

December 2013

*the*

# pcb magazine

AN I CONNECT 007 PUBLICATION

**8 The Wrap-Up**  
*by Ray Rasmussen*

**18 Can Scrap be Beaten?**  
**A Strategy for 2014 and Beyond**  
*by Gray McQuarrie*

## The (PCB) World According to Our Columnists

### 2013: A Look Back

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## The (PCB) World According to Our Columnists!

This month, our feature columnists are exploring their various areas of expertise in the PCB industry by taking a look back, and forward, to where the industry is headed both domestically and globally.

### 8 The Wrap-Up

by Ray Rasmussen



### 18 Can Scrap be Beaten?

A Strategy for 2014 and Beyond

by Gray McQuarrie



### 12 2013: A Look Back

by Steve Williams



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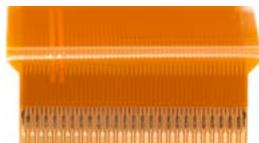
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According to  
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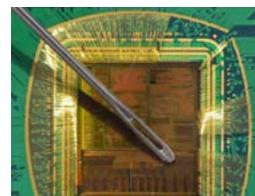
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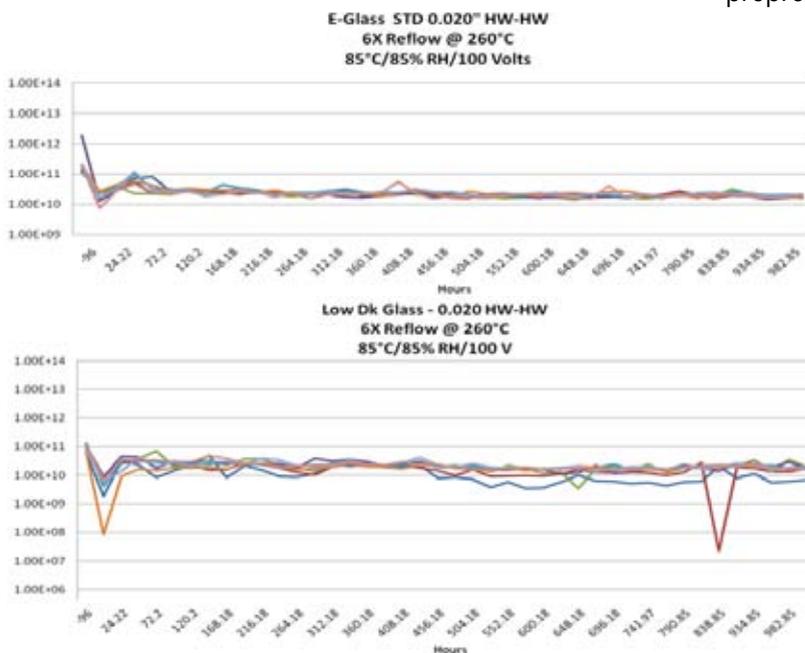
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# The Wrap-Up

by Ray Rasmussen  
I-CONNECT007



## Good Riddance

Tying up 2013 into a nice, tight bow, tossing it over my shoulder and then dusting off my hands comes to mind when trying to wrap up the year. I didn't much like the year that was.

Politics seemed to take center stage for most of us as those we elected to keep us on track did nothing to improve the economy.

A few changes should be noted. On the PCB side of things, we lost Endicott Interconnect Technologies to bankruptcy and in August, Hitachi Via Mechanics sold to the Longreach Group. Hitachi has claimed the global top spot over the last decade, filling Chinese factories with their drilling equipment. The reliance on that low-margin sector, even though they sold

a ton of machines, may have cost them their business.

TTM COO Shane Whiteside left the company "to pursue other opportunities," and a few months later, his boss, Kent Alder retired. Those two built one of the world's largest PCB companies, but it makes you wonder. Their departures were so close together, it almost feels like they were jumping ship, although there aren't any indications that there's anything wrong with the company. The stock is doing fine. But it makes you think.

Other notable M&A activity includes Kyocera buying NEC Toppan Circuit Solutions; Graphic Plc buying Calflex; Elga Europe entering into a joint venture with Eternal Chemical;





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Eltek joining with Nistec, an Israeli EMS provider; R&D Circuits acquiring PCB design company Altanova; EPEC and Suncoast Digital joining forces (EPEC also purchased UPE back in January to enhance its extreme copper technology); China's Fastprint picked up eXception's PCB business; SMG and Global Circuits merged operations; Yash Sutariya's management team purchased Alpha Circuit Corp; Zutron acquired Teknoflex; and All Flex started off the year by acquiring Tri-C Design.

On the EMS side of things, CirTran finally got out of the EMS business and is now putting all of their focus on beverages. I have not spent time figuring out how and why they made the switch from electronics manufacturing to playboy energy drinks. Not a big loss, I guess. CTS also left the industry, selling its EMS capabilities to Benchmark Electronics so that they could focus on their sensors and components business. I guess focus is good. Hunter Technology acquired NBS's design assets; Natel bought EPIC Technologies while assembly equipment supplier Essemtec sold its operations to a private investor group. GE bought Imbera Electronics to advance its capabilities into advanced embedded electronics packaging. LTX-Credence bought Dover's Multitest and ECT, while Molex bought FCT Electronics, only to be acquired by Koch one month later.

Flextronics made a few acquisitions picking up RIWISA to strengthen its position in medical. They also picked up a couple of factories from Motorola Mobility (Google), one in Brazil and the other in China. Sparton bought Creonix to strengthen its mil/aero offerings and also picked up Aydin Displays. They bought Onyx at the end of 2012.

Jabil bought Nypro; OSI bought Briton EMS; Season Group acquired OEL; ENRI merged with Abotron; TPG and Goldman Sachs bought the rest of eXception; Probe bought Trident; JUKI and Sony merged their SMT equipment businesses.

## Moving On

China's been sucking wind most of the year. Seems like things are improving but it's anybody's guess. China's official numbers are suspect at best.

Europe is finally coming out of recession, which is good, but it will take some time for things to get moving again.

In the U.S., we've had to deal with the repercussions of the budget sequestration (artificial slowing of the economy) and the government shutdown by a few radicals (another artificial slowing of the economy).

It's been painful. We need to pull out all the stops and allow the economy to grow at full speed. We can work on the structural stuff later, once we have full employment and tax revenues flowing in. We take two steps forward then one step back. It's crazy.

Market news is getting the most reader interest from our websites. Anything with market information seems to be of great importance these days. Leading indicators from

The Conference Board captured the most attention. Those indicators

have been climbing for most of 2013, which is a good thing, just not fast enough. All economists believe economic growth is being hindered by partisan politics in the U.S. Congress.

IPC continues to evolve and along with it, some more personnel changes. We've lost Susan Filz (conference coordinator) and Mary MacKinnon (APEX show sales). IPC has also added [PERM](#) into the stable of groups under its control. PERM is a group working to help high-reliability companies move to lead-free. Driven mostly by mil/aero suppliers, they're working hard on a solution for tin whiskers. They made some good, but rather expensive progress. As one gentleman from Raytheon said at the recent tin whiskers conference, they haven't seen any increase in failures due to whiskers, but he also acknowledged they are spending a ton of money to ensure that.

“  
***As one gentleman from Raytheon said at the recent tin whiskers conference, they haven't seen any increase in failures due to whiskers, but he also acknowledged they are spending a ton of money to ensure that.***  
”

IPC also broke bread with SMTA by co-locating their fall meeting in conjunction with the SMTAI show. It seemed to work well for both groups. Let's hope for more cooperation and, ultimately, the merger of these groups.

A bright spot for me in 2013 was the new [Viasystems factory in Anaheim](#). I liked that. It's good to see what may be a taste of things to come. Let's hope so.

## Looking Ahead

What can we expect in 2014? I'm optimistic. It sure seems like the market is ready to roll if politics can stay out of the way. That's the only area of real concern I have. When you look at the raft of new technologies under development, conventional and alternative energy, printed electronics, 3D, new products based on exciting materials like graphene, the U.S. and Europe are in pretty good position to capture serious market share. Those innovations will translate into some type of electronics, which will drive our industry forward. The U.S. now has a pretty solid and reliable energy supply. Huge improvements to the energy infrastructure will keep energy prices relatively stable for years to come—a huge benefit for our manufacturers. This gives companies confidence that the costs of manufacturing will be fairly stable as they expand their businesses. Infrastructure and rule-of-law (IP protection), proximity to customers, and low levels of corruption are advantages we have over most of the developing world.

As a result, I think we'll see some surprising on-shoring initiatives in 2014 as companies make the move back to North America. China will continue to lose its luster. Things are beginning to come back into balance.

Another change we're starting to see and will continue to see expand in 2014 is the number of talented young people entering the industry. It has been a cry heard for years at industry events: Where are all the young people? How can we get them involved in the industry? Actually, these engineers, product designers, and entrepreneurs have discovered our industry because of printed electronics and 3D printing. They're going to rock our world. They don't have the mindset we all

have. They're going to develop the systems to build the electronics of the future, not based on what we know with traditional PCBs but on PE and 3D platforms. So for those of you who've been wondering where all the young people are, ask no more.

What will we see from the PE and 3D sectors in 2014? No big game changers, really. Just lots more low-cost prototyping systems. In a recent PCB assembly association survey, printed electronics scored highest as the area of greatest interest for its members. Just a couple years ago, PE was hardly on anyone's radar.

The link below is an example of the kinds of efforts being made by GenZ (get it, Z axis, third dimension) of circuit manufacturers.

[Circuit-printing startup reaches 30-day kick-starter fundraising goal in 5 hours](#)

And to help us get a glimpse of the kind of energy going into this, Oak Ridge National Lab is giving 35,000 3D printers to U.S. schools. Again, the concern about the lack of young people in our industry won't be an issue for long. It's just not going to be the industry we're used to. Read more about this initiative [here](#).

Tremendous opportunity awaits all those who grab it, and 2014 holds a lot of promise for our industry. You have to open your eyes, though, to see it. I'll leave you with a few famous quotes on the topic. **PCB**

*The reason a lot of people do not recognize opportunity is because it usually goes around wearing overalls looking like hard work.*

—Thomas A. Edison

*A pessimist sees the difficulty in every opportunity; an optimist sees the opportunity in every difficulty.*

—Winston Churchill



Ray Rasmussen is the publisher and chief editor for I-Connect007 Publications. He has worked in the industry since 1978 and is the former publisher and chief editor of *CircuiTree Magazine*. To read past columns, or to contact Rasmussen, [click here](#).

