel expenses and can have a direct benefit on your company's and your industry's future as well as your country's future. Plus, it is interesting, educational and we have some fun, too.

***Goldman:** There's a pretty heavy schedule this year, from what I understand.*

Raby: We're hearing from four different presidential campaigns this morning, which is something that of course we didn't have last year. It may not be a kind way of saying it, but it's a straight-from-the-horse's-mouth type of thing that you don't get sitting at home on the couch. It'll be interesting to hear how that goes and we get to question each candidate on their thoughts on keeping (or making) American manufacturing competitive with the rest of the world. Then we're also meeting with several congressmen and it will be great to get their perspective on things, and also give them our perspective.

One of the things I'm talking about is the NNMI, the National Network for Manufacturing Innovation. We are meeting today with Senator Orrin Hatch, who's the head of the Senate Committee on Finance. Senator Hatch is number three in line to be president, as far as a succession plan.

***Goldman:** That's not somebody you can just knock on his door and talk to.*

Raby: I'm from a little town in Alabama. That's not somebody I'm used to talking to. I'm a little nervous about that, but I also know from last year, IPC will get me through it.

Congressional meeting.

Goldman: *Right, they keep you well-informed of all the important stuff.*

Raby: They've educated me, but they're also going to be sitting next to me. If I start to stumble, they'll steer me in the right direction, or if the senator asks a question that I don't know the answer to, I just look over and they'll help to answer it.

Goldman: *And John Hasselmann said they have all the data ready as well. So they'll have a lot of answers.*

Raby: John and his entire team do a fantastic job.

Goldman: *Okay. It's probably about time to head in to the meeting. Well thanks so much for your time, Dave.*

Raby: Thanks Patty, I appreciate you being here, because publicizing this can do nothing but help it.

Goldman: *That's what I hope to see happen also.*

Raby: IPC does a great job on this. There's nobody else up here looking out for us in the electronics industry. **PCB**

Creation Technologies on IMPACT Washington, D.C. 2016

Meeting with congressional leadership, peers, competitors—it's all valuable, according to Bhawnesh Mathur, president and CEO of Creation Technologies. Here are his thoughts on the benefits of the event after the close of the first day of IMPACT Washington D.C.

Patty Goldman: *Bhawnesh, tell me about your day here at IMPACT. How was it for you?*

Bhawnesh Mathur: There are so many good things that come out of these annual IMPACT events. First of all, I feel like it's always important to partner with our political leaders. Their interests and our interests are the same. We want to see the economy grow. We want to find jobs. We want to move technology forward. I think when people have aligned interests, they should meet, talk and find ways of working together. It's always good to do that.

The specific issues that we talked about today will help us get better aligned. It's not an overnight thing, but for the last several years that we've been coming here we've learned to speak with each other. We've developed credibility with each other. We've actually shared accomplishments with each other that we can celebrate and so on. Every time we come here I think we move the ball forward and that's a good thing.

I also enjoy meeting all of my peers, and suppliers and competitors. I think it's pretty cool that we can be competitors in the morning and come here and work together on behalf of the industry, and that benefits everybody. Obviously we're trying to win against each other on certain days, but if our industry doesn't win, we don't win. I feel a sense of urgency to do everything we can to help the electronics and manufacturing industries grow and get some of the benefits.

Goldman: *How many years have you been coming to IMPACT?*

Mathur: I think this is my fourth or fifth year.

Goldman: *Do you recall what prompted you to attend the first time?*

Mathur: I do remember. I was in Denver, Colorado then, and I thought if I met my politicians, my senators, and my congress people, I could do more with them in Denver. I came and advocated on behalf of my company at that time. I told them, if you help me I can create jobs here, and I asked them if they could help my company get economic relief in this or that way. And we started a dialogue, and it actually helped. It didn't solve all of our problems of course, but it was enough to get me started. I also began to network with their connections and that helped too. So I definitely benefited from attending the first time.

Goldman: *So you came back the second time?*

Mathur: I came back, and now I manage a company that's in 12 different locations around the world, with nine in the U.S. and Canada. So I find benefit. Representative Paul Ryan visited our Milwaukee manufacturing facility the week before he got named to Speaker of the House, and we told him we could use some help with an OEM that we wanted to partner with. He said, "I visited your facility, I spent the whole day here and I liked it all. I'll talk to those guys." And I don't know if that played a part, but we did end up winning the business in the end.

Goldman: *Have you had congressmen come and visit in any of your other locations?*

Mathur: Yes, we like to invite them—there are lots of benefits to that. First, they get to understand who we are and a little about our industry. One of the benefits, which is really at the top of our list now, is when people like Mr. Ryan visit, is giving our people a chance to meet local leadership and ask questions at a town hall meeting. They likely would not otherwise get this chance. We may have anywhere between 200–500 people in a Creation business unit and this is a way for us to bring the community to our team. That's another benefit of coming to work with our company.

Goldman: *So actually getting a congressman to your facility came about because of coming to IMPACT?*

Mathur: Yes, when we meet these fellows, we're always trying to figure out the next step, and one of the next steps is to say, "Why don't you come visit us?" That actually became an initiative that John Hasselmann and his team run now. We measure how many visits we have, we have targets and a process. We've invited Prime Minister Justin Trudeau of Canada, we've invited President Obama, and he wrote us a letter back saying "No thank you, but Penny Pritzker, the Secretary of Commerce, will be available to come meet with you."

Goldman: *Nice!*

Mathur: Yes. We're finding that we get some recognition, our people can meet the leadership, and that's a good thing.

Goldman: *And conversely, your congressman learns a little bit about you and about the industry.*

Mathur: Absolutely, that's right. Many of them completely understand what we're doing and some of them have no idea what we do. It becomes especially clear when they take a tour, though, because it's hard to explain exactly what we do in a conference setting like this.

Goldman: *A picture is worth a thousand words, but I'm sure a tour is worth a gazillion words.*

Mathur: For sure. When you see 200–300 people making state-of-the-art medical equipment, which is an area Creation specializes in, and you see an incubator we made where a baby is brought after she is born, or a CAT scan machine that we designed, or an ultrasound machine that we worked on, that's very powerful.

Goldman: *It sounds like lots of good things happened today then.*

Mathur: Absolutely.

Goldman: *How many congressmen did you meet with?*

Mathur: Formally, three.

Goldman: *Of course everybody has their own three that they meet, I guess.*

Mathur: Everyone has their own three. I feel like because I've been coming to IMPACT for a while, I try to not be as vocal. I think others need to participate and feel like they've been a part of it. But our message is getting across, and I certainly believe the view that it's the authentic person who makes the biggest difference. You can't just hire someone to come in your place and represent whatever it is you believe in.

Goldman: *Excellent! Any final thoughts?*

Mathur: I think politics are always dynamic. One of the things I'm learning is that while we've done all of this, you can't ever stop or let your foot off of the accelerator. If anything, I think we need to do more of it in more places. Creation Technologies is a global organization with global customers, so there's Europe, Asia and other places where we can get involved and make a difference.

Goldman: *Bhawnesh, thank you so much.*

Mathur: Thank you. **PCB**

IPC is One Thing, but Constituents are Quite Another

As I was unable to attend the actual meetings with the representatives, I wanted to catch the thoughts of those who did. I've known Nilesh Naik, CEO of Eagle Circuits in Dallas, Texas, for many years. We sat down for a chat after the first day's events.

Patty Goldman: *Nilesh, tell me how things went on the first day of IMPACT.*

Nilesh Naik: It's been a great day. Unfortunately I've missed Capitol Hill Day, or IMPACT, for the last two years, and was excited and glad to make it this year. It's just a great opportunity to visit with senators and congressmen. The exciting thing is they passed the R&D tax bill last year, so it was a good chance to finally say thank you. Interestingly, we've been on the Hill for the last seven or eight years asking for it to become a permanent tax credit. It's neat to see the process come to a complete end, and actually have a permanent tax credit. So I'm excited from that point of view.

It's quite amazing; every time we come to Capitol Hill, whether it's the legislative system, the congressmen or the senators, they do genuinely want to listen and hear from you. It's always great to present your perspective and situation when you get a chance to talk to them. They say, "These are my constituents," and they do listen.

Goldman: *So it's been worthwhile for you to attend?*

Naik: Absolutely worthwhile.

Goldman: *You get to meet with your own congressman tomorrow, is that right?*

Naik: Yes, and I'm looking forward to that. We've been fortunate enough to have Congressman Johnson come to our factory, so that was just even more fun. The Congressman has actually seen the manufacturing process. He's touched the product and talked to our people.

Goldman: *They actually begin to understand…*

Naik: They absolutely understand. Surprisingly, they do know a lot of what's going on. The challenge for them is they've got numerous other issues that are also going on. They're looking at a bigger picture and still saying, "Hey, how do we solve your problem?"

Goldman: *Your congressman knows what's going on. He's been to your factory, but what about all those congressmen who represent those companies that are not here? What do they know about your business or circuit boards and our industry?*

Naik: It's a great question, and one of the things that always concerns me. It is disappointing—that we don't get more of our member companies out here. This is the one time of year where you get a chance to meet your congressman, and you get to talk about your industry. It's amazing, they're eager to listen and learn, but you've got to come tell them. If you don't, you miss out on it. You've got to build those relationships.

Goldman: *It's a great opportunity to get your voice heard.*

Naik: Absolutely. They hear you, and today there were very positive responses with all the congressmen and senators that we spoke with. They're all for it. They understand what we're talking about. Heck, they want manufacturing

back in the United States. It's not like they want to get rid of it. When you can point out certain things that are hurting U.S. manufacturers, they're going to listen and they're going to see what they can do to fix that.

Goldman: *That's good.*

Naik: We had a great talk about that, and we had a great talk on TSCA. One very concerning topic that will affect all the PWB guys is the changes in regulations that are being proposed by the EPA. They're trying to get us to document all recycled material. The way the EPA has proposed the regulation, they are actually disincentivizing the PCB shop to recycle product. It would be cheaper for us to go send our waste streams to the landfills. This is totally counterproductive.

Obviously, recycling is the best way to do things, but the way it's being written and the way it's being proposed by the regulators right now will actually be a disadvantage. Again, this is a great conversation to share with the senators and congressman and say, "Wait a minute, that doesn't make sense. Why are we doing this?"

Goldman: *How far along is that? How critical is it to get that message out right now?*

Naik: I believe it's something that is going to come up within the next few months. The EPA is close to the end of writing their regulations. It's something that all the board shops need to be aware of or else we will just be creating more work.

Goldman: *They all should at least be calling their congressmen right now.*

Naik: Without a doubt. The challenge is exactly that. If we don't bring it to their attention, then they don't know how to fix it. Then all of the sudden you've got the EPA who just goes and creates all this stuff. If you want change, you have to be a part of the change.

Goldman: *You've got to have the answers for them.*

Naik: Absolutely. From that point on, the IPC does a fantastic job, with Fern Abrams and the whole team that John Hasselmann has here. They've got a hand on all the issues affecting us as an industry, so they can give you that feedback and answers. But at the end of the day, the congressmen don't want to listen to IPC staff. They want to hear from their constituents. The constituents have to show up. Actually, they can even just make a call. Even if they call the congressman, that's a huge thing. One interesting thing we learned today was even just a hundred call-ins about a particular topic will actually change the needle and may even change the direction a congressman would go. We do have to get active if we want to have change.

Goldman: *I imagine face-to-faces are even more persuasive. If a number of people get in touch with the representative in their district and get a face to face with them, that's got to have even more sway.*

Naik: A face to face is totally worth it. If a congressman is having a town hall meeting in your district and you go see them, it makes a huge difference. Especially if they hear the same message a couple of times, they are going to come back to D.C. and talk to the legislative assistant and say, "Okay, this is what I heard back in the district, so what are we doing about this?" Your voice is heard, but you've got to speak up.

Goldman: *What are you expecting for tomorrow?*

Naik: I'm looking forward to seeing Congressman Johnson tomorrow and possibly Senator Cornyn. I'm looking forward to both of those meetings. Again, just see if we can further the message and continue asking for their support.

Goldman: *Excellent. Thank you so much, Nilesh.*

Naik: You're welcome. **PCB**

The Many Reasons why People Attend IMPACT Washington D.C.

At the end of Day One, spirits were high within the IMPACT group. They had heard from the top presidential campaigns, met with key representatives on the top three issues, and were now relaxing on a private terrace with a great view of the U.S. Capitol building. Everyone was looking forward to a pleasant awards dinner. I had the opportunity to converse with Tom Edman, CEO of TTM; Ed Moll, VP of Viscom; and Tim Redfern of Redfern Associates, who was at the event representing Insulectro. Not able to convince them to give up their spots on the terrace, the four of us had a great chat on the spot.

Patty Goldman: *Tom, why don't you begin by telling me how your day was? What did you learn?*

Tom Edman: It was a good day. Number one, I thought the morning was very interesting. While we didn't get a chance to hear from the presidential candidates, we had a chance to hear from their proxies. I thought they did an excellent job of representing the candidates, and to hear it in person and hear some of the positions that they've taken. That was very interesting.

Tim Redfern: I also found that interesting. I have never experienced anything like that before, talking to proxies, and getting the experience of both the democratic and the republican campaigns was an interesting comparison. I think the importance of selecting the right proxies came through today.

Goldman: *That's good. How about your afternoon sessions?*

Redfern: In the afternoon we actually came over to Capitol Hill and had meetings with four different congressmen and senators. We got a

(L-R) Tom Edman, Tim Redfern, Rick Lies, and Ed Moll.

chance to really get up close and personal and actually have real dialogue, which I thought was a great opportunity and in some cases very timely for what's happening right now.

***Goldman:** Is this your first time to IMPACT?*

Redfern: Yes, it is my first experience here.

***Goldman:** Why did you decide to attend?*


Tim Redfern

Redfern: Mikel Williams inspired me, and he's not even here! He's been encouraging me for the last four or five years to participate and get involved in this event. I talked with him a couple weeks ago and told him I was coming and he said, "I'm not going to be there this year." He's always attended and has been very involved on the IPC Government Relations committee. But I'm really happy to be here. It's a great opportunity to see how this side of the business works.

***Goldman:** Ed, is this your first time here?*

Ed Moll: Yes, it is.

***Goldman:** And what are your impressions?*


Ed Moll

Moll: I've loved it. This has been very informative for me. I've never done anything like this and this is the first time I've had the opportunity. I'm here because my boss, Carsten Salewski, couldn't make it because of business travel, so he asked me to attend for him and I jumped at the opportunity.

***Goldman:** Even from the very start this morning there was some serious discussion about which topics to discuss and the agenda—and that was impressive in itself. Some of us don't always pay attention to this stuff, and there's a lot that goes on behind the scenes that affects everybody. That was surprising to me.*

Moll: The entire day was eye-opening for me. Meeting with Congressmen or their staff makes you feel as though you are making a contribution to our industry. I look forward to the meetings scheduled for tomorrow. It's been more than interesting being here.


Tom Edman

Edman: I was one of the spokespeople for the TSCA reform and I think the timing couldn't have been better. I've come to Capitol Hill not with IPC, but with other organizations before, and we never had this kind of timing. We have a bill that has been passed by the house and the senate but was then sent to conference. So we had a chance to directly impact some of the wording, we hope, that will go into the final bill. I think that is an unusual opportunity and definitely an opportunity on something that we feel is very important to the industry. From that standpoint I think we had a very good day.

***Goldman:** What do you plan to do tomorrow?*

Edman: Tomorrow we're off to the individual meetings with each of our local representatives where we expect to have more focused discussions about where we operate and more local issues. Today we were focused on broader industry issues that IPC had set up in advance for us to discuss.

***Goldman:** Thanks very much guys.*

Moll: See you next year. **PCB**

Making Connections at IMPACT Washington, D.C. 2016

Rick Lies is CEO of Chemcut, an equipment supplier to the PCB industry. He's a veteran of the IMPACT Washington, D.C. events and shared his experiences at this year's gathering at the close of Day One.

Patty Goldman: *Rick, we're at end of Day One here at IMPACT. I've been busy getting everybody's thoughts on the day. How did things go for you today?*

Rick Lies: It was definitely a full day. As usual, IPC has done a great job of putting together a group of speakers and meetings for us. It's always interesting and informative to come to Washington D.C. and see what our legislators and our representatives are doing and what their thought patterns are.

I've been doing this for four or five years, but this year was a little bit different because we had the surrogates from the different candidates come in. I don't think they changed my mind on any of them, but they probably reinforced some things that I already was thinking. They definitely reinforced the fact that things are not going completely smooth for either party.

With the meetings that we had, IPC did a good job with the talking points, which are important. The companies here mainly come to support IPC and the customers—the people we sell to. A lot of the things that they were going after, like the Toxic Substance Control Act

Rick Lies

Congressman Bill Johnson (R-OH) addresses the IMPACT 2016 participants after dinner.

(TSCA) don't directly relate to us, but if it affects their business it ultimately affects our business. So for them to be successful we need to modernize it. Other issues like the R&D tax credits are important to us, where they need to increase the tax credit from 14 to 20%.

Goldman: ***What would you say to somebody who is thinking about coming to IMPACT next year—or not thinking about it?***

Lies: I definitely think it's worthwhile to come, if for nothing other than to support the industry. Again, IPC does a great job of identifying and developing an action plan for the issues that are important for the industry, our survival, and our growth in the future.

Goldman: ***Have you seen results over the five years you've been attending?***

Lies: Definitely, there have been good results. The R&D tax credit was made permanent, and TSCA is seeing legislation moving forward that will modernize it.

Goldman: *Fantastic.*

Lies: What's interesting is I think people need to come up here to reinforce these things with their own representatives. It has helped me develop a relationship with our local Congressional Representatives and Senators.

Goldman: ***So you actually could invite them into your factory.***

Lies: In 2015, we had our Congressman Glenn Thompson, who represents our district, take a tour of our facility in State College. Since then he has actually called us to set up another visit.

Goldman: ***That's great. What are your expectations for Day 2?***

Lies: The first day is always sitting down and everything is very formal, you have your meetings you go to. Tomorrow is more the individuals to meet their own representatives and senators.

Goldman: ***Now will you meet anyone new tomorrow, like your senator?***

Lies: I'll meet with my representative, Congressman Thompson. We're not a large community so he knows many of the people that work for Chemcut.

Goldman: ***But still, there's nothing like having that relationship. Thanks so much, Rick.***

Lies: No problem. Thank you, Patty. **PCB**

A First-Timer's Perspective on IMPACT Washington, D.C. 2016

I met with Faisal Pandit, president of Panasonic Factory Solutions Company in Illinois, for a quick chat about his experience at IMPACT Washington D.C. 2016.

Patty Goldman: *Faisal, how was your day? I'm curious about what you got out of it and what your experience was like.*

Faisal Pandit: This is my first year at IMPACT and I've got to tell you it has been very exciting and a great opportunity for me to take in a lot of valuable information. I've been in the electronics manufacturing industry for more than 25 years and there are certain serious impediments affecting the growth of this industry in North America. It's important for us to take a very proactive stance in trying to remove those impediments if we are to ever drive any meaningful organic growth.

So an opportunity to interact with our leaders who make decisions for us is a wonderful thing. IPC put some serious issues on the table and the congressmen listened. Ultimately, when you tie the growth of manufacturing—or the importance of manufacturing—to job creation, that resonates well with politicians.

Goldman: *Somehow they just don't get that until you tell them.*

Pandit: Right. They may not necessarily link it otherwise. I think that worked out quite well in terms of communicating the message and getting that going, but as somebody said earlier, in Washington things move at an incremental pace. There are no revolutions or anything major right away.

Goldman: *Right—you are not going to see anything tomorrow.*

Pandit: It's a matter of continuing to raise your voice and having these interactions from time to time, but overall it was a great day.

Goldman: *So what made you decide to come this year?*


Faisal Pandit

Pandit: I'm on the supply side of the industry and in the past I didn't really think about attending. But this year was different because I'm personally a big advocate of reviving manufacturing in North America, and we as a company are trying to work with some private and public partnerships to help enhance the manufacturing skillset in North America, which I consider to be a major impediment to the growth here.

I know a lot of people are focusing on STEM programs and things like that. We are in the early stages of trying to put a focus on the manufacturing skillset within community colleges, within high school programs and things like that. We are trying to see what we can do as a company, and I think it would require some level of support from various levels of the political establishment. By coming this year, I wanted to get a sense of what people are talking about in terms of political issues and get an understanding of the process and how we can leverage these contacts and build up on what IPC is doing.

Goldman: *Did you meet your objectives or your expectations?*

Pandit: Absolutely. I learned a lot about what IPC is doing on the regulatory side and on the political establishment contact point of view, and I think it's very positive. It did meet my objectives. I think IPC has strengthened its focus on becoming a very powerful voice for the industry.

Goldman: *That's excellent. Would you return next year?*

Pandit: I look forward to being here again.

Goldman: *Thank you so much, Faisal.*

Pandit: Thank you. **PCB**

Shaping the Issues that Matter Most at IMPACT Washington, D.C. 2016

IMPACT Washington, D.C. 2016 encompassed two intensive days of meetings for the participants. I tried to catch their thoughts at various stages of the event. Optimum Design Associates' VP and General Manager Everett Frank was happy to provide some concluding thoughts.

Patty Goldman: *Everett, here on this final day of IMPACT Washington D.C., what are your overall impressions of your time here and how it's been for you?*

Everett Frank: It's been wonderful. I think this is my fourth year attending IMPACT.

Goldman: *It seems everybody comes back to IMPACT.*

Frank: Yes, most people do. There's a very high return rate. It's a great opportunity to connect with what's going on in the industry, particularly from the regulatory perspective. We spend a good portion of time advocating for industry issues, both with departments of the administrations and with members, and so it's a very good opportunity to impact those issues.

Goldman: *IMPACT is a good name for the whole thing.*

Frank: Exactly—you can't overuse that term.

Goldman: *How were your meetings yesterday?*

Frank: Really good. It's always interesting and fascinating to look at the different perspectives and where they're coming from. As an example, we were on the labor issue quite a bit yesterday, and trying to relate our issues differently versus republicans and democrats and how we present our business needs in a way that resonates with both sides.

Everett Frank

Goldman: Do you feel there were accomplishments yesterday?

Frank: Well, I guess the proof is in the pudding, but they were well received. We certainly consistently hear back from the members that these kinds of conversations are productive to them and that they're impacted by them. They listen, I think. You always kind of wonder how much, but I do think it moves the needle and that us being here reinforces the industry's messages.

Goldman: *How about this TSCA issue they keep talking about?*

Frank: You know, honestly, it's not a direct impact to my business.

Goldman: *Just to your customers or suppliers?*

Frank: It does impact my suppliers. In our industry, PCB manufacturers who buy the chemicals are the ones who are impacted. So my supply chain is impacted. I buy from those guys, but I don't sell to them.

Goldman: *That's important too.*

Frank: It's very foundational. I mean really everything in electronics rests on what the PCB fabrication guys do. I was joking with some of them yesterday that represent those interests that they needed to speak more highly of what their companies do when they introduce themselves. Because some of these companies in the room are just foundational to the technology in our country and in our world. The things that the chemical and PCB fabrication guys do are just so important. Like Tom's company, TTM, is the largest company in the world

of PCBs, which are literally the backbone of everything that happens. Then companies like Isola are the raw goods material suppliers to them. Isola is the most innovative company in PCB materials in the world. It's not just some company called Isola. These companies are just crucial to technology development.

***Goldman:** You probably want to point to your congressman's little phone and point out they wouldn't have that without us.*

Frank: It's really true. To the congressmen and women's credit, the blur of issues and the range of issues that they face is just stunning. By and large they engage, they understand, and they know the issues we come in and bring up. It's not some obscure thing they have never heard of.

***Goldman:** Anything else you'd like to add about what's been happening the last couple of days? My impression is that everybody here is very focused. This is no lark down here, this is serious business, and very important business at that.*

Frank: Yes, our government relations staff at IPC and the Prime Policy group just do an outstanding job of shaping the issues. Obviously the industry can sort of highlight the main issues, but if you were to look across the range of things, there are hundreds of things going on in the regulatory world that affect our industry, but they do a great job of shaping and funneling us to the critical things. There's an interplay there, too, between what's important to the industry and what we can actually have an impact on. For instance on TSCA, that's an element where we can actually make an impact on certain things.

***Goldman:** Fight the battles that you can fight and win.*

Frank: These things are just the craziest things too, like in the past there's been language that gets inserted into various types of regulations that might take years to settle. For example, we spent a couple of years on very subtle language related to how PCBs are delineated on the U.S. Munitions List, which controls ITAR classifications. Two or three years over literally one sentence. But to our industry and to our PCB manufacturers in particular, that language was very, very important. But unless we tell Congress, how would they know?

Isola's president Jeff Waters (L) with Everett Frank, VP/general manager (R) at Optimum Design Associates.

Again, our government relations team and Prime Policy put us in the right meetings at the right times. We were in meetings over the years with not only members and committee staff, but with staffers at DoD and in the White House who were specifically controlling that language. The opportunity to do that is impressive. If you step back and think about it, it's impressive that IPC is coordinating an effort to target us at issues that can really make a difference in our industry.

***Goldman:** It impacts the everyday workings of your companies.*

Frank: They do a great job with that. This year they have us focused on the Department of Labor and the classifications of direct versus indirect employees. What the Department of Labor is talking about doing is just crazy talk and frankly I wasn't really that aware of it until IMPACT this year. They've pointed it out to us as something that we can go and be heard on.