# 2013: A Look Back

by Steve Williams

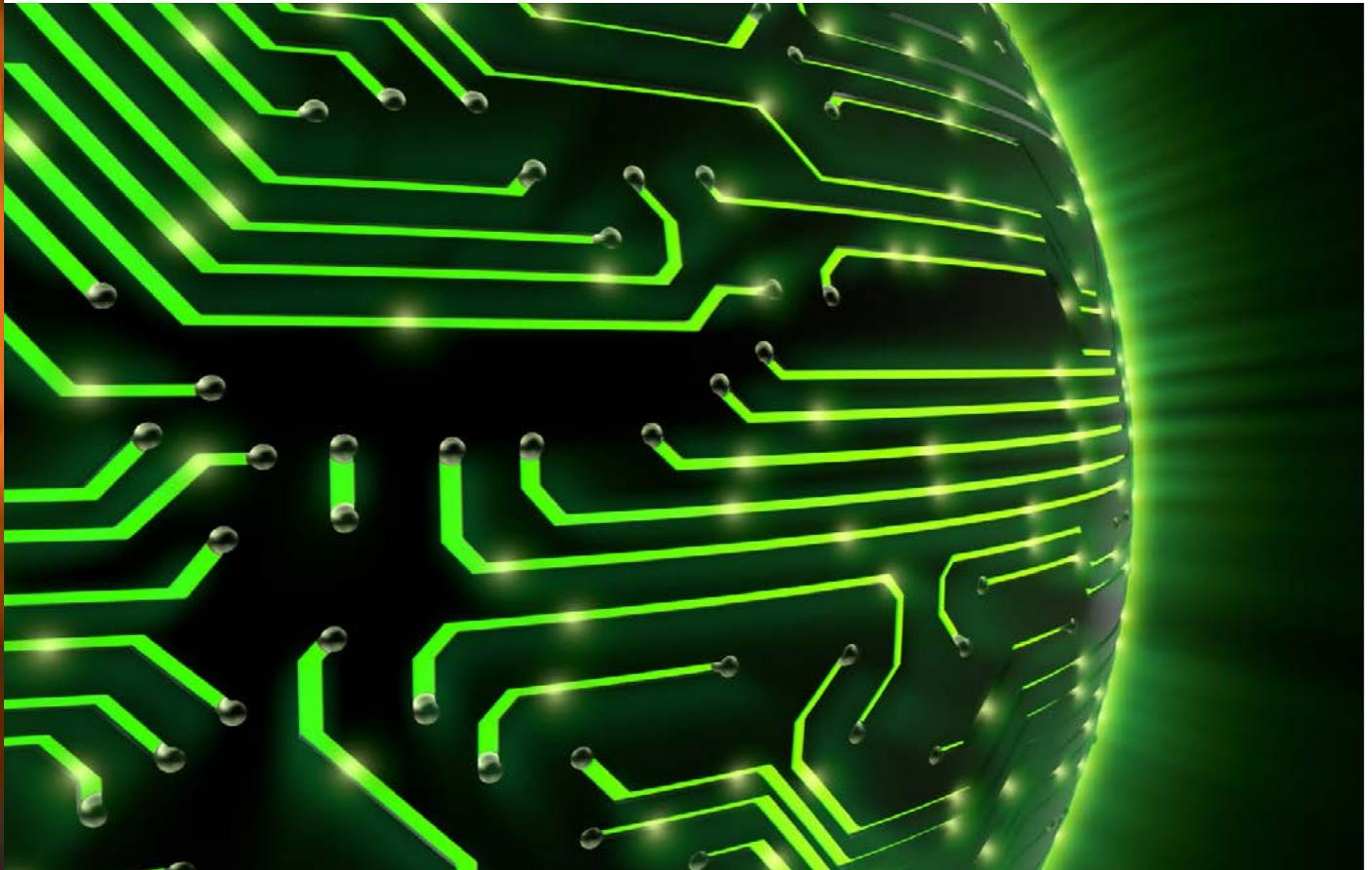
STEVE WILLIAMS CONSULTING LLC

After a very challenging year for the domestic PCB industry, global business conditions are slowly improving. Let's take a look back at 2013 and also a look forward to what we can expect as we move into the New Year.

Like many of you, I grew up in this business. I cut my teeth (and more than a few body parts) in this industry working for my dad in the family business. At the risk of dating myself, this was well before the advent of CNC machines, CAD/CAM and automatic plating equipment. Throughout the past three decades, I have been proud to see this business grow into the professional industry it has become. I am vested in the success of our industry; it matters to me.

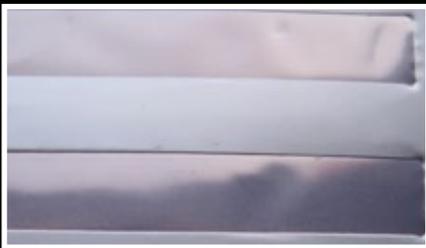
## 2013 News Flash: The U.S. economy is still not working!

After a number of false starts, missteps and failed technologies in the renewable industry, solar/photovoltaic demand is beginning to recover. Europe's tighter fiscal policies have squeezed consumer purchasing power and increased sovereign-debt tensions, which has an impact on global business. U.S. consumer confidence has not improved and is still hovering around 80%. The unemployment rate is 7.2% (published), which is bad enough, but after factoring in the millions of people that are no longer counted because they have flat-out quit looking, the "real" unemployment number



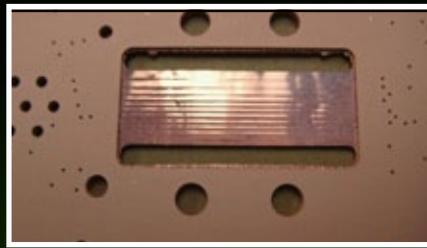
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is somewhere north of 14% (Forbes/BLS). The U.S. is dead last in the world for Gross Domestic Product growth in 2013 at 1.7%; forecasts for 2014 are only slightly better, at 2.8%, pulling ahead of only Japan and the EU. Whether it is RoHS, conflict minerals or the EPA, restrictive legislation continues to make it harder for PCB manufacturers to not only make a profit, but survive. Look for the biggest to get bigger through acquisitions both domestically and globally.

In 1990 there were roughly around 1,000 U.S. printed circuit board manufacturers; in 2000 there were 700, and in 2010 the number of domestic shops had fallen to only 365. Unfortunately, I fear this number will be less than 300 by the end of 2015, a short two years away. Where the U.S. market needs to continue to compete are QTA/proto business, advanced technology and short run orders.

### Global PCB Snapshot

The global printed circuit board industry's total available market is currently at a little more than \$60 billion, with Asia still dominating world production. There are a little over 2,900 printed circuit board manufacturers globally, and the United States held onto its fifth-place rank with just under a 5% share, which may look encouraging. However, this is extremely misleading as the top four countries are responsible for 89% of the total global PCB pie. People much smarter than me are only forecasting single-digit growth of the industry for the next five years.

### Bright Spots Looking Forward

There are a few positive signs looking forward: Leading indicators are rising in some regions and new product designs are starting to show some life. The overall world PCB production is increasing (100% growth over the past



10 years), which will continue to present more opportunities for the U.S. market.

Much of the talk at April's IPC APEX EXPO was how to bring manufacturing back to the U.S. Onshoring (the preservation of existing manufacturing in America) is increasing as a result of U.S. companies becoming more globally competitive through efforts

such as Lean, product design, reduced labor cost through increased efficiencies, and improved customer responsiveness. Reshoring (the return of work to America that had been previously lost to offshore competition) is also on the uptick. China's rising labor costs, political unrest and weaker exports are driving this trend. Apple plans to move \$100 million of Macintosh computer manufacturing back to the U.S. While this may be a public relations move on Apple's part, it is still \$100 million worth of work coming back.

“  
***In 1990 there were roughly around 1,000 U.S. printed circuit board manufacturers; in 2000 there were 700, and in 2010 the number of domestic shops had fallen to only 365. Unfortunately, I fear this number will be less than 300 by the end of 2015, a short two years away.***  
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### Smart Connected Devices

*“I think there is a world market for maybe five computers.”*

—Thomas Watson, chairman of IBM

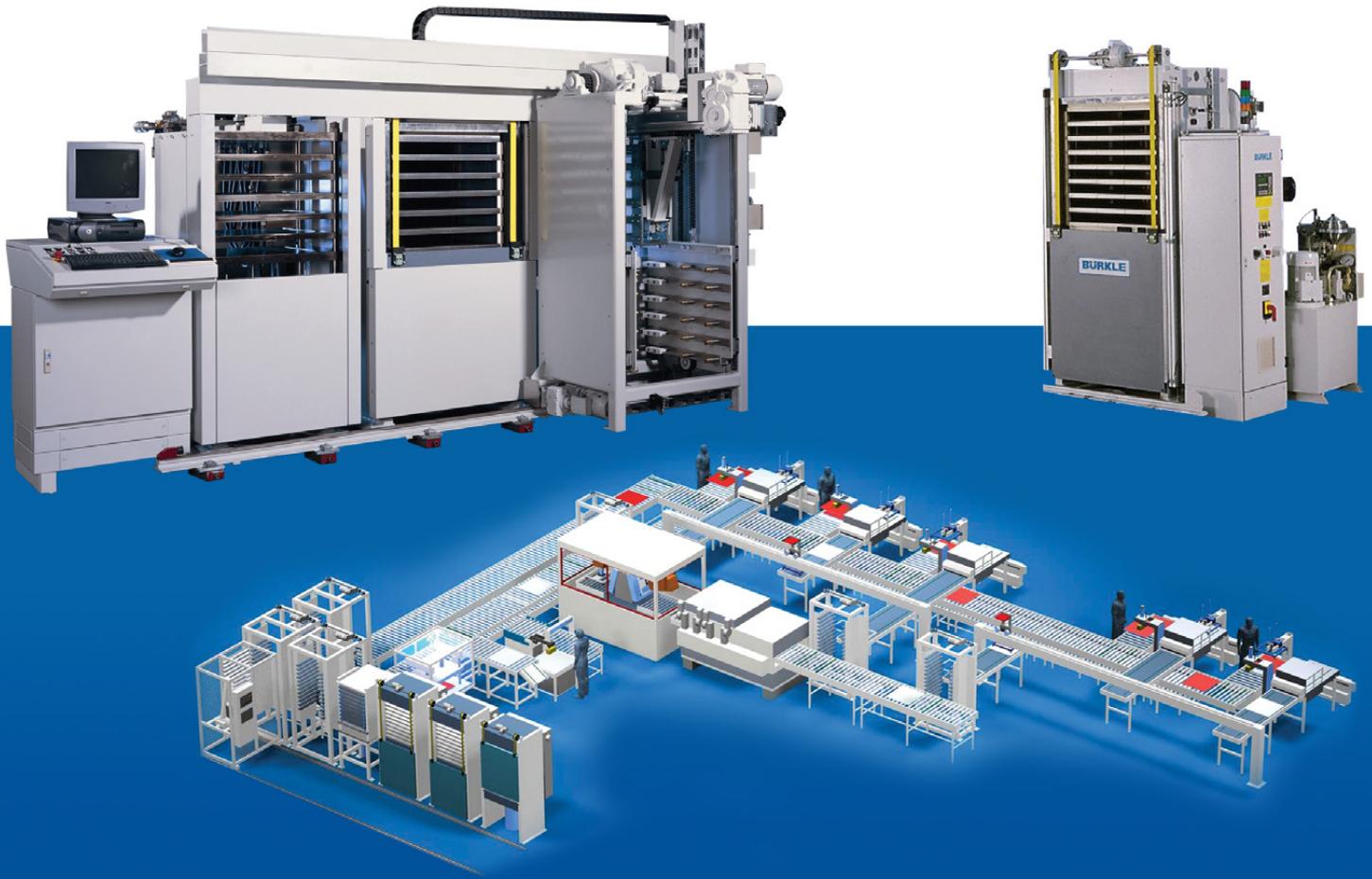
*“There is no reason for any individual to have a computer in his home.”*

—Ken Olsen, founder of legendary mini-computer company DEC

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*“So we went to Atari and said, ‘Hey, we’ve got this amazing thing, even built with some of your parts, and what do you think about funding us? Or we’ll give it to you. We just want to do it. Pay our salary; we’ll come work for you.’ And they said, ‘No.’ So then we went to Hewlett-Packard, and they said, ‘Hey, we don’t need you. You haven’t got through college yet.’”*

—Apple Computer Inc. founder Steve Jobs, on attempts to get Atari and HP interested in his and Steve Wozniak’s personal computer

Fortunately, these three boneheaded visions couldn’t have been more wrong; printed circuit boards are the backbone of electronic technology and have taken us to a place that none of these “prophets” could have imagined in their wildest dreams. The smartphone market is approaching a billion units a year with tablets adding another 400 million to this number. Every one of these devices has at least one printed circuit board that needs to be redesigned and replaced with each new generation launch.