***Goldman:** Everett, thank you so much.*

Frank: Thank you. **PCB**

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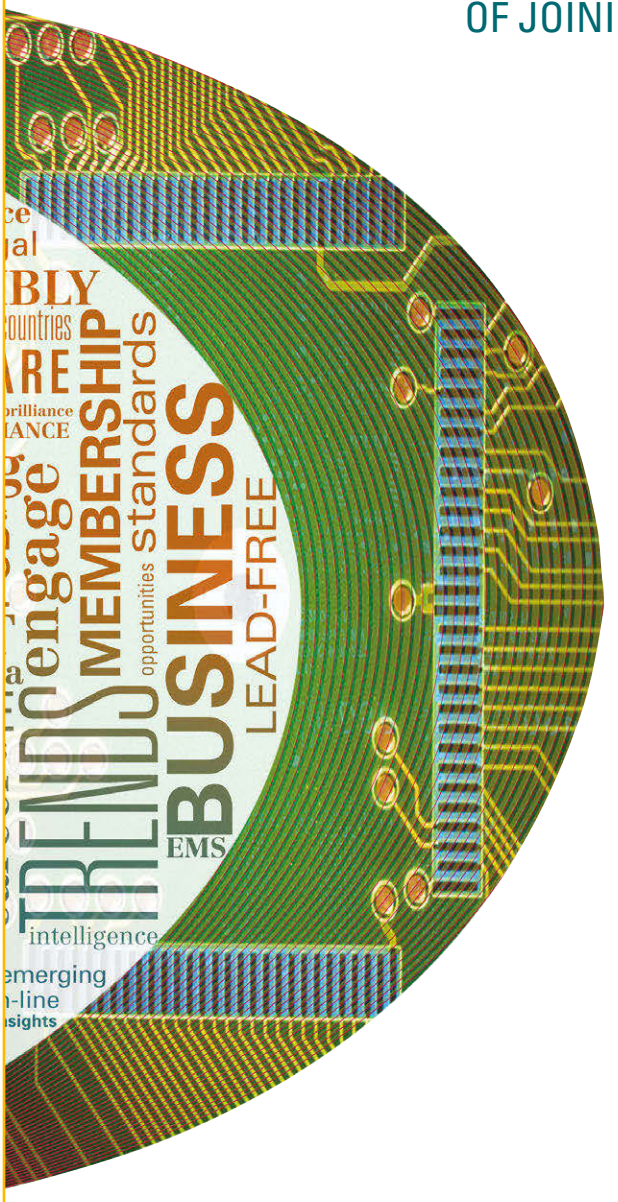

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MilAero007 Highlights

Beyond FR-4: High-Performance Materials for Advanced Designs, Part 1

In the past 40-plus years of PCB manufacturing, the primary material of choice has overwhelmingly been e-glass supported FR-4 resin laminates. This is due to the excellent dimensional stability and reasonably acceptable thermal performance (based on glass transition temperature and decomposition temperature).

IMPACT Washington, D.C. 2016: Industry Leaders Advocate for a Pro-Manufacturing Policy Agenda

IPC places a high priority on educating government officials about key policy issues of importance to the electronics industry. That's why top executives from leading electronics companies gathered in Washington, D.C. recently for "IMPACT Washington, D.C. 2016."

NASA Investigates 3D Printing for Building Densely Populated Electronic Assemblies

As detector assemblies get smaller and denser—packed with electronic components that all must be electrically connected to sense and read out signals—it's becoming increasingly more challenging to design and manufacture these all-important instrument devices.

Dragon Finalizing Departure Preps

The SpaceX Dragon is being packed with critical science today and tomorrow before its release and splashdown on Wednesday. The crew is also reviewing Dragon departure procedures and training for its release from the grip of the Canadarm2 robotic arm.

Beyond FR-4: High Performance Materials for Advanced Designs, Part 2

In Part 1, we covered basic FR-4 and variants that have been used in the commercial and military market for the past few decades, but in this column we will delve into the newer materials that target a specific application and/or market segment.

Industry Weighs in on Green Aviation Tech

Aviation's future is bright…green. That was the environmentally promising message delivered during the Green Aviation Technical Interchange Meeting (TIM), held recently at NASA Langley Research Center in Hampton, Va.

NASA, Virginia Tech Test Management Platform for Unmanned Aircraft Traffic

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

Raytheon to Start Production of First Multi-spectral Targeting System

The U.S. Air Force awarded Raytheon Company a $90 million first-lot production contract for the next-generation Multi-Spectral Targeting System. The AN/DAS-4, the latest variant of the MTS family of sensors, incorporates greater fire control and Target Location Accuracy technology for precise coordinates.

NASA Space Launch System's First Flight to Send Small Sci-Tech Satellites into Space

The first flight of NASA's new rocket, the Space Launch System (SLS), will carry 13 CubeSats to test innovative ideas along with an un-crewed Orion spacecraft in 2018.

Station Readies for BEAM Expansion

The Expedition 47 crew is getting a new module recently attached to the Tranquility module ready for expansion later this week. The International Space Station residents are also running experiments today exploring a wide variety of phenomena and checking station gear.

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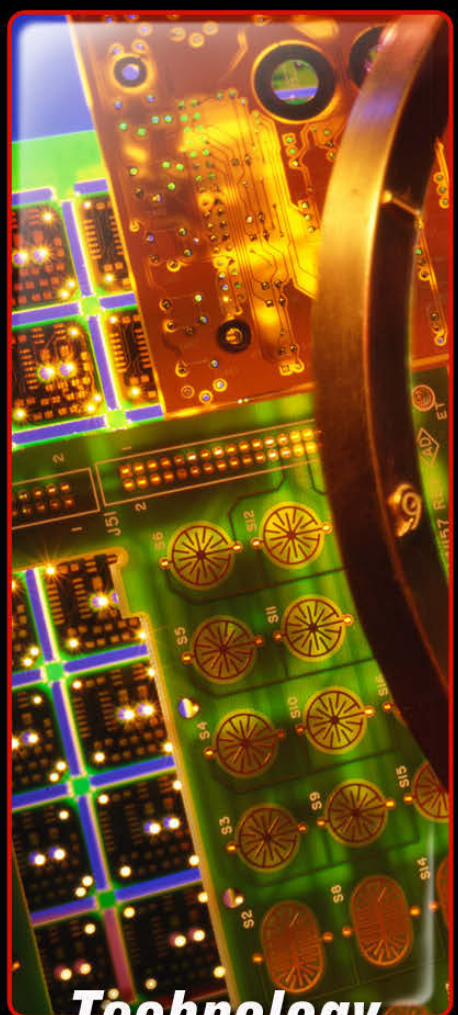

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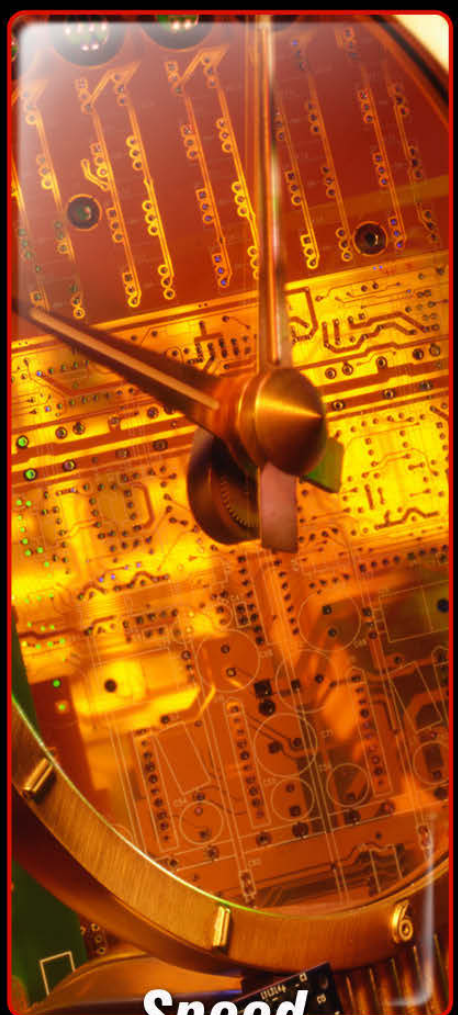

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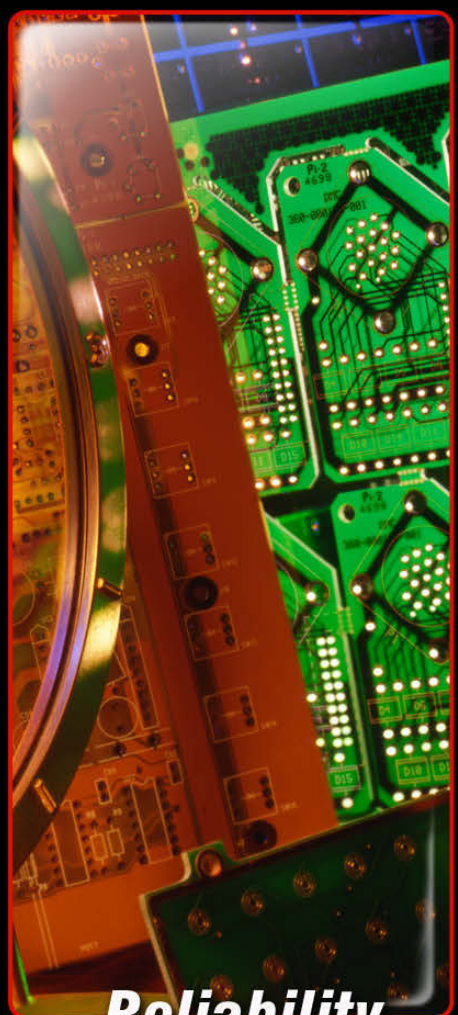

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Primary Imaging for Pattern Plating, Part 2: Development

by Michael Carano
RBP CHEMICAL TECHNOLOGY

Introduction

The proper development of the primary photoresist is critical to the overall success of the imaging process and in turn the processes that follow—either etching to form innerlayers or the electroplating processes on outer layers. In this step, the unexposed photoresist (after resist lamination and exposure) is washed away via the developing process. Further, the quality of the electroplated trace, pad and via are influenced by the developing process. Why is this an issue? Well, for the electrolytic copper to adhere to a developed surface it must be free of resist residues and the adhesion promoters in the unexposed resist. This means that the unexposed resist gets solubilized by the action of the chemicals in the developing operation.

Typical developing chemistry for aqueous photoresists is made up of either solutions of sodium carbonate or potassium carbonate. Equation 1 below illustrates how an aqueous resist is developed. (Potassium carbonate is used to show how the reaction proceeds.) With either potassium or sodium carbonate mixed with water, the process occurs as follows:

$$K_2CO_3 + H_2O \rightleftharpoons KOH + KHCO_3$$

(carbonate) (bicarbonate)

(Equation 1)

Unexposed resist gets solubilized (developed) when the carboxylic acid groups of the resist binder react with base to form soluble sodium or potassium salts of the binder. Equation (1) shows two bases, K_2CO_3 and KOH, which get consumed during development. Equation (2) illustrates the consumption of the stronger base KOH (1).

$$R\text{-}COOH + KOH \rightleftharpoons R\text{-}COOK + H_2O$$

(carboxylic acid) (carboxylate salt)

(Equation 2)

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As the unexposed resist is developed away, pH will decrease. Thus it is critical—especially for higher density circuits—that the operating pH of the developer solution be controlled to a fairly tight range (typically 10.5–10.8). One practical approach consists of selecting a desired pH (e.g., pH 10.6) to be maintained in the developer. This pH value can be dialed into a pH-controlled feed and bleed system. The system may be set up to trigger feed at pH 10.5 and cut it off at pH 10.7. One must also prevent the re-deposition of the developed resist back onto the circuit traces as this will adversely affect the quality of the electrodeposited copper. Such concerns include pitting, mouse bites (more on this in a future column), peeling copper, domed copper, non-uniformly plated traces and incomplete etching. Figure 1 depicts an example of incomplete developing.

Figure 2 depicts another issue often blamed on the developing process. The problem is a scumming on the board due to incomplete and/or poor developing practice.

In addition to underdevelopment, there are several other plausible causes for resist scumming. These include:

- Phototools with low density in the opaque areas
- Resist partially exposed to white light prior to development

Figure 1: Narrow traces due to incomplete developing.

Figure 2: Example of resist scumming.

- Poor filtration in the developer chamber
- Insufficient water rinsing after development
- Resist build-up in develop—ineffective feed and bleed system
- pH of developer too low
- Plugged spray nozzles in the developer chamber

One of the areas to investigate (if resist scumming is suspected) is the rinsing step after develop. Developing solutions are alkaline and need more water to rinse the resist developer residues from the copper surfaces and along the sidewalls of the exposed resist. Ensure there is sufficient water pressure in the rinse chamber to flush away the dissolved or partially dissolved unexposed resist. Failure to remove all of the unexposed resist can also result in what is known as a positive resist foot. (More on the positive foot will be presented in a future column.)

Rinse water temperature should at least be 17°C. In addition, that rinse is more effective if the hardness of the water is between 150–350 ppm $CaCO_3$ equivalents. The hardness of the water acts as a "stop develop" by forming insoluble binder salts. These salts are more easily rinsed away. As an aside, monitoring the pH of the resist rinse is an effective way to insure a more complete developing and rinsing operation.