### Keep Your Chin Up

Process equipment manufacturers are growing at a solid rate, which is a positive indicator for the PCB industry as a whole. Laminate and other material suppliers are also showing slight growth. So 2013 was a bit of a wash, but in this economy that is a win and with any luck, 2014 looks to be a little better. **PCB**



Steve Williams is the president of Steve Williams Consulting LLC ([www.stevewilliamsconsulting.com](http://www.stevewilliamsconsulting.com)) and the former strategic sourcing manager for Plexus Corp. He is the author of the books, [Quality 101 Handbook](#) and [Survival Is Not Mandatory: 10 Things Every CEO Should Know About Lean](#). To read past columns, or to contact Williams, [click here](#).

## VIDEO INTERVIEW

# Outlook for the Global Electronics Industry

by Real Time with...productronica 2013



Walt Custer discusses the key points of his analysis of the global electronics industry, as presented at productronica 2013. All those interested in receiving a copy of the full presentation are invited to e-mail him at [walt@custerconsulting.com](mailto:walt@custerconsulting.com).



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# Can Scrap be Beaten? A Strategy for 2014 and Beyond

by **Gray McQuarrie**  
GRAYROCK & ASSOCIATES

*Disobedience, the rarest and most courageous of the virtues, is seldom distinguished from neglect, the laziest and commonest of vices.*

~George Bernard Shaw

Is the key to beating scrap simply following process instructions and procedures? No! Scrap can't be beaten. Well, maybe, if we had really easy boards to build or very similar part numbers run at very high volumes or better equipment that was more up to date; maybe then we would have a lower scrap rate. But that isn't what is going on today. Look at what we have to contend with: different materials, more complicated sequential processing, and ever-greater densities, spacings, and geometries.

So we missed that important order. What did you expect? So we didn't make money this month. Again, these things happen. With the missed delivery came the missed quick-turn bonus and the inability to ship enough product to

cover our costs. It's time for our investors, corporate owners, board members, the bank, and Wall Street to understand that a high scrap rate is just a fact of life in this business. Our excuses for lack of performance driven by unpredictable scrap events, over which we have no control, needs to be accepted without question. In fact, nobody in this industry is doing any better. If there were a solution to scrap, it would have already been found. So, end of story, end of this month's column. Thank you for reading.

Throughout 2013, as technology continued to advance and our processes became even more complex, this was our excuse dialogue. Many of us are hoping in 2014 for some sort of outside technology miracle cure. I for one am not banking on this, because I believe our true salvation in beating scrap already exists. I talk about the solution to any chronic problem we face being within our four walls in my book, [You Have a DAM Problem](#). This is good news if we are will-



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ing to fundamentally shift our focus away from excuses, take accountability for the problem, and change our approach to almost completely the opposite of what we are doing today. This backwards thinking approach has a very positive precedent, as described in the book, [What-ever You Think, Think the Opposite](#). The solution being within the four walls of our business, and thinking and doing the opposite of the conventional approach is exactly what led to my rapid success at defining the true source of the registration problem and reducing registration scrap back in the '90s. Moreover, these two truths have always been there for me since my earliest days in the industry.

I remember back in the early 1980s when I first set foot in a PCB factory. The extremely frustrated general manager said to me, "Gray, this would be a great business if it didn't have any people in it. What I need is a factory without people and a bunch of obedient robots. Then all of my problems would go away." I was speechless. And yet, I have heard this very thing recited to me in different ways, again and again: the unquestioning belief in the need for total, rigid obedience by staff, a total lack of faith in this possibility due to "bad" employees, and the completely impossible task of finding "good" employees.

My first job in this industry was at a modest-sized manual electroless line, where I began to see that a lack of obedience created serious quality problems. The first problem I encountered was that operators were expected to take the samples, perform the titrations and chemical tests, and make the adds to the tank. This was a disaster. Quality and yields were horrible. What I did was take full responsibility for doing the chemical analysis and making the adds, and I simply followed the instructions. Within a couple of weeks, yields improved by more than 20 yield points. I was

considered a bit of a miracle worker, and yet the only thing I did was follow instructions. Even though these tasks were menial and boring for me, the value my chemistry and chemical engineering education provided was a full understanding of the consequences and health and safety risks related to not following the instructions.

Within a month or two, I began to see why the general manager had lost his faith in humanity and decided to place his faith in the machines; perhaps he desired everyone to be wired up like in [Star Trek's Borg](#). If we were short a line operator for several weeks, I operated the line myself. It was no surprise that the quality level was extremely high, because I prided myself in following the instructions exactly. This, of course, couldn't continue, so I trained a person who was intelligent and capable

of operating the line. I walked him through the line multiple times showing and telling him exactly how the boards were to be processed. Guess what happened? Within a couple of hours, he was improvising!! Yes, he was making crap up! I was speechless.

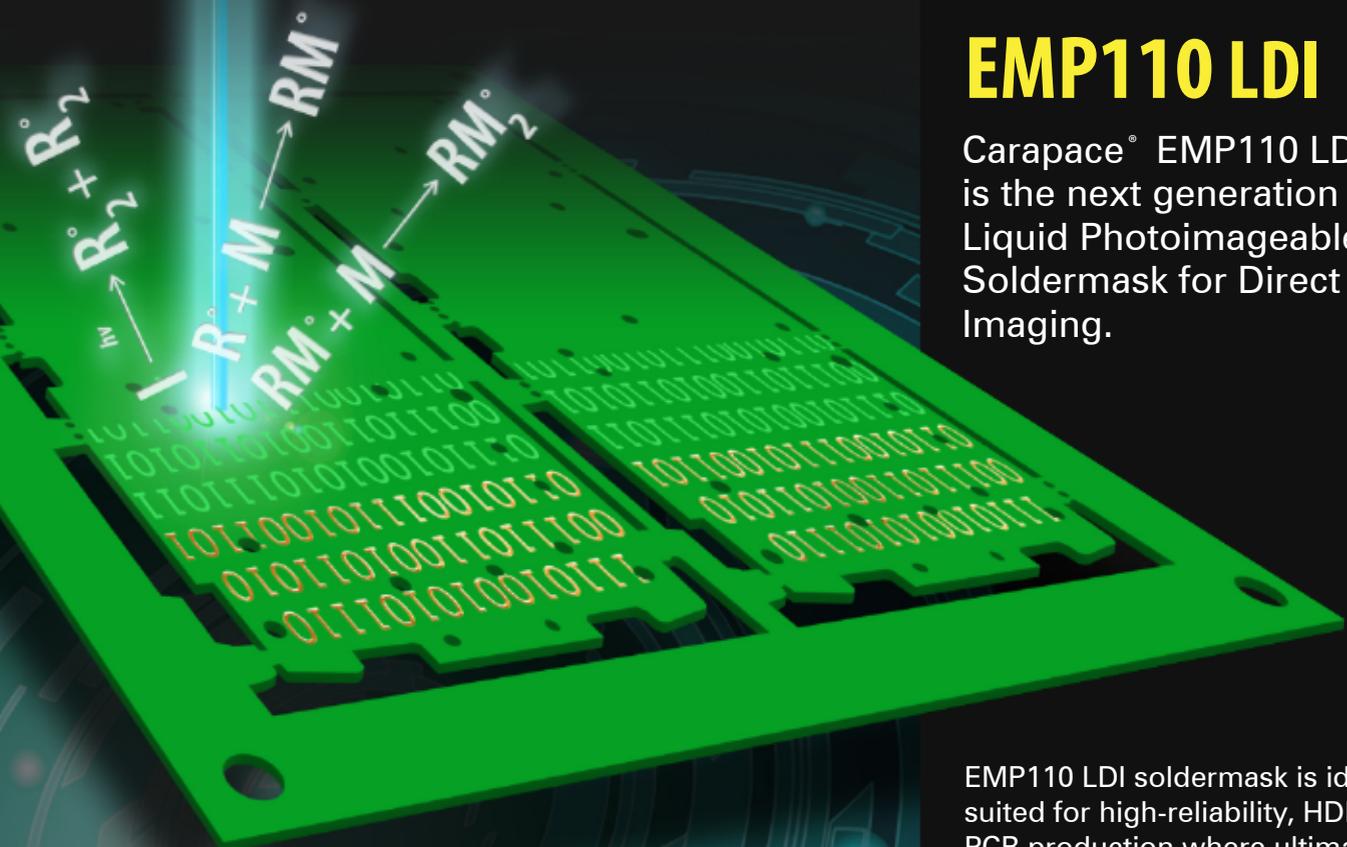
This disobedient behavior is the reason why anyone in our industry groans when they hear of a shop operating a manual plating line. No matter how many engineers you hire, because of the fantastical way human beings can make stuff up instead of follow instructions, you will rarely find the true root cause to a plating problem or for that matter any quality problem. And if you do find the cause, it all can be traced in some way to not following instructions, or a process operating

outside of specifications. What this means is scrap isn't (as popularly believed) a technical problem. Scrap is absolutely a people problem; it is a cultural problem.

Now, of course, you can start a quality improvement initiative such as using a fishbone

“  
***I remember back in the early 1980s when I first set foot in a PCB factory. The extremely frustrated general manager said to me, "Gray, this would be a great business if it didn't have any people in it. What I need is a factory without people and a bunch of obedient robots. Then all of my problems would go away."***  
”

# Direct Image Solder Mask



## EMP110 LDI

Carapace® EMP110 LDI is the next generation in Liquid Photoimageable Soldermask for Direct Imaging.

- **Low Exposure Energy (50-80 mJcm<sup>-2</sup>) to Resolve Small Features**
- **Tack-free Surface During Exposure**
- **Fine Solder-dam Resolution (50µm, 2mil)**
- **Lead-free Compatible**
- **High Chemical Resistance to ENIG & Sn Processes**
- **RoHS Compliant and Halogen Free**
- **Non Toxic**

EMP110 LDI soldermask is ideally suited for high-reliability, HDI PCB production where ultimate resolution and registration is required.

The EMP110 LDI formulation has been engineered to deliver straight sidewalls and fine solder-dam resolution over the wide range of coating thicknesses associated with screen-printed and sprayed PCBs.

Optimised radiation curing characteristics deliver high levels of through-cure at low energy levels without compromise in surface tack or chemical resistance.



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diagram, or cause-and-effect matrix, or mental map, or any tool of this type.

Allow me to lead you through this with some questions. How much of your scrap problem has to do with people? How much of your scrap problem has nothing to do with people? You might not like these questions and you might even decline to answer them. You might at this point stop reading and turn off your computer. So let me ask another question. What percentage of scrap has to do with operators not following procedures and the process not operating to specifications? If you are irritated with my one-track mind and feel compelled to be disobedient to this line of questioning, I understand.