Insufficient water rinse after development	• Check spray nozzles for plugging • Maintain sufficient rinse water temperature • Use high impingement fan nozzles • Check pH of water rinse
Spent developer	• Was resist loading factor exceeded? • Monitor feed and bleed to maintain resist loading factor • Make-up fresh developer solution
Incomplete development	• pH of developer solution too low • Temperature too low • Over exposure • Resist lock-in due to excessive lamination temperature • Excessive hold time between lamination and develop

Table 1.

A helpful trouble shooting guide for the development process operation is shown in Table 1.

Summary

With today's high-density circuit designs with increasingly finer lines and spaces, tighter control of the developing process is critical to provide circuit features that meet these specifications. To ensure straight sidewalls and a copper surface free of unexposed resist, the process engineer must control the pH of the developing process within a more narrow range than was perhaps required when wider lines and spaces were the norm. Also, fresh developer solution must be continuously transported into these finer lines and spaces. Thus uniform developer solution movement is provided by high impingement fan nozzles.

In addition, developing is aided by use of sufficient rinse water volume and pressure to remove remaining developer-resist residues from the sidewalls and copper surfaces.

It stands to reason that processes in printed circuit board fabrication are as much dependent on the equipment as the chemistry. By all means, follow a strict preventative maintenance schedule on your equipment. This includes replacement of worn nozzles, changing of filters and cleaning additional debris and resist materials that may remain in the sumps of the chemical and rinse chambers. **PCB**

References

1. Private communication with Dr. Karl Dietz, DuPont.

Michael Carano is VP of technology and business development for RBP Chemical Technology. He can be reached by clicking here.

ARTICLE

The 21st Century PCB Factory– Designed to Eliminate Offshore Cost Advantages

by Alex Stepinski
WHELEN ENGINEERING

Over 15 years have passed since North America and Europe ceased being the center of worldwide PCB fabrication and were supplanted by a Chinese market with low-cost labor, lax environmental requirements, and strong government support. In just a few short years, the superior offshore cost advantages of this new dynamic put volume PCB production in the West out of business, aside from the military and specialty technology applications contained in the few shops that continue to exist today.

Recently, however, the conditions that created the current equilibrium appear to be shifting again. In this new dynamic, automation, innovative green wastewater technologies, and next generation process equipment innovations have combined to make new factories capable of achieving rapid ROI for PCB fabrication almost anywhere in the world. This paper means to illustrate this new dynamic, and provide case study examples from the new greenfield installation at our captive facility in New Hampshire.

Automation

The number of equipment offerings in the PCB fabrication automation business has increased by a factor of 10 in the past five years. At the 2015 HKPCA show, automation could be found on almost every piece of process equipment being shown. Automation of many serially interconnected processes can also offer far greater labor efficiency gains than simple load/unload automation on an individual piece of equipment, especially when inline QC/fault management and automated production control are included in these fully engineered pro-

Figure 1: Requirements for full PCB fab automation.

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cess segments. The Whelen fully automated line contains 38 integrated pieces of equipment in a single piece-flow digital process.

Process-to-process transfers are most economically accomplished when the process steps are laid out in a continuous inline fashion, although autonomous transport systems can also be utilized where the luxury of an open floor plan does not exist. With an inline configuration, the cost of automation equipment and associated floor space for said equipment can be reduced by more than 35% since there is no longer a need for separate loaders/unloaders. Inline QC inspection (AOI) and even electrical test can also be integrated using tools on the market today. An inline AOI scanner was incorporated directly into the primary image process, which proved to have few enough defect escapes to qualify as the only necessary solution for the entire circuit patterning process.

As cycle time decreases due to process efficiency gains, the cost of production control also decreases. The short cycle times of inline processes limits production control to only two decisions, which can then be highly automated:

1)Deciding the priority order to feed jobs through, with no concern for in-process priority changes.

2)Determining if remakes are necessary based upon

	WHELEN PROCESS SEQUENCE	WHELEN LABOR REQUIREMENT
1	Loader	TECH #1
2	Deburr	
3	In Line Load/Unload	
4	Conductive Polymer/Horizontal Cu Plate	
5	In Line Load/Unload	
6	Pre-clean	
7	30 Panel Smart Buffer (First In/Any Out)	
8	Inkjet Primary Image	
9	In Line Load/Unload	
10	30 Panel Smart Buffer (First In/Any Out)	
11	Tin Plate	
12	FIFO Buffer	
13	Resist Strip (Plate & Etch)	
14	90 Degree Turn	
15	Etch	
16	Resist Strip (Print & Etch)	
17	In Line Load/Unload	
18	Tin Strip	
19	In Line Load/Unload	TECH #3 (Back-Up)
20	Oxide/Mask Pre-clean	TECH #2
21	In Line Load/Unload	
22	Oxide Post-Dip	
23	In Line Load/Unload	
24	Solder Mask Screen Coat	
25	Solder Mask Tack Oven	
26	In Line Load/Unload	
27	LDI with Robot	
28	In Line Load/Unload	
29	Legend Printers x 2 with Robot	
30	In Line Load/Unload	
31	Final Cure	
32	In Line Load/Unload	
33	90 Degree Turn	
34	HASL Pre-clean	
35	HASL	
36	HASL Post-clean	
37	90 Degree Turn	
38	Unload	

	OFF-LINE PROCESSES	
I	Drill/Rout/Score	TECH #4
II	ET/Final Inspect/Shipping	TECH #5
III	Layup/Press/Plasma	TECH #6
IV	Maintenance	TECH #7

Figure 2: Process flow (50 panels/hr. outer layer and 18 panels/hr. multilayer).

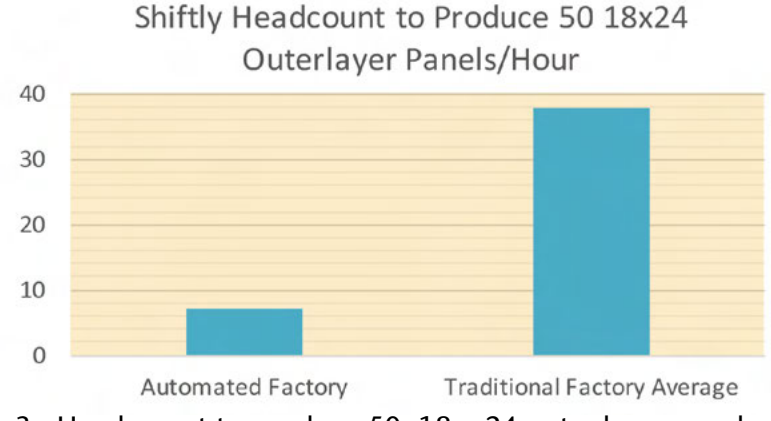

Figure 3: Head count to produce 50, 18 x 24 outer layer panels per hour.

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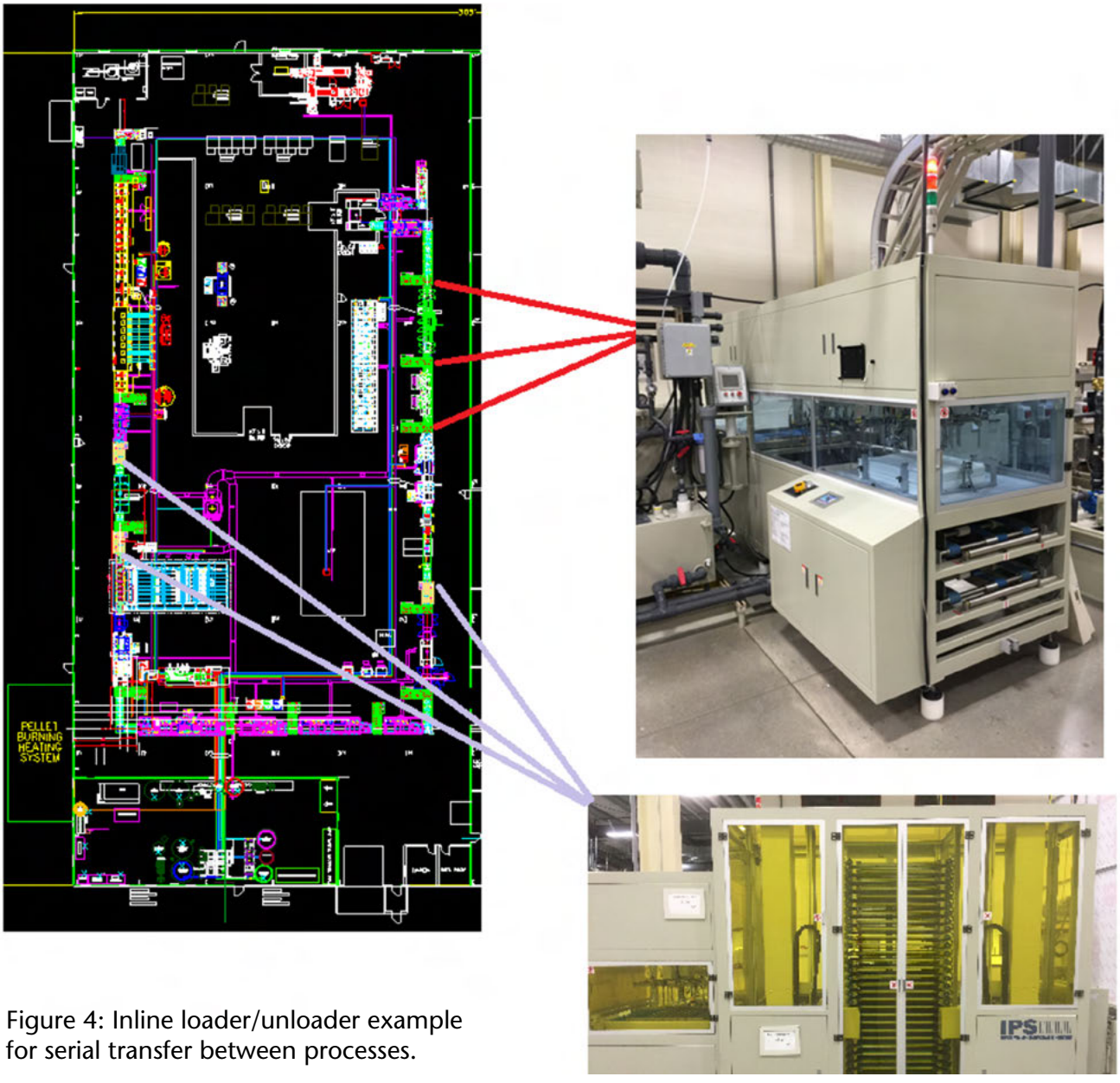

Figure 4: Inline loader/unloader example for serial transfer between processes.

quality feedback/issue management.

Inclusion of dozens of inexpensive, redundant fiber optic sensors in the process line allows real time tracking of jobs as they progress. This information can be easily appended live to an SQL database. For the annual cost of two seats of Oracle 12c, a shop can purchase 12 annual seats of easy-to-use visual software from the Google marketplace that also integrates with the SQL backend. This can then be integrated with ERP, QMS, and Mediawiki systems. Self-training to integrate can be completed using Lynda.com for $30/month (it took the project manager three months of on-again/off-again training to complete this at the Whelen site).

Automation of chemical dosing, cleaning cycles, and wastewater management are quite inexpensive to execute and pay for themselves quickly by reduction in errors and provision for programmable alerts. By having day tanks sized to the packages being purchased, and integrated with continuous sensors, a live chemical inventory of the factory can be made available on a web page. It has now been proven that a factory

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Figure 5a: Examples of visual job movement and analytics. (Courtesy of Google Marketplace LeanKit Software with SQL integration, usable via PC, tablet, and smartphone.)

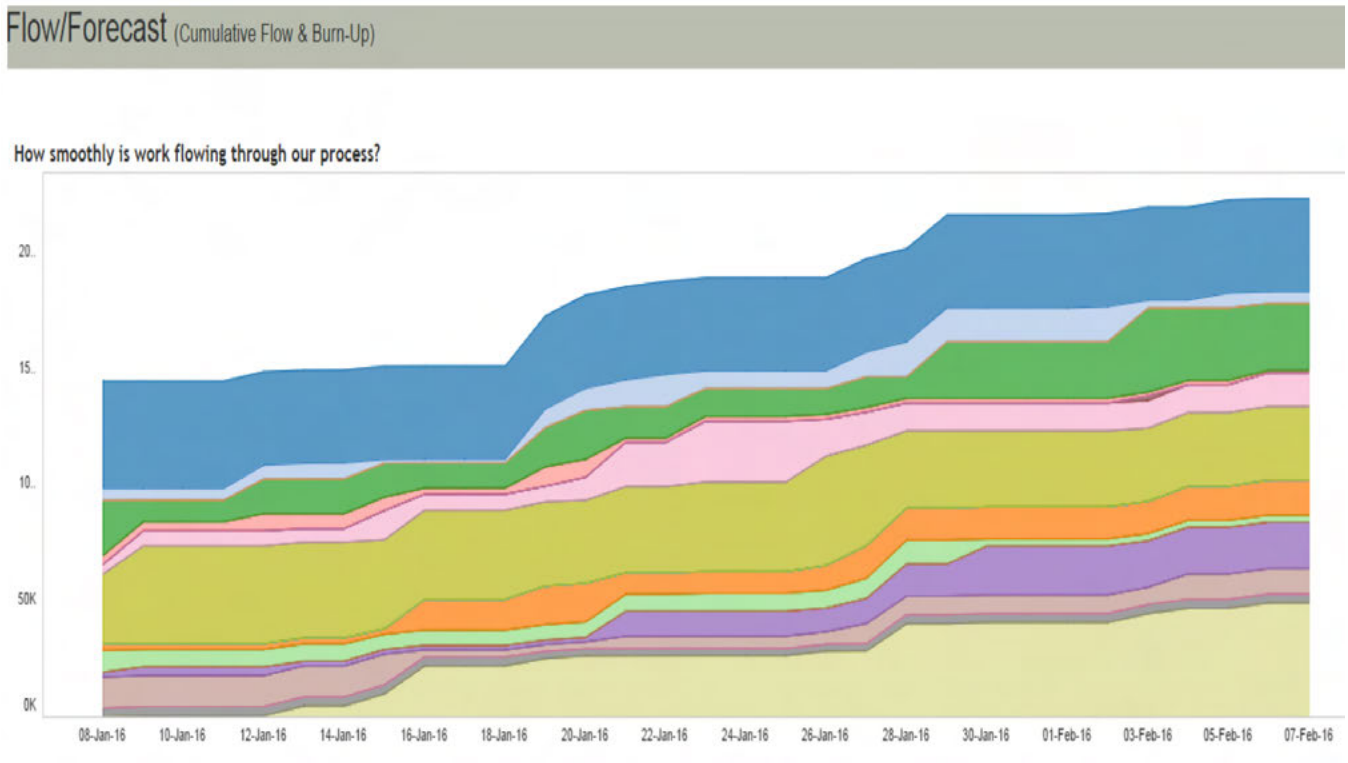

Figure 5b.

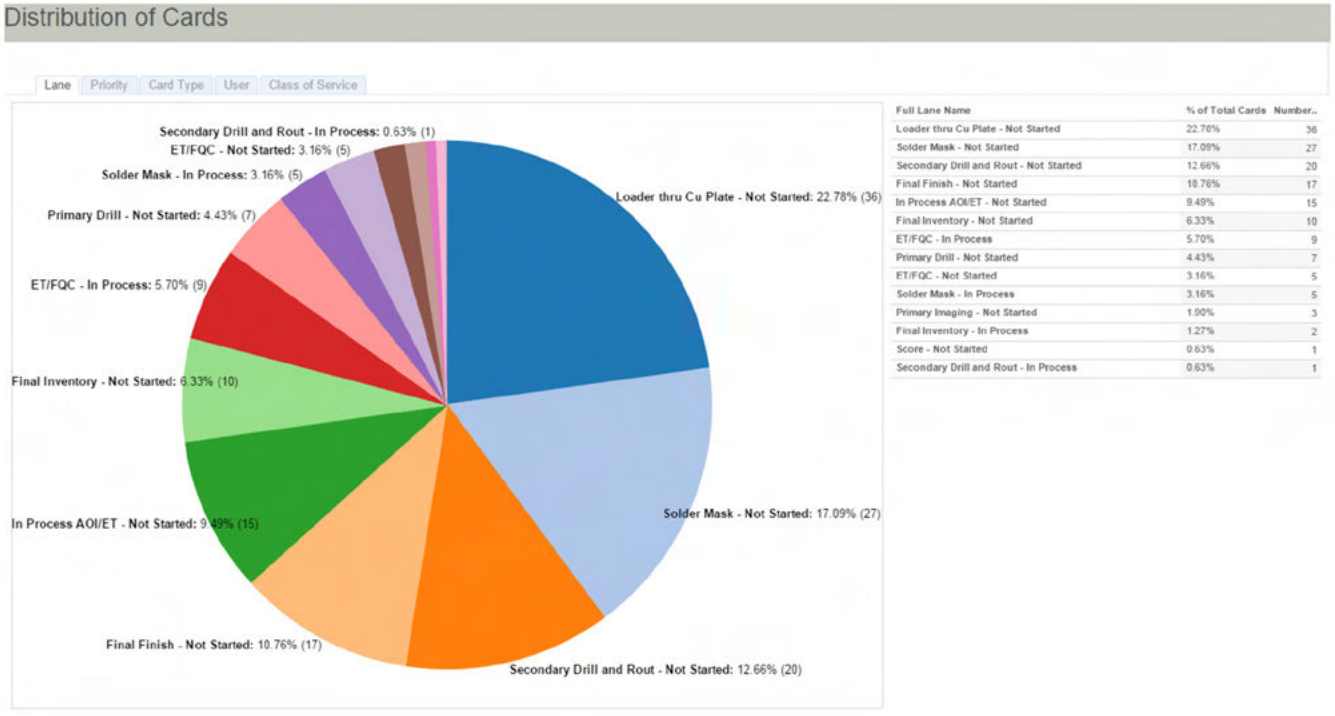

Figure 5c.

Figure 6: Examples of automated chemical dosing systems.

using these techniques will typically need only 20 hours/week of lab analysis.

Once all of the programming logic has been scripted for the factory automation, a consolidated live list of issues should then be developed for driving tactical corrective actions for escalated issues as well as continuous improvement of the systems. A modified version of the open source Bugzilla software (also with a connected SQL backend) can be used to manage this. The software auto-escalates when issues are not closed in a timely fashion and is used to facilitate periodic management review. Software setup takes just a few days and is free.

In general, the control afforded by a fully automated factory has enormous consequences for cost reduction. An in-line process flow allows for the removal of the cleaners, micro-etches, and anti-tarnish baths found in most PCB shops, since the need to compensate for handling/hold times with these chemistries is mitigated by handling and hold time reduction or elimination. This yields a direct savings in process chemical purchase cost as well as waste treatment. Additionally, chemical dosing and process set-points can be reduced due to the low process variability, so that there is near zero economic loss due to excessively biased mean target values which are required to compensate for highly variable processes in most PCB shops.

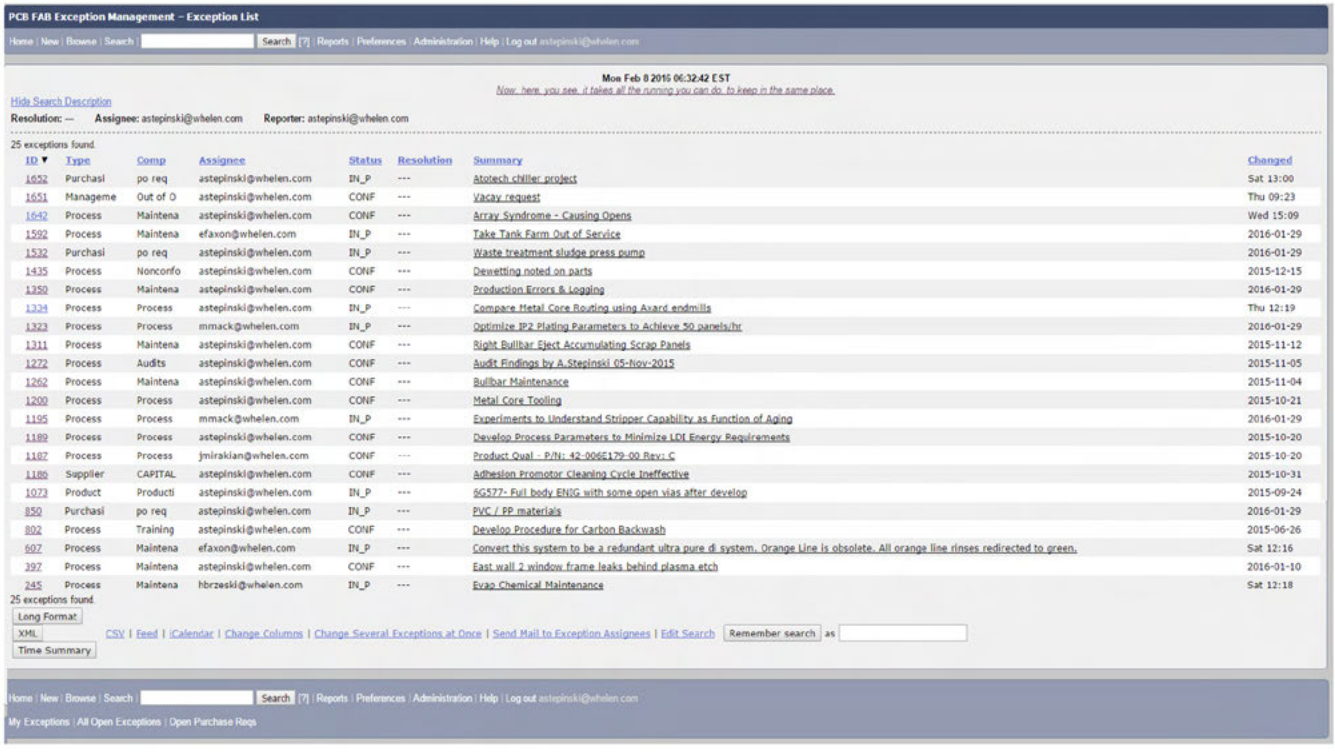

Figure 7: Example of consolidated live web list of action items.

Typical Top PCB FAB High Impact Waste Streams	Example Countermeasure
Wastewater Effluent	Recycle Wastewater
Spent Etchant	Closed Loop Etch Recycling
F006 Sludge	Implement F006 Precursor Point Source Systems
Ammonia Gas	Closed Loop Etch Recycling
Solvent Emissions	Design out Toxic Solvents

Figure 8: Typical top high-impact environmental waste streams in a PCB fabrication operation.

Green Process Technologies

The opportunities for designing out toxic chemicals and implementing chemical and water recycling are tremendous in the PCB industry, yet few factories realize these solutions. Most recycling systems max out at around 75% recycling due to increasing costs and diminishing returns. The reason for this upper limit is that the conventional technologies (membrane systems and ion exchange) also produce large quantities of brine either continuously or through regeneration—and this by-product can be quite expensive to treat.

The key to achieving an economical zero liquid discharge PCB fab plant is to properly research each waste stream, adjust its attributes if necessary, and segregate streams to achieve the most efficient overall solution. Control of the waste stream at the point of generation is the key to achieving high efficiency. Additionally, chemical suppliers invariably sell chemicals that will become "spent" and need to be replaced by fresh chemicals. They in fact research how to make them optimally become spent (think of the former Tobacco Institute, Inc.). Without this, they cannot make money. With a little bit