My services were being considered in a shop not long ago where managers were greatly frustrated with their yields, and they felt they needed to go on a very expensive engineering campaign to figure out narrow, specific technical reasons for their scrap. They were hoping I might tell them what data they should collect that would reveal the answer. Instead, I told them I wouldn't collect any data; I would go talk to the operators. I didn't get the job. However, when I asked how much their scrap rate would improve if the operators followed instructions and the process was operated to specification, the managers said this would account for a third to half of their scrap. This was a company that has a \$1 million/month scrap problem. Instead of hiring me they hired a DMAIC expert. Their hope is that they will see a small, incremental improvement in scrap of a few percentage points. Why was their target set so low? Because they had lost faith. They no longer believed they could beat scrap. And that loss in faith, though they would never outright admit it, had everything to do with their loss in faith with people. Since they didn't know how to address their people problem, they chose an alternative path that

gave them a false sense of control over their world.

What few of us in our industry realize is that we are absolutely in the people business. Dividing our sales by our total head count is one quick way to prove this. Because we are in the people business, without people following instructions and the process operating within specifications, people aren't a 30% or more contribution to scrap; people are 100% of the source of our entire scrap problem. If you can fix the people problem, then you can beat the scrap problem. Is there a real world example where obedience to process instructions solved a large scale quality problem?

I have read thick books that attempt to explain why the Japanese had such a fast turnaround to become the envy of the world for their high quality. I have been inside a handful of factories in Japan, including a couple of Hitachi factories outside of Tokyo, too. So, I have seen firsthand what they do in production and how their engineering teams respond abruptly and en masse when a process starts to produce defects. What I have come to realize and understand is this: In the 1960s, the Japanese had horrible quality. A lot was made of W. Edwards Deming and others going to Japan and playing a significant role in their [rapid monumental improvement](#). But what made Deming successful and what made this rapid shift possible was Japan's rigid, obedient culture. Without it, the shift would not have happened.

A nation full of obedient people is great when it comes to a uniformity of production. And the quality from such production will be outstanding provided the process procedures and instructions as well as the factory design and equipment are good. But as good as obedience may be in manufacturing, a rigid, unquestioning, unthinking obedience has a dark and destructive side. World War II and the need to

“  
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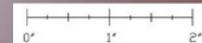
$\epsilon_r = 3.0$



$\epsilon_r = 6.15$



$\epsilon_r = 10.2$



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drop two nuclear bombs is just one tragic case of how difficult it is to get an entire rigidly obedient nation to change course. A more recent tragic case took place in Japan just a few years ago. The Fukushima Nuclear Accident Independent Investigation Commission (NAIIC) said, “its fundamental causes [for the accident] are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to ‘sticking with the program’; our groupism; and our insularity.” If that doesn’t make you think twice about the potential problems around obedience I am not sure what could change your mind.

When Japan’s methods were brought over with high expectations of improving the quality of U.S. manufactured goods, like PCBs, they fell well short of expectations.

Why? We Americans aren’t an obedient people. We never have been. Disobedience, after all, is how our country was founded: “Live free or die!” A Japanese culture cannot be injected into the United States. The problem is that management tries to force-fit these systems that are not to be questioned, be it the quality circles of the 1980s or more recently Six Sigma, DMA-IC, or Lean. And the companies that finally get their workforce to conform may have improved their quality, but they wind up with serious sales and profit growth problems; just consider Motorola, the former AlliedSignal, and GE. It’s not that the tools are bad, it’s the expectation that we are supposed to be obedient slaves to these tools that ultimately proves damaging. It’s no wonder some people think of these initiatives as cults. I found this quotation on a blog: “Six Sigma is a cult, kinda like Dianetics. Once you’re in it, you can’t change without reprogramming.” Scary.

I have had VPs and general managers of some of our biggest board shops in this country

ask me if it is possible to be too Lean. What they are really asking is, is there any wiggle room with the Lean rules, because we are beginning to suspect that following them rigidly and obediently—with no means to question, challenge, and experiment with them—may be hurting our business. They are right to feel uneasy about the rigidity of many Lean experts and practitioners.

So if all of our scrap can be attributed to people not following instructions and in this country we live in a culture where workers won’t be unquestionably obedient, what can we do? Well, first, if you have made it this far and see some merit to what I am saying, then you have come very close to defining the true source of your scrap problem. Congratulations, because

only when you have defined the true problem can you design and implement an effective solution. We can’t get into this solution in depth in this month’s column. However, if you understand people, know what motivates them, and are mindful about how they think about their work, then you can design a work environment where quality will be high. This is what Zappos, IDEO, and Pixar have done.

Let me give you a couple of rules and a few ideas to try. First are the rules.

1) If you tell people what do and threaten to use force to get them to comply, they still will not comply 100% of the time. This is because doing what you want them to do will make them feel insignificant.

Therefore, either consciously or subconsciously, they will break the rules in order to meet their need for significance. This is what I call the “Live Free or Die” rule. And what you have become as the enforcer of the rules is the common enemy, just like the British were to the colonies in 1776.

2) Breaking the rules is part of a theory called Broken Windows, which I cited in my

“  
**When Japan’s methods were brought over with high expectations of improving the quality of U.S. manufactured goods, like PCBs, they fell well short of expectations. Why? We Americans aren’t an obedient people. We never have been. Disobedience, after all, is how our country was founded: “Live free or die!” A Japanese culture cannot be injected into the United States.**”

column, [Standards are DAM Important](#) (August 2013). When someone breaks a rule, like throwing a rock through a window, and they are not caught and the window is not repaired, others are compelled to throw more rocks and break even more rules. Their reward? Recognition and respect within their counterculture peer group. Yes, this is the basis of gang violence that existed in New York City before the Broken Windows theory was applied. And this is why the eradication of graffiti on the subway system helped to drive crime out.

So those are two very important rules that give you huge clues on what you can do to start managing your company culture so that it delivers much lower scrap rates. Now consider trying the following ideas:

1. Set high standards and enforce them, not the rules to be followed. The standard could be a measured compliance on how well each department is following process instructions.
2. Describe this new activity as an important mission vital for the success of the company. If you wish, you can get people to sign up publicly and display the signatures very close to the front door, for all to see: customers, vendors, investors, managers, and workers.
3. Measure specific work teams' performance for following the instructions. Create a competition. If you can, create a common enemy that unites everyone even more deeply to the mission and creates a burning need within the teams to be successful.
4. Reward the outstanding teams with a ceremony defined and conducted by their peers spontaneously and on the spot.

The last one, and how it is conducted, is crucial. Why are gangs so strong? It is because of peer pressure and the recognition and resulting significance they receive from their peers.



Formal celebrations, in which people are recognized by upper management, are not going to be as powerful. The other crucial point is that people have complete and total control of what they are being held accountable to. For example, if you hold people accountable for scrap, but they have no control over what someone else upstream or downstream does (bad board design, defective material that entered into the process, etc.), no matter how much you threaten, or how great the incentives for improvement, nothing will be improved and sustained. That is why a key part to Honda's and Toyota's quality improve-

ment was giving operators the ability to shut down the line if they observed anything out of compliance.

I don't expect you to be obedient to what I am saying here. I can only hope I was provocative enough to spur your mind to think and restore your faith in yourself and your people. Scrap can be beaten.

It comes down to your choice. Are you willing to accept that the solution to your scrap problem is within your four walls? That you can do things much better in 2014 than you did in 2013? Instead of treating scrap as almost entirely a technology problem, are you willing to create an environment for your people that motivates them to follow instructions and operate the processes within compliance? Yes, beating scrap is that easy and that hard. **PCB**



Gray McQuarrie is president of Grayrock & Associates, a team of experts dedicated to building collaborative team environments that make companies maximally effective. To read past columns, or to contact McQuarrie, [click here](#).

# PCB007 Supplier/New Product News Highlights



## [Isola's Taoyuan Plant Earns Recognition for Cleanliness](#)

Matt LaRont, president of Isola Asia Pacific Ltd. stated, "We are pleased to be the first copper clad laminate facility to be recognized by the Taiwanese government for our green initiatives, which were achieved by our capital investments in the Taoyuan plant."

## [DuPont Debuts MELINEX TCH Series](#)

DuPont Teijin Films (DTF) is introducing a new series of clear films for the flexible electronics market, designed to reduce haze and eliminate the iridescence commonly found with polymer films containing refractive index mismatched coating layers.

## [PCB Solutions Creates Engineering, Design, & Layout Division](#)

The company is pleased to announce the ability to provide engineering services available to customers looking for assistance with engineering, designing, and laying out products that require PCBs.

## [Ucamco Delivers LED-based Direct Imaging to ACB](#)

ACB is Europe's leading manufacturer of quick-turn and high-reliability prototype and small series PCBs. Typically an early adopter of new and enabling technologies, the company recently took delivery of a top-of-the-range LED-based direct imaging (DI) system from Ucamco.

## [Isola & Holders Technology Partner in UK](#)

Karl Stollenwerk, president of Isola GmbH, stated, "Holders Technology is an ideal partner to complement Isola's European sales channel. Holders has a reputation for providing a professional and

high-quality service to its customers, and we look forward to a long and successful partnership."

## [PPG's Eng Receives Committee Leadership Award from IPC](#)

IPC recently awarded Douglas Eng, business development manager of PPG Industries' fiberglass business, its Committee Leadership Award.

## [Epec Examines Reverse Engineering Obsolete PCBs](#)

Epec will hold a webinar that will review the items required to make the process of redesigning a customer's antiquated or obsolete PCB into a contemporary and cost-effective product.

## [Gardien to Showcase Scanner, New Tester at productronica](#)

Gardien is bringing their new flying probe equipment range to productronica as well as the Unique Acceler8 Electromechanical Scanner. In addition to equipment demonstrations, the company will be demonstrating a wide range of services using Aurasma augmented reality.

## [Orbotech's PCB Business Down Slightly in Q3](#)

Asher Levy, CEO, said, "We are pleased to report a strong third quarter, in which we posted increased revenues and improved gross margins and operating income. While revenues from our traditional PCB business were slightly lower than in the second quarter, we posted record quarterly revenues of more than \$10 million in our electronics component manufacturing business."

## [Uyemura Announces Staff Expansion](#)

Don Walsh, director of operations for Uyemura USA, has announced three strategic additions to the company's professional staff.

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# Ledia

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Ledia is *the* production machine  
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75 installations of which  
47 for solder mask in daily production



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Solder Masks

Imaging times (incl 4-point registration, 460x610mm)

High sensitive DFR	269 Sides/Hour
Standard DFR	192 Sides/Hour
Standard Solder Mask	65 Sides/Hour

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# Automated Optical Rework Replaces Manual Method



by Bert Kelley  
ORBOTECH INC.

**SUMMARY:** *Manual rework may soon be a thing of the past, as the use of automated optical rework continues to spread. The quality results of AOR are now well proven for even the most complex PCB designs.*

Automated optical rework (AOR) is a new method of reworking shorts by using a fully automated fine laser beam to ablate any excess copper in fine-line PCB patterns. This includes shorts, protrusions, copper splashes, minimum space violations, underetched conductors, excess features and more, without damaging the panel's substrate.

In the traditional PCB production process, following automated optical inspection of a panel, the operator of the verification system manually reworks any excess copper using a knife. Manual rework can damage the adjacent conductor, penetrate the laminate, create cosmetic defects in outer layers, and more. In fine-line production (sub 60  $\mu\text{m}$ ), quality manual

rework is not possible, even by highly skilled operators. This includes, for example, the most advanced smartphone designs with line and space of sub 50  $\mu\text{m}$  and prepreg lamination thickness of 40  $\mu\text{m}$  and below. In addition, many PCB shops' customers prohibit manual rework of PCBs.