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NORMAL PRODUCTION										MAINTENANCE				
Process	Waste Stream from Normal Operations	pH Range	Destination	Working Volume (Liters)	Hourly Waste Volume (Liters)	Hours/Week Production	Weekly Volume	TDS (mg/L) as CaCO3	TDS (kg/week)	Waste Stream from Maintenance Operations	Waste Volume	pH Range	Destination	TDS (mg/L) as CaCO3
Deburr	Water	5-9	Green Line	360	300	50	15,000	130	1.95	Dump of Process Bath	360	5-9	Green Line	130
Horizontal Plater	Monopersulfate Cleaner	1-2	Blue Line	155	1.2	45	54	33,000	1.782	Dump of Process Bath	155	1-2	Blue Line	33,000
Horizontal Plater	Monopersulfate Cleaner Concentrate Rinse	1-4	Blue Line	103	0	45	0	2,000	0	Dump of Concentrate Rinse	103	1-4	Blue Line	2,000
Horizontal Plater	Monopersulfate Cleaner Cascade Rinse	4-7	Green Line	310	40	45	1,800	500	0.9	Dump of Cascade Rinse	310	4-7	Green Line	500
Horizontal Plater	Conditioner	8-10	Blue Line	207	0.2	45	9	42,000	0.378	Dump of Process Bath	207	8-10	Blue Line	42,000
Horizontal Plater	Conditioner Cleaner Concentrate Rinse	7-9	Blue Line	103	0	45	0	2,000	0	Dump of Concentrate Rinse	103	7-9	Blue Line	2,000
Horizontal Plater	Conditioner Cleaner Cascade Rinse	7-9	Green Line	310	40	45	1,800	500	0.9	Dump of Cascade Rinse	310	7-9	Green Line	500
Horizontal Plater	Adhesion Promotor Pre-Rinse	5-8	Green Line	103	0	45	0	2,000	0	Dump of Concentrate Rinse	103	5-8	Green Line	2,000
Horizontal Plater	Adhesion Promotor	5-8	Blue Line	415	0.3	45	14	112,000	1.512	Clean-Out with Peroxysulfuric Solution	415	1-2	Blue Line	139,000
Horizontal Plater	Adhesion Promotor Concentrate Rinse	5-8	Blue Line	103	0	45	0	2,000	0	Dump of Concentrate Rinse	103	5-8	Blue Line	2,000
Horizontal Plater	Adhesion Promotor Cascade Rinse	5-7	Green Line	310	40	45	1,800	500	0.9	Dump of Cascade Rinse	310	5-7	Green Line	500
Horizontal Plater	Conductive Polymer	1-2	Red Line	150	0.2	45	9	28,000	0.252	Dump of Process Bath	150	1-2	Red Line	28,000
Horizontal Plater	Conductive Polymer Concentrate Rinse	2-7	Red Line	103	0	45	0	2,000	0	Dump of Concentrate Rinse	103	2-7	Red Line	2,000
Horizontal Plater	Conductive Polymer Cascade Rinse	4-7	Green Line	310	40	45	1,800	500	0.9	Dump of Cascade Rinse	310	4-7	Green Line	500
Horizontal Plater	Sulfuric Acid Predip	0-2	Blue Line	103	0	45	0	150,000	0	Dump of Process Bath	103	0-2	Blue Line	150,000
Horizontal Plater	Copper Plate	0-2	Blue Line	5000	0	45	0	388,000	0	Dump of Process Bath	5000	0-2	Blue Line	388,000
Horizontal Plater	Copper Plate Concentrate Rinse	1-4	Blue Line	103	0	45	0	3,000	0	Dump of Concentrate Rinse	103	1-4	Blue Line	3,000
Horizontal Plater	Copper Plate Cascade Rinse	4-7	Green Line	310	40	45	1,800	500	0.9	Dump of Cascade Rinse	310	4-7	Green Line	500
Ink Preclean	Monopersulfate Cleaner	1-2	Blue Line	190	1	50	50	33,000	1.65	Dump of Process Bath	190	1-2	Blue Line	33,000
Ink Preclean	Monopersulfate Cleaner Concentrate Rinse	1-4	Blue Line	115	0	50	0	2,000	0	Dump of Concentrate Rinse	115	1-4	Blue Line	2,000
Ink Preclean	Monopersulfate Cleaner Cascade Rinse	4-7	Green Line	190	6	50	300	500	0.15	Dump of Cascade Rinse	190	4-7	Green Line	500
Tin Plate	Tin Plate Predip	0-2	Blue Line	965	0	45	0	150,000	0	Dump of Process Bath	965	0-2	Blue Line	0
Tin Plate	Tin Plate Tank 1	0-2	Blue Line	2840	0	45	0	392,000	0	Dump of Process Bath	2840	0-2	Blue Line	392,000
Tin Plate	Tin Plate Tank 2	0-2	Blue Line	2840	0	45	0	392,000	0	Dump of Process Bath	2840	0-2	Blue Line	392,000
Tin Plate	Tin Plate Drag-out Rinse	1-4	Blue Line	965	0	45	0	10,000	0	Dump of Concentrate Rinse	965	1-4	Blue Line	10,000
Tin Plate	Tin Plate Vertical Flowing Rinse	3-7	Green Line	965	480	45	0	800	0	Dump of Flowing Rinse	965	3-7	Green Line	800
Tin Plate	Tin Plate Horizontal Spray Rinse	2-7	Green Line	0	480	45	0	500	0	-				
Tin Plate	Tin Plate Rack Strip	0-1	Blue Line	245	0	45	0	431,000	0	Dump of Process Bath	245	0-1	Drum up for pH Adjust	0
Resist Strip I	Resist Stripper I	10-11	Red Line	570	12	45	42	214,000	8.988	Dump of Process Bath	570	10-11	Red Line	0
Resist Strip I	Resist Stripper I Polish	10-11	Red Line	190	0	45	0	187,000	0	Dump of Process Bath	190	10-11	Red Line	0
Resist Strip I	Resist Stripper I Concentrate Rinse	7-11	Red Line	114	0	45	0	5,000	0	Dump of Concentrate Rinse	114	7-11	Red Line	5,000
Resist Strip I	Resist Stripper I Cascade Rinse	7-10	Orange Line	341	480	45	21,600	150	3.24	Dump of Cascade Rinse	341	7-10	Orange Line	150
Etch	Etcher	8-9	Oxidize+Electrowin	3200	0	50	0	185,000	0	-				
Etch	Triple Cascade Rinse	7-8	Electrodialysis	341	0	50	0	500	0	-				
Resist Strip II	Resist Stripper II	10-11	Red Line	570	12	5	5	214,000	1.07	Dump of Process Bath	570	10-11	Red Line	0
Resist Strip II	Resist Stripper II Polish	10-11	Red Line	190	0	5	0	187,000	0	Dump of Process Bath	190	10-11	Red Line	0

Figure 9: Example of waste stream characteristic catalogue.

Figure 10: The zero liquid discharge system at Whelen Engineering.

of research, making modified formulations that can last forever, or using the superior control of an automated factory to reduce consumption can yield tremendous savings in regulatory and process costs.

For under $1M in capital expenditure, a zero discharge treatment system can be implemented from a combination of ion exchange, membranes, distillation, crystallization, and etch recycling capable of supporting a 10,000 panels per week outerlayer operation. This represents a capital cost savings when compared to the current industry best practice solutions.

It should also be noted that in a well-engineered zero liquid discharge environment, water conservation is unnecessary. Instead, the

Zero Liquid Discharge w/ Etch Recycling		Equivalent Standard 75% Recycling System
Water	$8	$3,099
Power	$798	$714
Propane	$2,092	$0
Waste Treat Chemicals	$511	$1,354
Maintenance	$812	$680
Sludge Hauling	$1,521	$462
Permit Cost & Regulatory Analysis	$0	$2,200
Labor	$3,200	$9,600
Cu Recovery	-$6,758	$6,100
Monthly Total	**$2,184**	**$24,209**

Annualized Savings from Green Solution vs "Industry Best Practice"	**$264,305**

Figure 11: Zero liquid discharge chemical waste management costs vs. industry best practice.

Action	Impact
Convert all first rinses to static drag-outs & increase flow rate of cascade rinses to compensate for less cascade	Decreased IX Regenerations by 70%, while increasing concentrate waste dumps by 25%. Net reduction in total concentrate waste volume of 30%.
Develop a Closed Loop Cu Recycling System	Eliminated chemical costs for Etching and Yielded a Positive Cash Flow from Recovered 99.99% pure copper. Also, stabilized etch rate to +/-2%, eliminated venting of ammonia to scrubber, and recovered etch rinse dragout back to etcher.
Eliminate cleaners, microetches, predips, antitarnishes	Decreased wastewater system and chemical costs.
Increase temperature of process baths if possible, and replenish evaporative loss from dragouts.	Decreased Concentrate waste volume by 25%.
Develop a closed loop resist strip process	>$20,000 in annual savings from chemical usage and treatment
Develop a closed loop F006 precursor rinse recovery process	Reduced F006 hazardous waste by 95%
Conductive Polymer Metallization	Eliminated formaldehyde from eless Cu
Utilize Inkjet for primary image	Eliminated preclean, developer, tin plate cleaner/microetch/predip, and strip chemicals.
Horizontal Cu Pulse Plating w/ insoluble anodes	Huge waste reduction and improved thickness tolerancing. Control of roughness allowed elimination of microetching for adhesion as well.
Zero Liquid Discharge Waste Treatment	Eliminated permit, saved water.
Rotary Oxygen Plasma Etch	Eliminated need for chemical desmear with solvents and/or plasma with toxic gases.

Figure 12: Key Whelen “green” decisions.

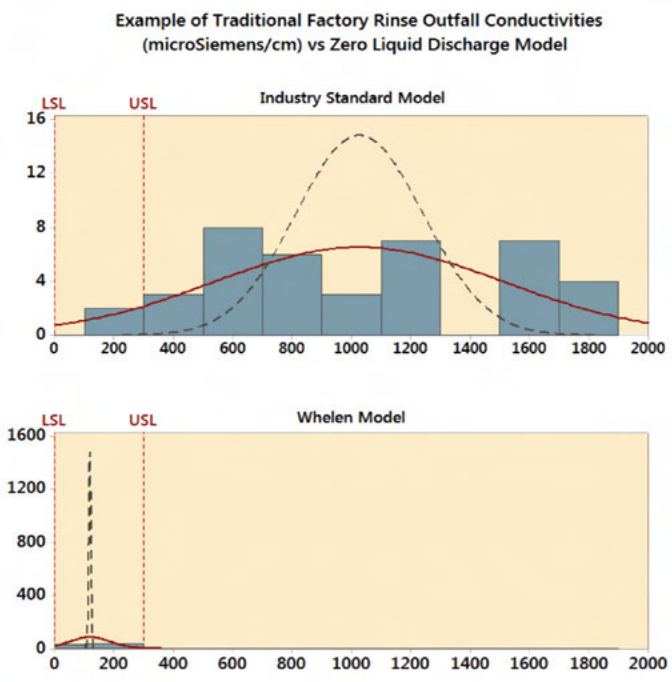

Figure 13: Comparison of spent rinse-water conductivity.

Figure 14: Horizontal conductive polymer metallization plus copper pulse electroplate.

focus is TDS (total dissolved solids) budgeting throughout the plant, along with analysis of specific critical contaminants. Water supply is only limited by the size of the pumps. For instance, in order to maximize absorption in the fume scrubber, 10 gallons/minute of DI water can be fed continuously into and out of the scrubber system reservoir. Additionally, rinses can be operated at 3–5 gallons/minute whether they need it or not. With a closed loop system, there is no sacrificing rinse quality to save water. Lift stations integrated with conductivity sensors can automatically identify an out-of-control waste stream as it happens, allowing for quick corrections by maintenance. Also, fresh rinse-water conductivity is always DI quality.

New Equipment Technology

In the past decade great developments have occurred in horizontal plating technologies along with direct imaging, inkjet, and CNC equipment. Only some of these have been realized in North American and European factories.

Horizontal copper electroplating is an especially rare technology in the U.S. market. The current state-of-the-art horizontal plater is capable of conformal panel plating 30 microns (1.2 mils) of copper at 100% throwing power in just 18 minutes at 50 panels/hour, for most designs, at a fraction of the cost and thickness variation of standard vertical plating. These platers can also fill blind vias, through-holes and even trenches for embedded transmission lines, realizing 1- and 2-mil feature resolution. Yet, there are only two of these units in the USA—and hundreds in Asia. At Whelen Engineering, the total surface copper thickness variation achieved from this process is just 3%. Additionally, the ability to control the pulse profile (and hence surface roughness) on each individual insoluble anode segment has successfully eliminated the need for subtractive etching of the copper surface for resist adhesion.

Direct imaging has been on the market for quite some time now, and is used as a mass production tool. At the 2015 productronica show in Munich, new LDI and MDI solutions, with lower operating costs than traditional UV laser systems, could be found everywhere. Also emerging now are inkjet processes, with some even containing integrated AOI solutions.

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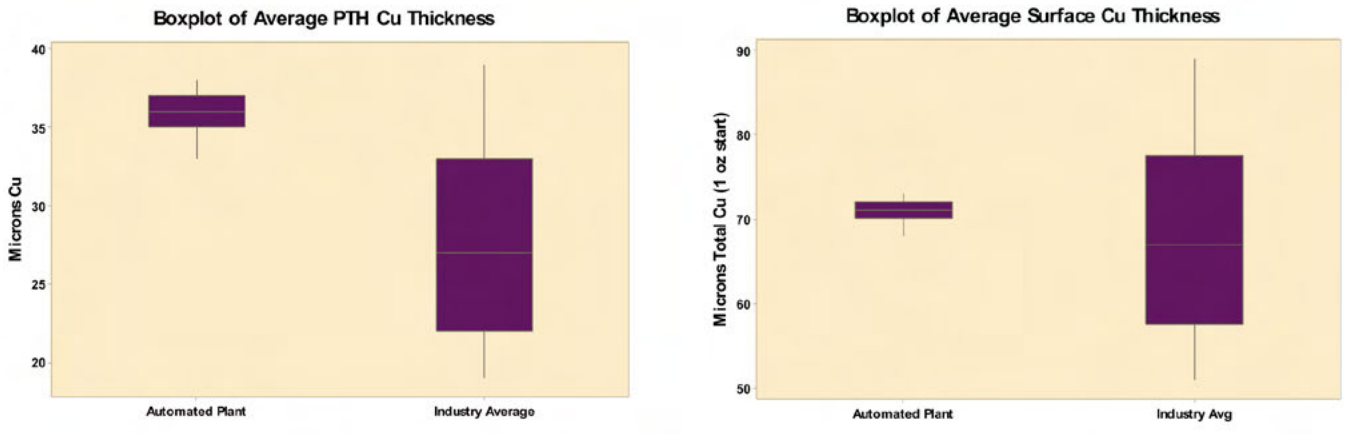

Figure 15: Copper thickness results.

Figure 16: Etch resist inkjet machine with integrated AOI.

Figure 17: Multi-purpose drill/rout single-station systems with cameras and loaders/unloaders.

Economical, new single station CNC systems with capability to drill/rout with the same spindles along with auto-load/unload and integrated cameras provide tremendous flexibility and can facilitate substantial savings in a high-mix environment.