The latest technology breakthrough in higher speed with no compromise on rework integrity has cleared the way for more widespread and mainstream use of this technology in the manufacture of today's demanding PCB applications. The advantages of AOR provide new opportunities for fabricators to move much closer to achieving zero scrap production, while continuing to push the boundaries of electronics innovation.

This article will describe AOR technology and its advantages for advanced PCB production, including examples of before and after results.

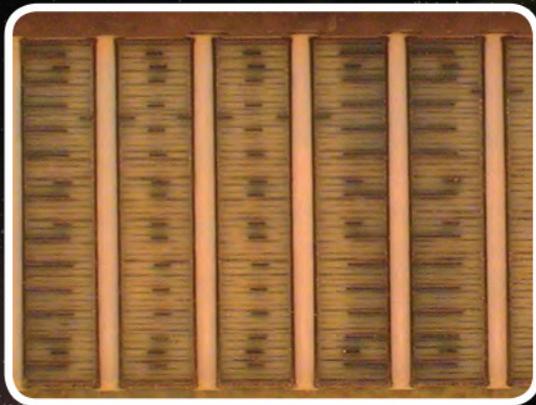
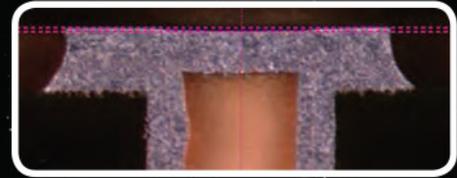
AOR is the new way of reworking shorts by using a fully automated fine laser beam to ablate copper in fine-line PCB patterns. AOR can ablate any excess copper such as shorts, protrusions, copper splashes, minimum space violations, underetched conductors, excess features

# The latest in hole filling at Taiyo

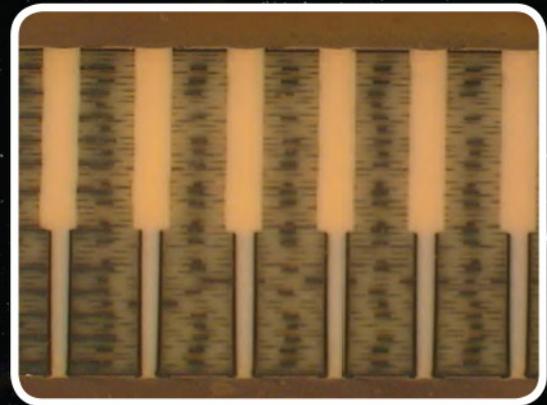
## THP<sup>®</sup>-100DX1 (HTG)

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and more, without damaging the panel's substrate.

Unlike manual rework, AOR provides accurate, repeatable and reliable rework without human error. This paper describes the technology and benefits provided by AOR to meet today's challenging printed circuit board production requirements.

AOR is a fully automated solution for the rework of shorts. This automated system removes excess copper and offers:

- Support for fine-line products (down to L/S resolution of 30 µm)
- Fast rework: typically 60 reworks per hour (including handling) for high-end HDI production
- High quality: minimum damage to laminate; typical penetration of 15 µm or less
- Accuracy: deviation from reference of less than 10%
- Repeatability: all reworks are of the same high quality
- An automated process: no human intervention

Its unique, patent-pending technology makes it possible to accurately rework any type of excess copper while eliminating the risk of human error and damage to the laminate. AOR introduces a closed-loop technology of iterative processes that consist of three parts:

- Image acquisition: captures white-light and UV images
- Image processing: analyzes and compares the images with the CAM reference data and defines the accurate ablation contour and parameters
- Laser ablation: based on the processed data, shorts are reworked using laser ablation

Figure 1 illustrates the iterative operation, where each cycle starts with image acquisition followed by image processing. If excess copper is identified, ablation is performed and then the system returns to acquire the new image, otherwise the defect is declared as reworked.

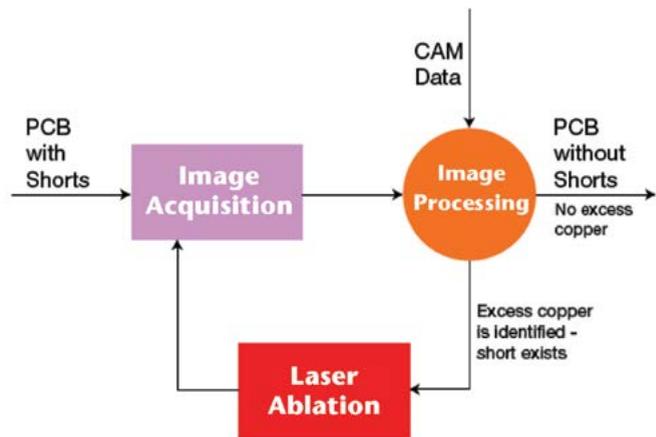


Figure 1: A flow chart describing AOR technology.

### Image Acquisition

An advanced high-resolution camera combined with a flexible illumination control system provides strong magnification and captures accurate images of the inspected defect for:

- Sharp and clear-cut distinction between the copper and the laminate
- Accurate identification of the ablation area

### Image Processing

Powerful algorithms concisely identify the ablation area of the excess copper. This area is defined through a series of image processing steps which include: analyzing the high-quality defect images to find the actual area of the copper, using CAM reference data and activating sophisticated panel understanding capabilities such as pattern excess copper analysis.

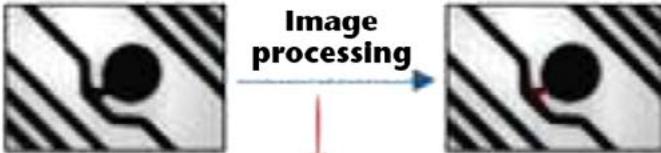
### Laser Ablation

A laser system specially designed for automated PCB rework emits high-frequency pulses coupled with ultra-fast moving mirrors for optimal control. All aspects of laser activity are fully managed including laser energy, spot size and spot position. An innovative optical mechanism optimizes the laser intensity and accuracy for best laser performance on a variety of materials. Customized ablation parameters are automatically selected for each individual ablation cycle which ensures accurate and reliable rework in the fastest manner.

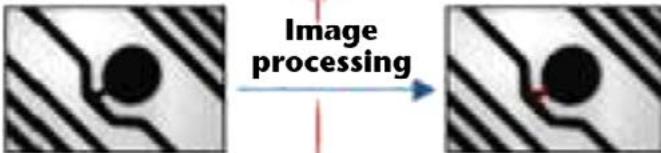
**Reference data (CAM)**



**1st Cycle**



**2nd Cycle**



**Last Cycle**



Figure 2: Demonstration of the rework process.

The full three-step cycle of image acquisition, image analysis and laser ablation is repeated until the rework is perfect, with no damage to conductors and minimum penetration to the laminate.

**Rework Process**

In Figure 2, the rework process is demonstrated. At the beginning of each cycle, the CAM reference data is compared with every acquired image. In the diagram, the first cycle shows the first acquired image (left). This is followed by image processing that provides the ablation contour (right). The first cycle is concluded with the completion of laser ablation. The second cycle starts with image acquisition (left) followed by image processing (right). As a

result, a new contour is set for the second cycle of the laser ablation. The process is continued, until the system's image processing decides that the short is completely removed and this is registered as the last cycle (last cycle image).

The following are a few examples of automatic rework carried out on FR-4 laminate 40-100 µm line/space designs.

**Rework Speed**

Today's most advanced AOR technology can now achieve throughput of more than 60 reworks per hour for typical HDI defects. This is as much as three times faster than earlier AOR capabilities, making it a viable solution for higher volume production environments that require shorter processing times and for high layer count, thick copper boards with large defects.

**Full Openness with Universal Access**

AOR has the full openness necessary to become the rework center for all excess copper defects detected along the PCB production line. This includes automatically receiving data from certain AOI or verification stations for maximum speed in mass production mode. It also includes quick and easy navigation to any marked defect identified by other AOI systems, electrical testers or at any stage in the process.

**Benefits**

**Technology Advantages**

- Accuracy: complete and accurate ablation of all excess copper without damage to the conductors or the laminate
- Repeatability: an automatic and accurate process that eliminates human error
- Reliability: no damage to the laminate, ensuring no effect on the following production processes

**Scrapped Panel Cost Savings**

With today's advanced products, manual rework of shorts with a knife frequently damages the adjacent conductors and the laminate, resulting in scrapped panels. With the precise rework capabilities of AOR, the following benefits are achieved:

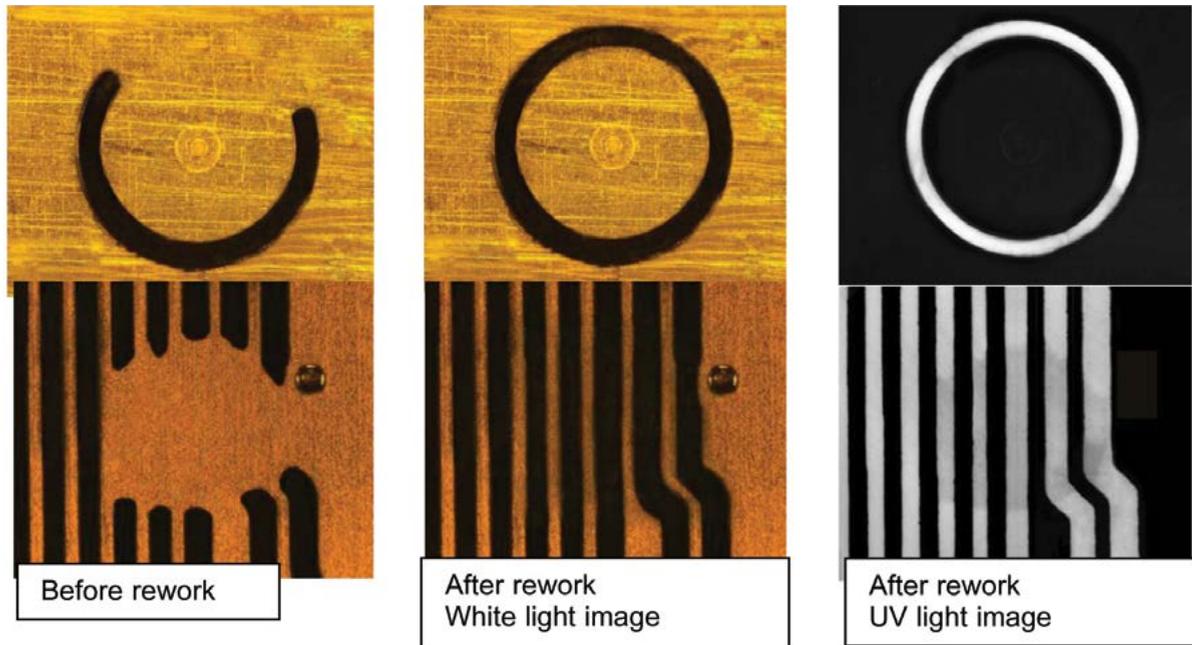


Figure 3: Examples before and after the AOR process.

- A significant cost savings on panels that would otherwise be scrapped
- Higher-quality products due to improved rework quality
- Increased competitiveness by enabling advanced product production at a lower cost
- Aesthetically pleasing outer layers

### Enabling Technology

Fine-line products such as advanced HDI cannot be reworked today due to human capability limitations. In addition, in many cases, expensive boards for critical applications such as communications and aerospace are also not manually reworked. In these segments, AOR is the only rework solution available, and the cost saving is extremely significant.

### Conclusion

Based on years of extensive research and development as well as rigorous testing in production, the quality results of AOR have been well proven for even the most complex PCB designs. The latest breakthrough in higher speed with no compromise on rework integrity has cleared the way for more widespread and mainstream use of this technology in the production of to-

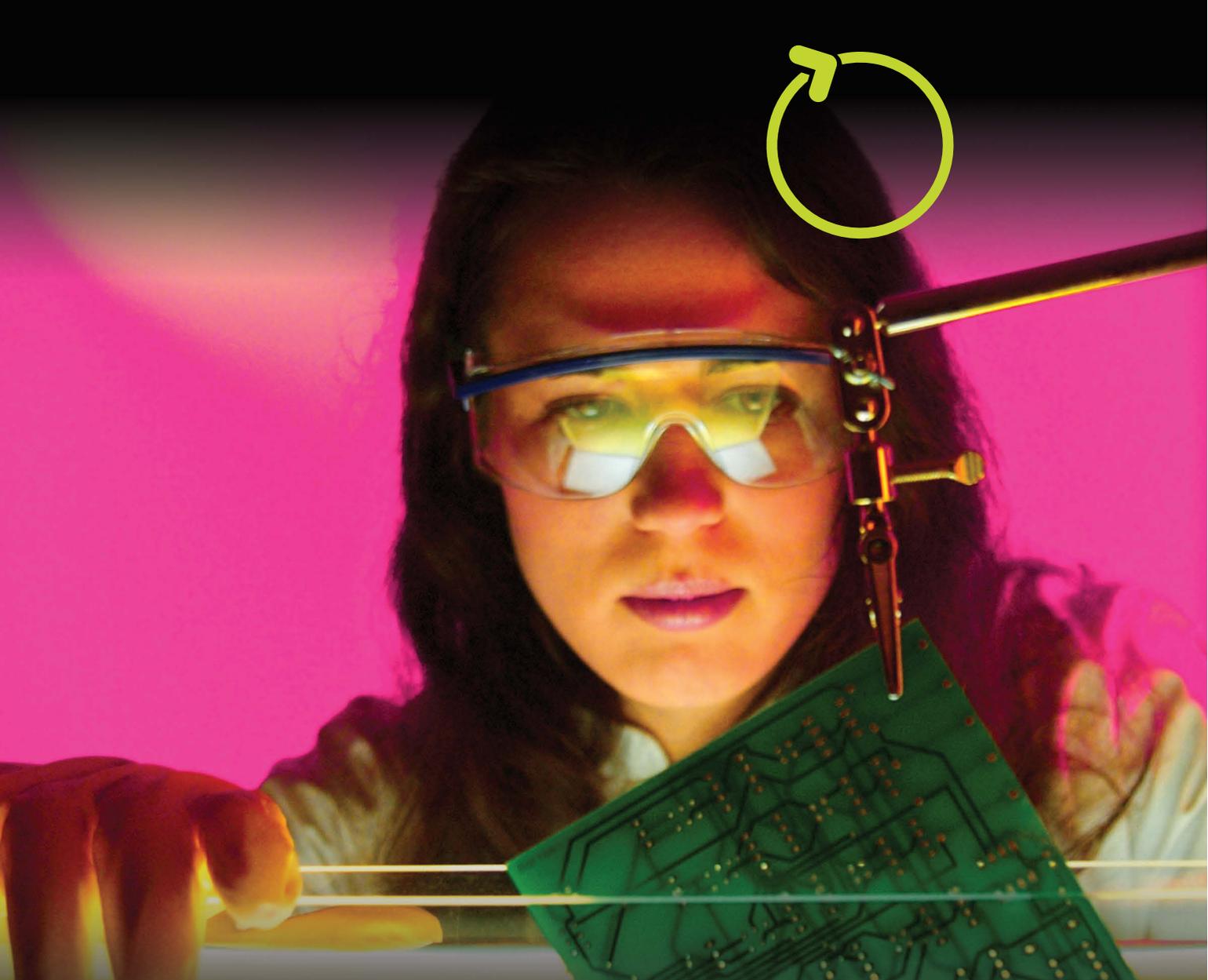


Figure 4.

day's demanding PCB applications. The advantages of AOR provide new opportunities for fabricators to move much closer to achieving zero scrap production, while continuing to push the boundaries of electronics innovation. **PCB**



Bert Kelley is a technical specialist at Orbotech Inc.



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# PCB007 Market News Highlights



## [Global Smartphone Market Up 38.8% in Q3](#)

The worldwide smartphone market grew 38.8% year over year in the third quarter of 2013, according to the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker.

## [3D Printing Market to Reach \\$8.41 Billion by 2020](#)

According to a new market research report, the 3D printing market is expected to grow at a CAGR of 23% from 2013 to 2020 and reach \$8.41 billion in 2020. The upcoming expiration of patents with respect to selective laser sintering (SLS) is also believed to provide a further impetus to the growth of the market.

## [Survey Reveals Technology Investment Predictions](#)

"CFOs continue to seek out technology that allows them to improve business performance and increase employee productivity," said Jay Cary, VP, Digital, Global Corporate Payments at American Express. "Mobile in particular is leading the way, both because of CFOs' familiarity with the technology and for the real-time benefits it offers employees."

## [Are Nanomaterials the Next Big Thing in Electronics?](#)

Senior electronics executives attending IPC's recent Management Meetings and Technology Market Research Conference in Chicago were treated to a positive and intriguing look into the future of the materials market.

## [Apple and Samsung Lead in Overall Satisfaction Performance](#)

"It's very interesting to see that satisfaction performance differs by smartphone brand across Tier 1 carriers," said Kirk Parsons, senior director of telecommunications services, J.D. Power. "This indicates that carrier services and how these carriers position specific features and services on their devices influence the experience customers have with their smartphone device."

## [Global Brands Need to Rethink Strategy as Asian Markets Remain Critical](#)

According to Profit or lose, a new report released by EY today, succeeding in emerging Asia is paramount, with the region set to generate 38% of the sector's growth by 2017 and account for 25% of the CP market, up from 15% in 2007.

## [Global Expansion Techniques for Chinese Smartphone Makers](#)

As Apple launches its 5C iPhone to compete in the Chinese market, Chinese companies are looking to the West to grow their businesses. However successful in their domestic market, Chinese firms should carefully consider their global expansion strategies.

## [Graphene Electronics Market to See 55% Growth](#)

According to a new market research report "Graphene Electronics Market: Materials (PV, Electronics); Devices (Supercapacitors, Transistors, Spintronics, Sensors, ICs and Chips, Lenses); Products (Computing, Consumer, Memory, Display); Developments (Nanotubes and Ribbons, Fullerenes) (2013 - 2023)," the total graphene technology market is expected to grow at an estimated CAGR of 55.54% from 2013 to 2023.

## [Global RFID Market to Reach \\$7.88 Billion in 2013](#)

According to a new RFID sector survey by IDTechEx Research, the RFID market will increase from \$6.98 billion in 2012 to \$7.88 billion, and will reach \$23.4 billion in 2020.

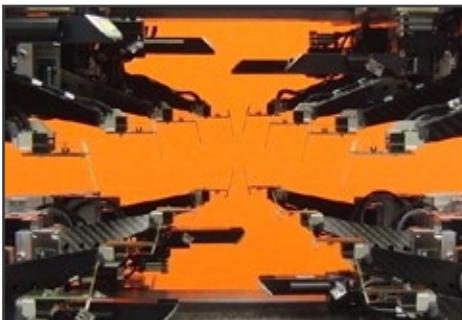
## [Consumer Electronics Spending to Grow 2.6% this Holiday Season](#)

The Consumer Electronics Association (CEA)® predicts consumer electronics (CE) spending will rise 2.6% this holiday season, down from 4% growth in 2012, according to CEA's 2013 holiday outlook released today at CEA's Industry Forum in Los Angeles.

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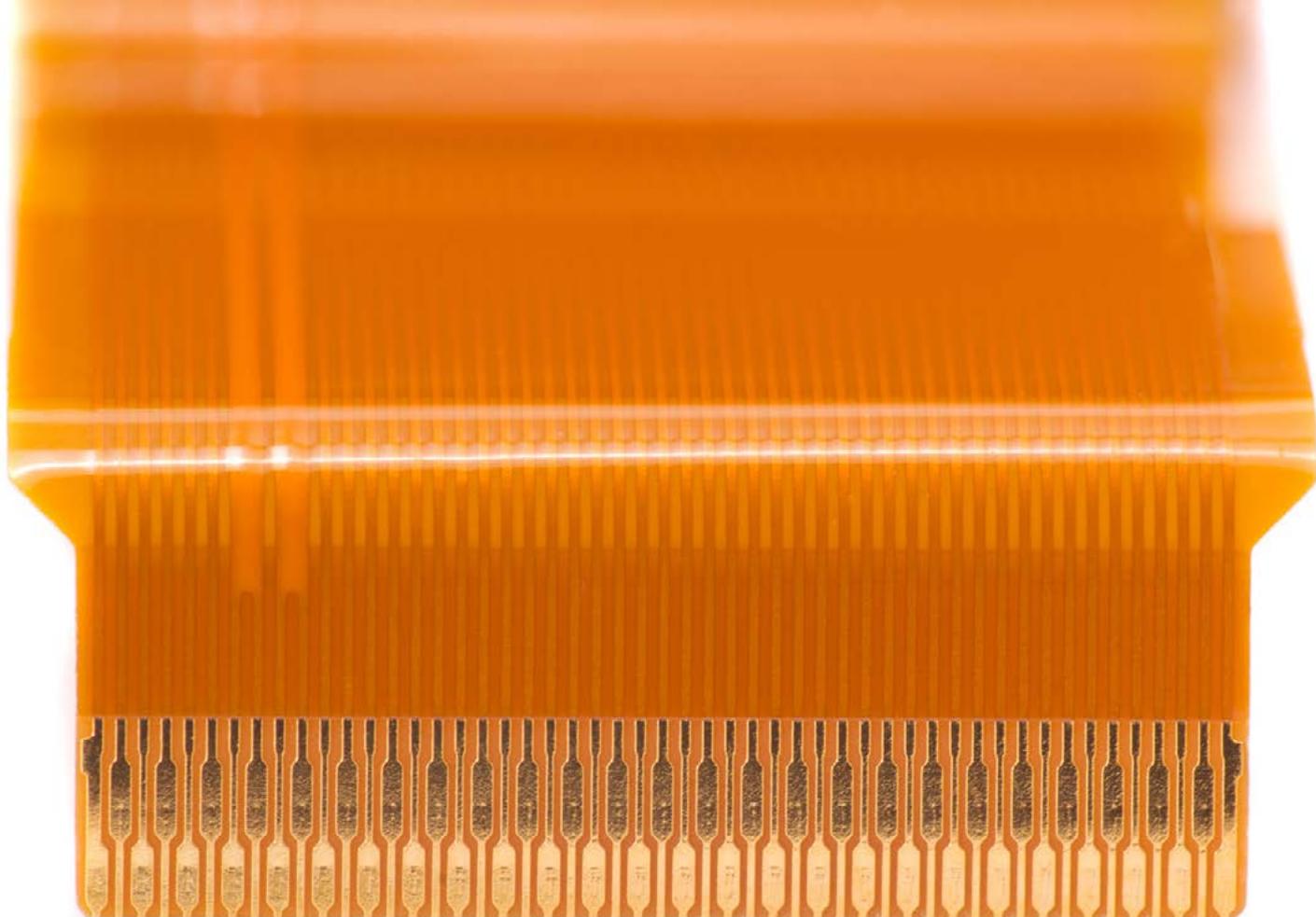
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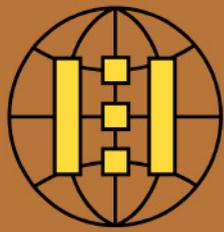
# Why Procuring Flexible Printed Circuitry is Different

by **Thomas Stearns**  
BRANDER INT'L CONSULTANTS

An article in the September issue of this magazine, [How to Select a Flex Circuit Supplier](#), featured an excellent article on how to select a flexible printed circuit (FPC) vendor. Herewith two thoughts on why procuring FPC is different from other products.