Conclusions and Summary

The net effect of integrating all of the various automation, wastewater, and new equipment technologies presented can result in tremendous savings in PCB cost. With the factory in New Hampshire only 35% utilized, a greater than 50% operating cost savings over the previous Chinese suppliers and an ROI of three years has been achieved.

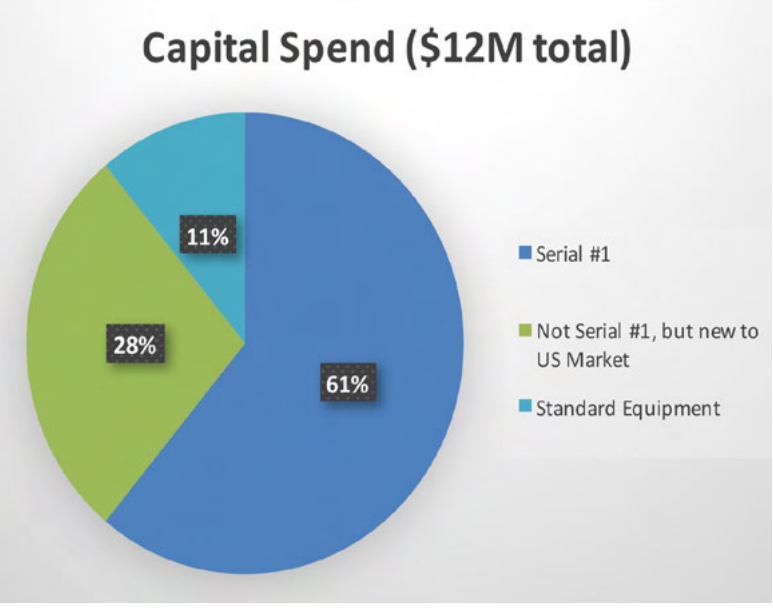

Figure 18: Whelen Engineering Company capital spend.

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30 minutes of FREE technical insight
from industry experts

September 21

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September 21–23

IPC India 2016 — Conference & Exhibition

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September 24–30

IPC Fall Committee Meetings — Meeting

Held in conjunction with SMTA International

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September 26

EMS Management Meeting — Meeting

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October 19

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IPC EMS Program Management Training and Certification — Certification

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A Vision for the Industry

December

IPC Education Online: Winter Semester — Webinar

December 7–9

HKPCA International Printed Circuit & IPC APEX South China Fair — Conference and Exhibition

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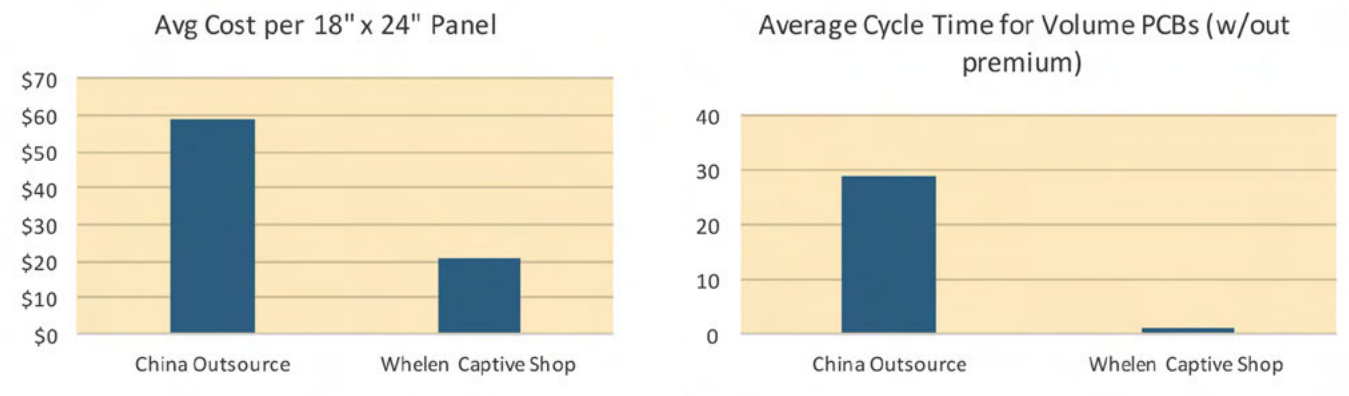

Figure 19: Automated factory differentiating performance metrics.

A more fully utilized factory could achieve ROI even faster. The company had to assume substantial risk and invest 89% of the factory budget into new and emerging technologies in order to accomplish the PCB FAB project, however, future and existing factories in North America and Europe can now stand to benefit from this R&D effort. **PCB**

This paper was originally presented at IPC APEX EXPO 2016 and published in the proceedings.

Alex Stepinski, PCB FAB division manager for Whelen Engineering.

Editor's note: To see more on the Whelen facility, refer to our October 2015 issue.

IPC Applauds Congressional Action on the Frank R. Lautenberg Chemical Safety for 21st Century Act

On behalf of the electronics industry and an estimated 800,000 Americans employed in 2,200 U.S. member facilities, IPC is applauding the U.S. Congress for taking the final steps toward passage of the Frank R. Lautenberg Chemical Safety for the 21st Century Act H.R. 2576/S. 697.

After months of work, the U.S. House approved the bipartisan compromise on a vote of 403-12, and the U.S. Senate is expected to follow suit within days, sending the measure to President Obama for his anticipated signature.

With input from its members, IPC has long supported reform of the Toxic Substances Control Act (TSCA) of 1976, which the Lautenberg Act would achieve. Most recently, IPC sent an endorsement letter to congressional leaders last Friday, and member-company executives communicated with their elected officials in recent weeks.

"Our industry strongly supports the goal of improving our nation's chemical management system, and this bill is a big step in the right direction," said Dr. John W. Mitchell, IPC president and CEO. "A cost-effective, science-based federal regulatory program is essential to our members who work with chemicals to manufacture products for the global market. This bill is good for the U.S. economy and the environment.

"IPC commends the senators and representatives in both parties who worked together to achieve this landmark legislation," Mitchell added. "Together with our members, we look forward to celebrating its passage, and remaining engaged in the regulatory process."

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Electronics Industry News
Market Highlights

Engineers Take First Step Toward Flexible, Wearable, Tricorder-like Device
Engineers at the University of California San Diego have developed the first flexible wearable device capable of monitoring both biochemical and electric signals in the human body. The Chem-Phys patch records EKG heart signals and tracks levels of lactate, a biochemical that is a marker of physical effort, in real time.

IBM Makes Quantum Computing Available on IBM Cloud to Accelerate Innovation
IBM scientists have built a quantum processor that users can access through a first-of-a-kind quantum computing platform delivered via the IBM Cloud onto any desktop or mobile device. IBM believes quantum computing is the future of computing and has the potential to solve certain problems that are impossible to solve on today's supercomputers.

Introducing the Disposable Laser
Since lasers were invented more than 50 years ago, they have transformed a diverse swath of technology—from CD players to surgical instruments.

Top Seven Vendors in the Global Semiconductor Packaging Materials Market
Technavio has announced the top seven leading vendors in their recent global semiconductor packaging materials market report. This research report also lists 36 other prominent vendors that are expected to impact the market during the forecast period.

Printed and Flexible Electronics in Automotive Applications 2016–2026
This report focuses on technologies and components in automotive applications that benefit from the advent of printed/flexible electronics and already represent a market of a few hundred million dollars in 2016.

Latest Advancements in Sensor Technology Examined at SEMI European MEMS Summit
After a successful inaugural event in Milan that attracted 265 attendees, this year's SEMI European MEMS Summit will convene in Stuttgart, one of the world's major MEMS and Sensor hubs.

Self-healing, Flexible Electronic Material Restores Functions after Many Breaks
Electronic materials have been a major stumbling block for the advance of flexible electronics because existing materials do not function well after breaking and healing.

NREL Theory Establishes a Path to High-Performance 2D Semiconductor Devices
Researchers at the Energy Department's National Renewable Energy Laboratory (NREL) have uncovered a way to overcome a principal obstacle in using 2D semiconductors in electronic and optoelectronic devices.

In the War against Dust, a New Tool Inspired by Geckos
Micrometric and sub-micrometric contaminant particles—what most of us call "dust"—can cause big problems for art conservators, the electronics industry, aerospace engineers, and others. These nanoparticles can prevent a cellphone from working or rob the vitality of a painting's colors.

MechSE Researchers Create One-step Graphene Patterning Method
Researchers from the University of Illinois at Urbana-Champaign have developed a one-step, facile method to pattern graphene by using stencil mask and oxygen plasma reactive-ion etching, and subsequent polymer-free direct transfer to flexible substrates.

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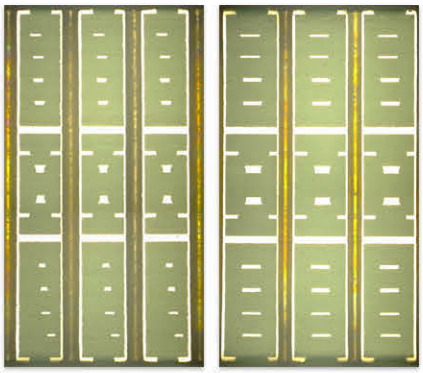

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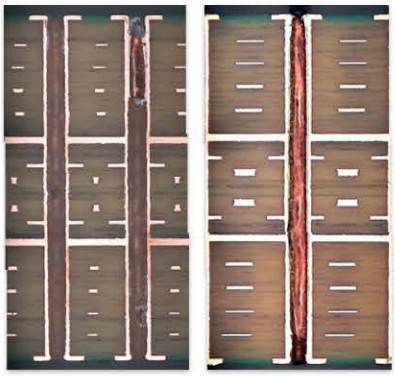

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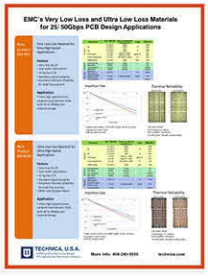

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Our IoT Lives

by Steve Williams
THE RIGHT APPROACH CONSULTING LLC.

In March, at the 2016 IPC APEX EXPO show in Las Vegas, the next big thing everyone was talking about was the Internet of Things (IoT). Equipment manufacturers were standing in line to tout their machines as IoT-capable and just waiting for the industry to catch up. But the IoT has been at play in our personal lives for quite a while…

IoT Defined

The universally accepted dictionary definition of the IoT is "A system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction."

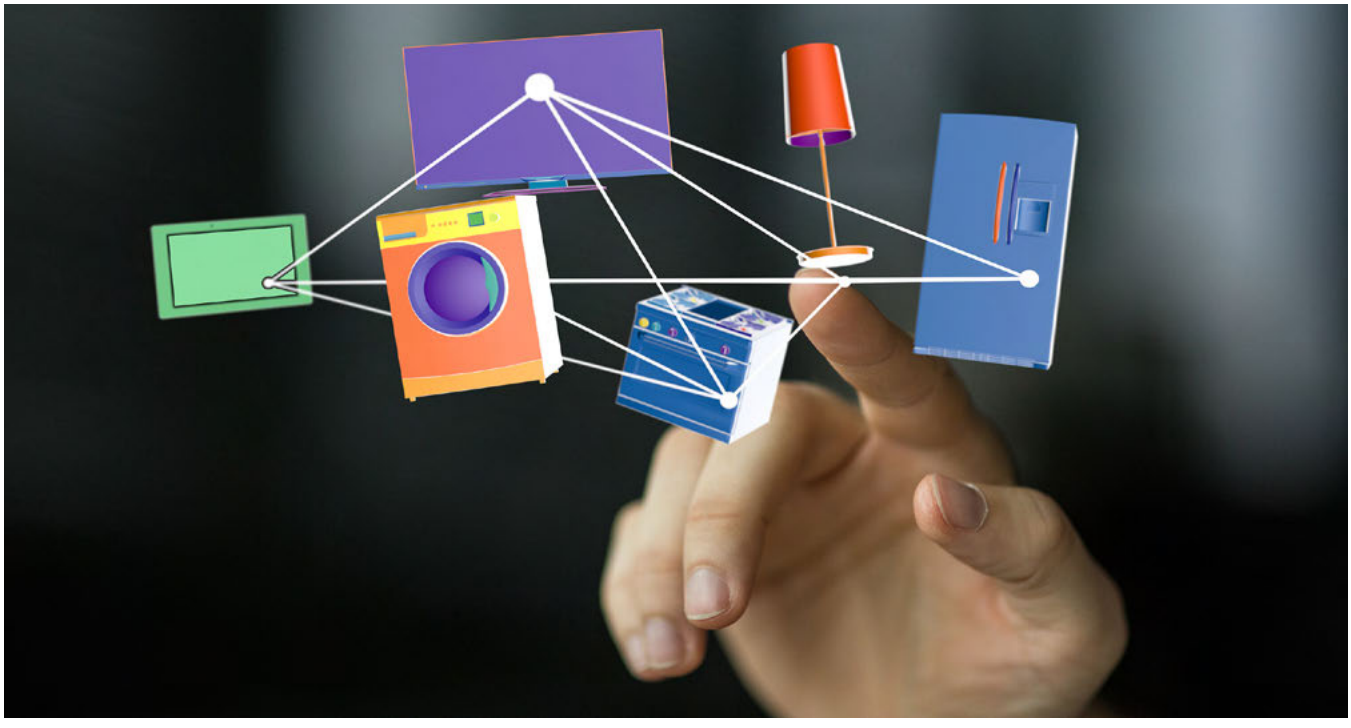
Steve's plain English definition is "Machines talking to machines."