Firstly, FPC specifications and quality controls tend to be too tight; FPC is, by nature, a flexible, easily formed product of thin sheets of plastic film and metal foils bonded together with flexibilized adhesives. It is not carved out of billets of metal in a machine shop and it is not reasonable to assign thousandths-of-an-inch tolerances to every dimension.

FPC appeared as a commercial product in the late 1950s. Back then, the manufacturing process consisted of fusion-bonding high-performance polymer films onto treated copper foil to form an initial laminate. This was imaged and etched to form the conductor pattern, then subjected to a second fusion bond process in which the covering film had pre-punched apertures to expose terminal pads, sometimes with an added piece of film attached to the backside of the pad to force it upward into the punched openings to stiffen and reinforce the area against solder heat and stress. Typical bonding temperatures reached 530°F or so, and distortion and residual stress were constant problems. But this was a product with outstanding chemical and environmental durability and superb electrical performance. There were no flexibilized adhesives here!



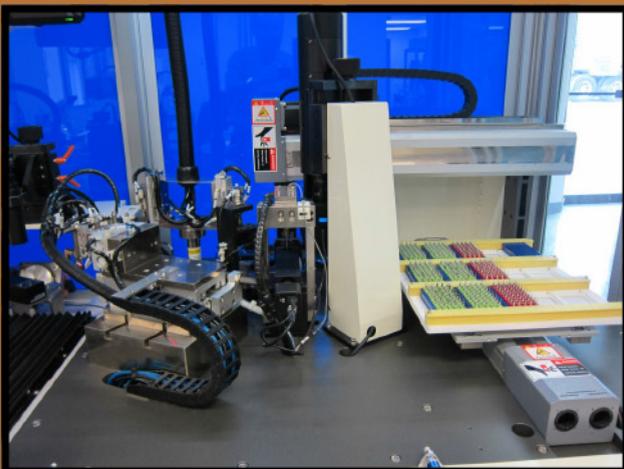
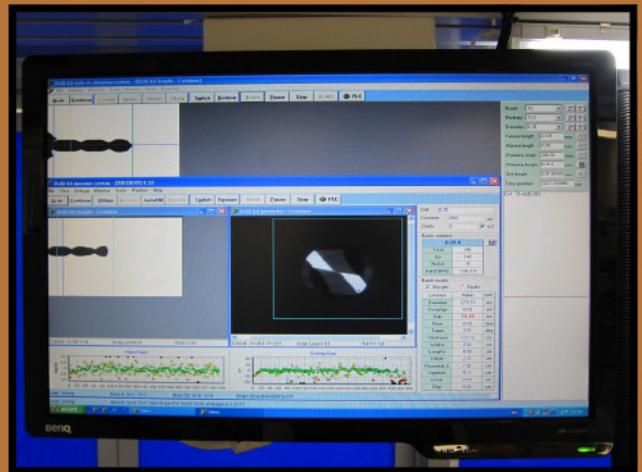
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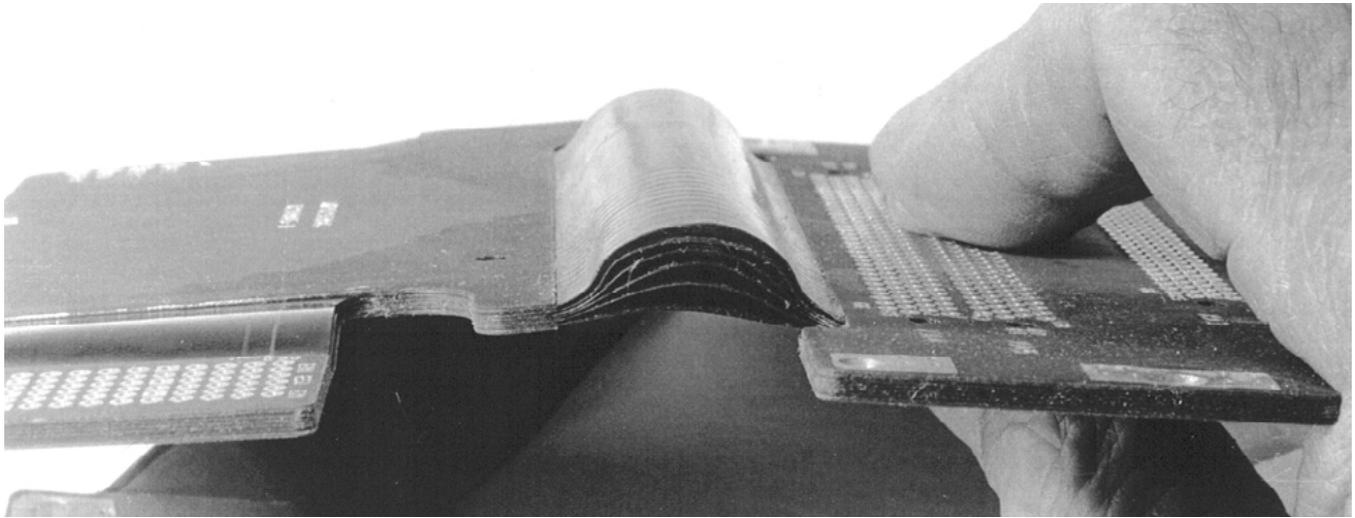
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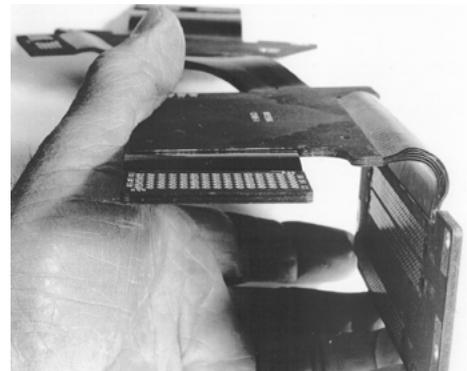
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Figures 1 and 2: Bookbinder, shown flat (top) and bent (right). In rigid-flex circuits with bookbinder construction, which is very difficult to produce, FPC layers that will be on the outside of bent areas are designed slightly longer to provide ease in the formed position.



At that time, almost all of the applications were in military or space equipment and nobody had a lot of experience with FPC. These quality-oriented customers were understandably suspicious—how much heat could it withstand? Could you flex it for long periods of time? Did salt spray affect it? And so forth. So naturally, there was a need for complete characterization and quality control which led to over specification. This was the era of “If you can build one part in 100 to plus/minus 0.002”, then let’s use that as a spec.”

Neither price nor yield was important to those uses—the only thing that mattered was performance, and FPC provided that wherever it was used. As the years passed, industry organizations came on the scene, and they wrote whole catalogs of specifications and test procedures, all with the intent of completely buttoning down everything from raw material to production code marking. This documen-

tary effort lowered the variation from vendor to vendor and improved product quality, but at a considerable effect on cost, hampering the use of FPC in commercial goods. Latterly, with increasing familiarity with the benefits of FPC in volume production—near elimination of interconnect errors, steep reduction in labor content and so forth—these excessively tight specs have been perceived as unnecessary, with the result that today we’re moving towards the “form, fit and function” end of the spectrum. But we’re not there yet: FPC is still subjected to excessive physical and visual inspection to tolerances which are not necessary to assure reliable function, but the situation is improving. A procuring engineer will always review the product specifications and quality control requirements to be sure they cover everything that matters and have limits to produce good product, and work with the prospective vendor to agree on specifications

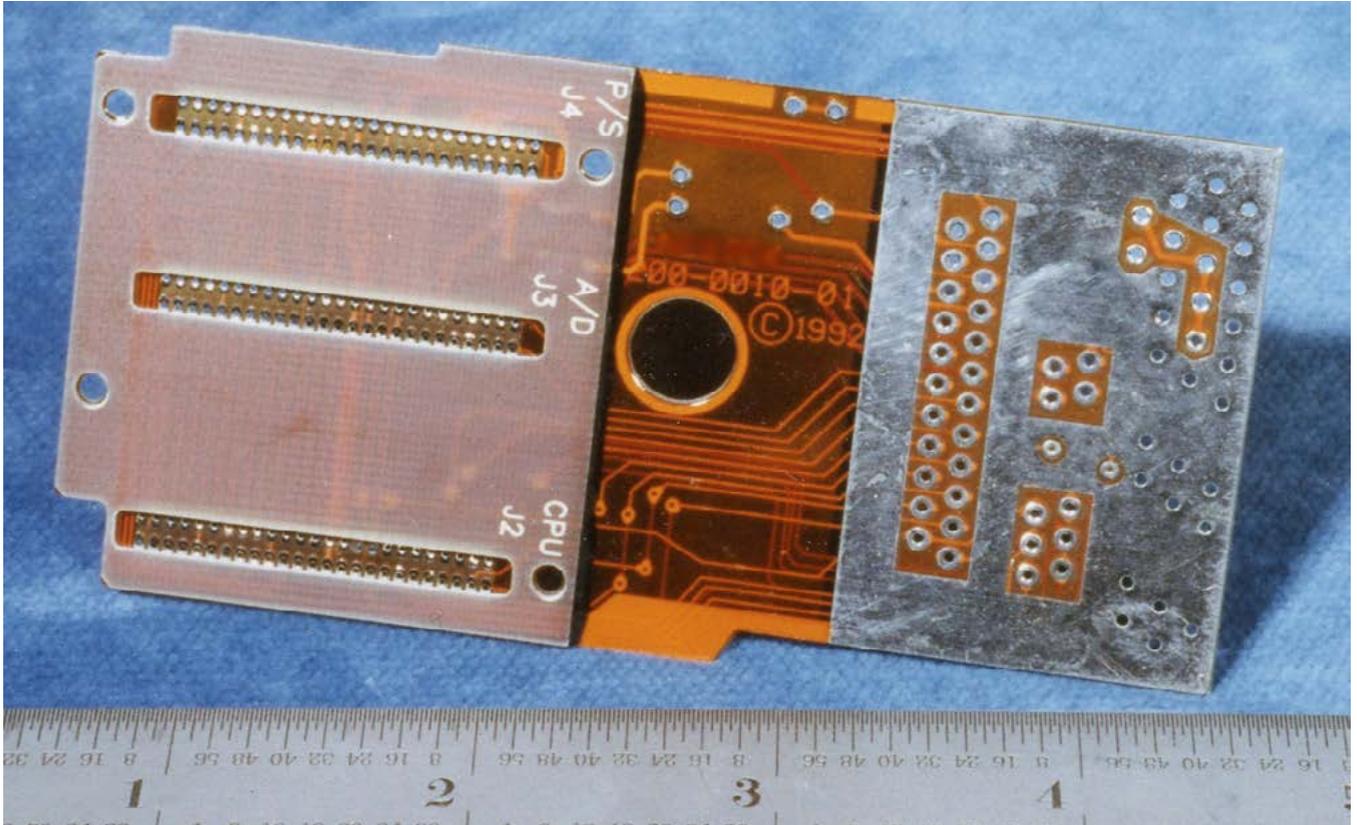


Figure 3: Stiffeners: FPC mimics PWBs when reinforced by an added structural layer; in this case (left end), epoxy-glass. The right end shows a ground plane or shield, which is part of the circuitry.

just tight enough to yield good product at the best price.