A *thing* in the Internet of Things can be a person with a heart monitor implant, your puppy with a biochip, the built-in sensors in your car that alert you when tire pressure is low, or your manufacturing equipment sending data, information and instructions to other machines. Basically a thing is any natural or man-made object that can be assigned an IP address and provided with the ability to transfer data over a network.

Our Connected Devices

The first smartphone was introduced in 1993, and today you would be hard pressed to find a single person in a crowd who doesn't have one on their hip, in their purse or glued to their ear. They are technical marvels, a computer in your hand, and most certainly the poster child for our IoT lives.

Let me give you an example. I can be driving to a client in Indiana and hear a song I like on the radio, and with one touch find out the name of the song and the artist, purchase the song and have it simultaneously added to my music app on the phone and instantly pushed



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to all of my other devices back in Slinger, Wisconsin. Think about that for a minute! Just the *Shazam* part of it blows my mind—and with voice recognition I don't even have to touch my phone. Our IoT lives!

I thought I was a pretty informed guy with all of the daily intelligence I get from my friend Walt Custer and various news outlets, but I have learned the hard way that I am always a step behind my wife and daughter when it comes to what is happening in the world. The newsfeeds continuously pushed to their devices via

> "Newsfeeds are simply machines talking directly to other machines (M2M) as news and entertainment outlets push this information to our devices."

Facebook and Twitter provide such a vast and instant update on seemingly everything that I rarely surprise them on anything newsworthy. "Oh, I saw that yesterday on Facebook, honey, didn't you?" Newsfeeds are simply machines talking directly to other machines (M2M) as news and entertainment outlets push this information to our devices. Social media is truly the way we get our news and information today. Our IoT lives!

Our Connected Homes

We have smart phones, smart watches, smart TVs, smart cars, smart security, smart climate controls, smart this and smart that… all talking to each other without human intervention. We can control our inside and outside lights, consumer electronics, heating and cooling, security, access our music and video libraries, watch and program our DVRs from the comfort of our sofa or a hotel room 1,000 miles away. We have all seen the commercial with the son joining the family for a weekend away and the father asks if he remembered to turn off the water, leave certain lights on and turn down the heat. When the son hesitates, the father picks up his phone and does it all remotely. There's even a smart doorbell that lets you answer the door from another location when traveling to foil would-be burglars. Our IoT lives!

Our Connected Lives

When I finally talked my wife into getting her first cellphone, she was convinced it was "only for emergencies." It took exactly three days for her to be calling her mom everyday on the way home from work, checking on the kids every couple of hours and finding out if I would be home on time for supper. Even my mom, who is not on a first-name basis with technology, is never seen without her cellphone and iPad within reach to keep in constant contact with the grandkids. I am embarrassed to say that our kids will text or call us from the other side of the living room wall to ask something instead of walking around. What would we do without our technology? Our IoT lives!

No off Switch

During one interview Steve Jobs famously revealed how his ambiguous thoughts on the afterlife influenced his designs, saying, "Yeah but sometimes I think it's like an on-off switch. Click, and you're gone," he said. Then, after a pause, he added, "And that's why I don't put on-off switches on Apple devices." Instead, the devices simply go into "standby" or "sleep" modes when inactive. Take a walk around your house and you might be surprised at the number of things that never really shut down, always drawing power, ready at a moment's notice for our instant gratification. TVs, DVRs, microwaves, ovens, coffee makers, alarm clocks, routers, modems, servers, printers, washers and dryers, to name just a few. Our IoT lives indeed! **PCB**

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

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Exceptional Service–Extra Toppings without Sacrifice

by Barry Lee Cohen

Editor's Note: New columnist Barry Lee Cohen will be writing on all things related to marketing and branding. This inaugural column appeared as a blog on his website[1].

Exceptional service is often recognized by not being recognized. Exceptional—not good—service is demonstrated by actions that are assumed and relied upon by the customer to be the norm. Exceptional service is providing the extraordinary and value-added without being asked. For companies that break this trust, being "recognized" may very well result in disenfranchised customers and lost business.

Exceptional service means continually providing the "extra toppings" instead of the "order in, order out" mindset that is unfortunately undertaken by many good souls who range from the online customer support person to the local pizza delivery guy. They are all vigilantly following their company's policy. However, if not clearly understood by the employee—the company's face-to-customer ambassador—the policy can negatively impact product quality, which is critical to establishing credibility, brand loyalty and increased profitability.

I'm betting that each of us at one time in our youth had the dubious distinction of being an accomplice to the pizza parlor pay-off. Like generations before us and what will be for generations to come, you were enlisted by your friends to help test the pizza delivery guy to see if he was going to get that round slab of irresistible cheesy goodness within the "30 minutes guaranteed or it's free!" challenge.

It was rare we ever got the savory saucer without coughing up some dough. The pizza parlor may have caught onto our devious, youthful indiscretions—or just as likely, not. The same order could have been placed for a party, family dinner or business function. Whatever the case, the pizza parlor thought that they had provided exceptional service, as they met the corporate 30-minute delivery doctrine. Order in. Order Out. Corporate policy followed. Take that, you rowdy, rebellious runts!

However, the pizza parlor's payday of the mere Hamilton or Jackson (soon to be Tubman) was short-lived. You see, the pizza-parlor pie maker (say that three times fast) was so focused on meeting the "one topping mandate" of speed, the pie was not baked to crispy crust perfection. Furthermore, the pizza delivery guy neglected to place the culinary delight in the insulated sack. It makes no difference if it was a bunch of adolescent pranksters. The flimsy, lukewarm pizza

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was on time, but unacceptable. While exceptional service was measured in speed, product quality was sacrificed. Customer retention, trust and preference were largely diminished.

Exceptional service should never sacrifice the quality of the product. Customers should never have to ask for exceptional service from their supplier as the extra toppings should be part of that supplier's culture and the way in which they conduct business.

References

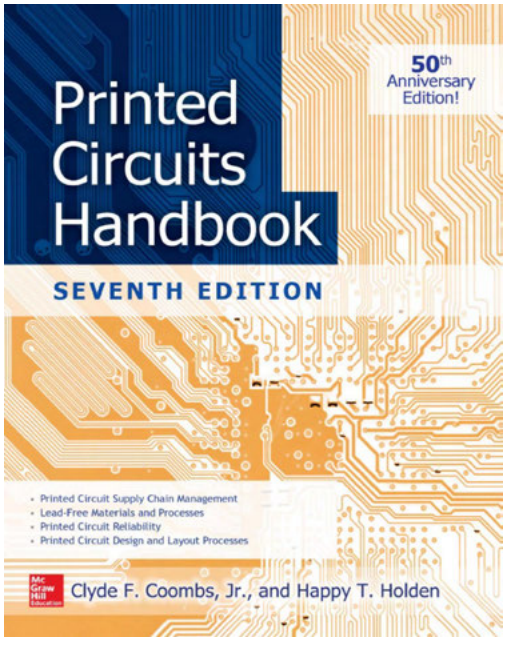
1. Launch Communications Blog.

Barry Cohen is president and managing director of Launch Communications. He can be reached by clicking here.

BOOK REVIEW: Printed Circuits Handbook, 7th Edition, 2016 (McGraw-Hill)

by Karl Dietz

It is great to see the venerable tradition of Clyde Coombs' Printed Circuits Handbook continued in its recently published 7th Edition, assisted by the highly qualified effort of Co-Editor-in-Chief, Happy Holden.



The Printed Circuits Handbook has been a classic reference to the industry for many years, and the new edition will assure its place for years to come. The 7th Edition features 71 chapters, four more than the last edition, structured in 12 parts, and authored by 38 contributors—a list of accomplished authors that could double as a who's who in the world of circuit boards.

It had also been my privilege and pleasure to write book reviews on the 5th and 6th editions of the Handbook. The ~1600 page 7th edition makes a worthy addition to the collection. There is always the challenge of adding pertinent, new information while curtailing older, less relevant information.

New is the "Supply Chain" section, acknowledging the commercial reality of an industry that has largely lost vertical integration. While the material and equipment supply base for PCB fabrication has largely gravitated to Asia, design is widely scattered throughout countries where OEMs, fabricators and end-users reside, often leaving unmet needs in design for manufacturability and reliability.

The "Imaging" chapter of the 7th edition has been competently updated by Gareth Parry, and is about the same size as the one of the 6th edition.

Enlarged is the "Design" section, while the "Fabrication" and "Assembly/Test" sections are basically updated, with some added material to the Quality section. Reza Gaffarian did an admirable job in a major rewrite of the "Reliability" section, expanding the bare PCB chapters with new information and explanations. All in all, the 7th Edition feels more like a new book rather than an update of an old version.

In summary, the latest edition of the Printed Circuits Handbook is a great reference book for the PCB engineer and anyone who wants to gain in-depth knowledge of PCB technology.

To read this book review in its entirety, click here.

TOP TEN

Recent Highlights from PCB007

1 Happy's Essential Skills: Technical Writing

Technical writing is one of those topics that they don't really talk about in college—at least not where I went. Writing and English has never been a strong like of mine compared to science and math. So I did my required time in English and wrote my lab reports the best I knew how.

2 Weiner's World

3D printing, China's SMT equipment and robotics markets, IPC's mandate, counterfeiters, and Taiwan PCB makers' shift to automotive electronics—Gene Weiner talks about these things and more in this new article.

3 'Can Do' in CAM Outsourcing: A Case for Outsourcing CAM Engineering

In the West, outsourcing is sometimes considered taboo and many believe it is one of the causes for shifting our manufacturing base to the East—specifically China and other lower cost Asian countries. In this series of columns, I will make a case in support of CAM outsourcing—especially for North American and Western European PCB manufacturers.

4 KCA Electronics and MEI Acquired by HCI; Shane Whiteside Named President and CEO

HCI Equity Partners (HCI), a middle market private equity firm based in Washington D.C., announced today that it has acquired both KCA Electronics in Anaheim, CA and Marcel Electronics International (MEI) located in Orange, CA in separate stock transactions.

5 All About Flex: Imaging Methods for Etch Resist, Part 1

Imaging is a major process step in creating a copper circuit or flexible PCB. In single-sided circuit fabrication, the imaging process creates the resist pattern that protects the copper from the etchant. It is critical that this pattern precisely define the circuit traces, as issues with imaging will transfer to the subsequent processes.

6 EPTE Newsletter: Many Plants in Japan Shut Down After Earthquake

Large manufacturing companies including Sony, Panasonic, Honda and Toyota suspended operations citing damage at their plants. The supply chain disruptions could keep them idle for up to a week. Toyota Motors was the hardest hit amongst the large corporations.

7 Advanced Circuits Acquires Assets of Micom Circuits

Advanced Circuits, North America's 3rd largest printed circuit board fabricator, announced today that it has entered into a definitive agreement to acquire certain assets from Micom Circuits of New Brighton, MN.

8 North American PCB Business Growth Accelerates in March

Total North American PCB shipments in March 2016 came in at 10.3% above the same month last year, bringing the year-to-date growth rate up to 6.1% for the first quarter. Compared to the preceding month, March shipments were up 18.6%.

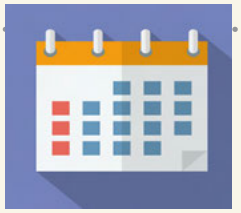
9 Teledyne Agrees to Divest Teledyne PCT to Firan Technology Group

"The divestiture of Teledyne PCT is consistent with Teledyne's ongoing evolution and focus on high-technology, proprietary engineered products," said Robert Mehrabian, chairman, president and CEO of Teledyne. "We will work closely with FTG to facilitate a smooth transaction and transition of the operations to FTG's U.S. operations, supporting the customers of Teledyne PCT."

10 A Conversation with Walt Custer: Market Report

In a recent conversation, Walt Custer shared current market data and industry trends, detailing those market segments and regions that are currently seeing growth and those that are in decline. Walt also offered his interpretation of the data, which he uses to forecast the upcoming month.

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



Events

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For the complete PCB007 Calendar of Events, click here.

IPC Conference on Emerging Critical Environmental Product Requirements
June 8, 2016
Arlington Heights, Illinois, USA

iNEMI Europe Roadmap Workshop/ Webinar
June 9, 2016
Germany

IPC Conference on Emerging Critical Environmental Product Requirements
June 10, 2016
Palo Alto, California, USA

iNEMI Asia Roadmap Workshop/Webinar
June 23, 2016
China

Symposium on Counterfeit Parts and Materials 2016
June 28–30, 2016
College Park, Maryland, USA

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August 18–20, 2016
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FUTURECAR: New Era of Automotive Electronics Workshop
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