Secondly—and this may seem obvious and unimportant, but is a big issue—FPC is not a catalog item. It is a custom manufactured item and that makes a world of difference.

A short story to illustrate: Once upon a time a consortium of PWB people bought control of an FPC manufacturing company. The PWB guys with their “commodity production” mindset thought the FPC managers were unimaginative and behind the times and that PWB management ideas and efficiencies would quickly turn a poorly managed business into a winner. This rosy thinking lasted through the first year, at which point the PWB guys realized that things were very different from what they first thought. In another year the company was dead and the assets sold at auction.

Unfortunately for the PWB guys (and their bankers), this lesson was learned too late for fi-

nancial recovery. What looked like an inefficient operation ripe for profit tweaking was actually a pretty savvy and experienced one struggling with an overload of variables and tight specs in a manufacturing environment significantly (perhaps 3X) more complicated than the one they knew. The biggest mistake in this tragic tale lay in the overpowering assumption that producing and selling FPC is the same as making PWBs, or razor blades, or any commodity.

Buying PWBs or FPC—anything that is built to a custom design—is very different from other procurement. To begin, you are trying to buy something that does not even exist yet! Both of these products, but particularly FPC, have proven their worth as cost reducers in electronic assemblies. PWBs have reached the maturity of a commodity; FPC isn’t there yet, but it’s gaining. Use of FPC is rising rapidly: In this modern world we would not have digital cameras or smartphones or any of a hundred other high

functioning, complex, yet reasonably priced and rugged products we use every day without a piece of FPC, deep inside, providing error-free, semi automated, rugged interconnections. If you expect your new electronic gadget to make a profit, FPC is almost mandatory, and if you understand why the buying process is different, you can approach FPC procurement with confidence.

### **Sales or Contract Negotiation**

Every manufacturer has a sales department, but in the FPC business it functions quite differently. In the FPC world, bringing customers in the door isn't selling; it's contract negotiation. The result of an FPC sales meeting is a document that reads something like, "based on your drawings and specifications, and assuming we get X and Y by Z date, and that the dam don't burst and the creek don't rise, we will (may be able to) deliver by the third week of..."

"Sales" is what you think is going on but the much more truthful "contract negotiation" is really how an FPC project begins. FPC customers come to the procurement meeting with an idea of what they want—those drawings and specs—not a catalog number. Selling other products involves a catalog and a price list; FPC sales involves discussion and estimation of new requirements based on similar products and past production experience and ends with a quotation that is embroidered with many clauses and contains much wordsmithing.

Suppose that we look at selling as practiced at Paradise Bolt & Screw and compare it with what goes on at InterGalactic Flex. PB&S has a warehouse full of bolts and screws of known quality and production cost, ready to ship. The selling price and profit are already determined because any wrinkles in the process have been ironed out and the cost to produce is already known. Long ago, and well before the sales meeting, somebody did a market survey, decided which bolts and screws to make, fired up the machinery and tuned up the process so that high-quality product fell out the end at high yield and lowest cost. If you're looking for nuts and bolts, you simply get with a Paradise salesman who shows you samples, quotes prices, and guarantees delivery. It's cut and dried.

At IGF, the quoting-negotiating-order closing process, although carried out in similar language and with the same goal, (i.e., "closing the sale") is completely different. At IGF, each order taken is a ticket to a custom manufacturing adventure. There's nothing in stock, no samples of product to fondle and discuss, and the cost to produce is unknown because each design, regardless of how well vetted to industry guidelines or scrupulously productionized, is a mystery until a pre-production pilot run has been made. Quality requirements can be scoped out by the use of standard classifications and requirements, but unexpected interactions between design, materials and production equipment can lead to ugly surprises. Much of this uncertainty disappears with a repeat order, but the basic problem remains: The partners to the deal are buying and selling something that does not exist yet!

### **Delivery**

A hugely important difference between procuring custom manufactured products and commodity products is delivery. In our example let's assume that IGF has a well-equipped factory, one that is just as good as PB&S's. Nevertheless, unless this is a repeat order, IGF's factory has no experience at all in the production of the new design. And if InterGalactic is any good at its business, the factory is already loaded with orders and delivery commitments to other customers. Delivery estimates assume that not only will the new design run smoothly, but that none of the existing orders will run into a disaster. Remember that existing orders, particularly those from established customers, are already on the factory floor; if they get into trouble, they will take priority. At PB&S, the factory is irrelevant—it could have even burned down—since your parts are already in stock and need only be dusted off, packaged and shipped; at IGF you and your project are just entering a complicated production process, vulnerable to Murphy's Law.

You may argue that we're comparing apples to jetliners because the complexity of flex manufacture is far greater than the production of nuts and bolts, and you'd be correct. Nuts and bolts are hogged out of stable, naturally-

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occurring raw materials with a BOM calling for two items—a base metal and a surface finish, if any. FPC manufacture involves many more materials including highly unnatural films and adhesives that are produced by film makers and compounders from polymers, which are in turn produced by other chemical companies. This is a much more complex supply chain with multiple layers of manufacturers. Latent defects are the rule. And that's just for the raw materials; making nuts and bolts is primarily an automated machine-shop enterprise, while FPC production takes multiple interacting processes using thermal, chemical and mechanical forces and process equipment all influenced by both operator skill and latent defects in those complex raw materials. There is no comparison in degree-of-difficulty and the horrors of compounding yield losses, but this only adds to the argument: If the situation were reversed and the complex product was a commodity and the easy-to-build product was custom made, these problems would disappear. But FPC is the tough one to make and can't be sold from a catalog be-

cause it's a custom product. You sell something that you have; you contract to make something you don't have. Selling something you don't have is pretty close to fraud.

**Competition, Second Sources and Partner Selection**

What about competition? PB&S makes a catalog product, but so do all of the other bolt and screw makers of the world. If your project needs 1,000, 1/4-20 round head

1" brass screws per day and Paradise can't supply them, there's always somebody else with an identical and fully interchangeable part that can. In the case of an FPC buy, a hiccup at the factory—your personally selected, custom-contracted factory—means that you start production all over again: there's no backup supplier ready to ship on demand. You selected a production partner and that partner has just let you down. You could leave in a huff and start finding a new partner, but that's more time wasted and you would be even further from production with no greater assurance of success.



Figure 4: Four connectors: A three-layer FPC with central shield. Terminations are plated through and have soldered connectors.

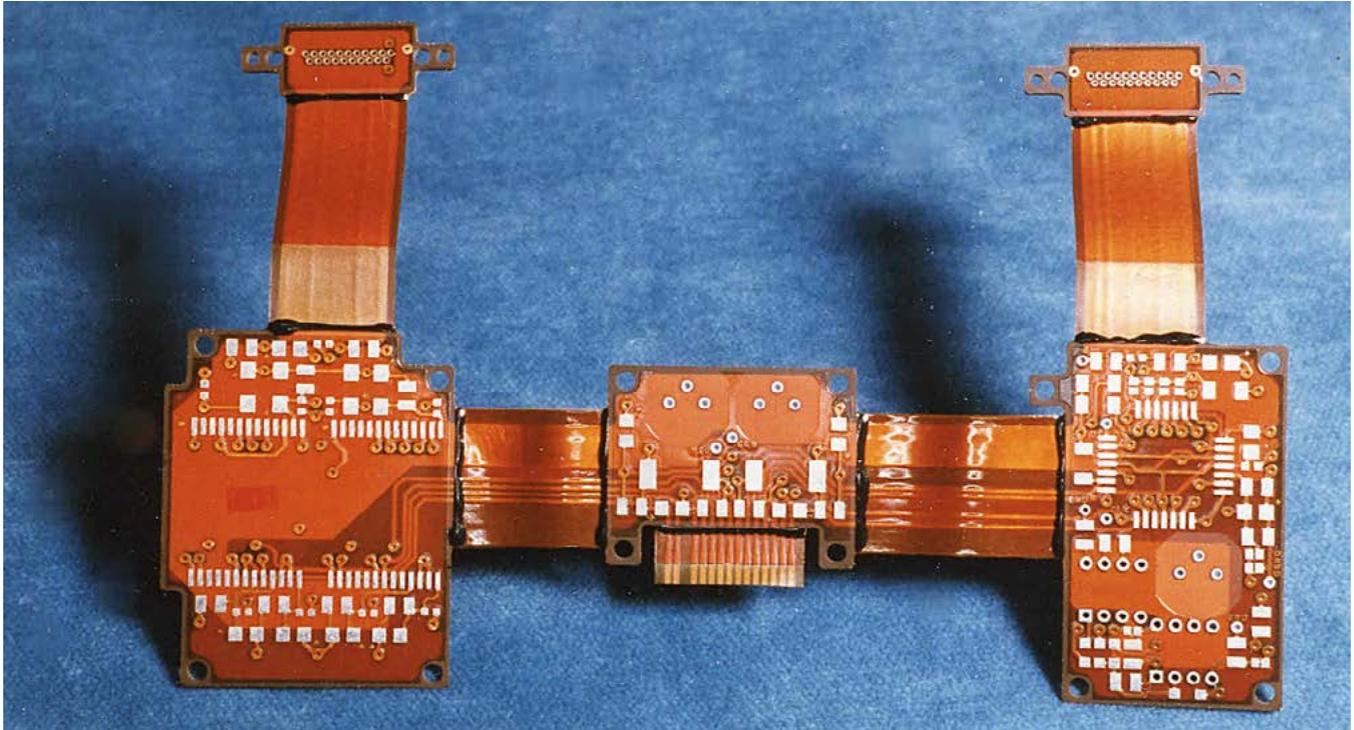


Figure 5: Rigid-flex circuitry provides the most space and weight efficient interconnection. This circuit has five rigid terminal areas with plated through-hole interconnections. Black material along the rigid edges is semi-hard and gives strain relief.

This is why selecting a vendor for an FPC requirement is a contract negotiation and partner-selection, and not just a price comparison.

In most cases, the Number 1 factor in choosing an FPC source is delivery and the reliability of same. Piece part cost may seem important at the negotiating table but your production line will shut down if you don't get the FPC you need for your assembly. FPC is usually the starting point in product manufacture, so regardless of its cost position on the BOM, and it is usually a trivial cost item, if the FPC isn't at your factory you will produce nothing. At this point the FPC will assume major importance: Remember the old adage, "For want of a nail the shoe was lost...." Tiny problems can stop big enterprises!

The only way to choose between vendors is by history (i.e., past performance). The negotiating chatter may be about NREs, tooling and lot charges, but in the back of the (knowledgeable) buyer's mind the big issue is: if he says four weeks, will I see parts by the end of June? And if he doesn't deliver, what do I do? You can stare

cold-eyed at the IGF salesman, trying to read his intentions, but your best guide is how IGF performed in the past. Do they recover quickly from disaster? Do they have the necessary materials on hand, ready to re-release to the factory? And so forth.

### **Repeat Orders and High Volume Production**

You might expect that custom manufacture is used only for prototypes, but since there are almost no catalog FPCs, it is the rule in the FPC universe. A second order should run much more smoothly than the first order; if it doesn't, start looking for another vendor because good vendors learn from mistakes and all others should be avoided. Much of the high cost of first-run FPC comes from the engineering supervision that is needed to assure a decent yield on a new design; this extra oversight goes away when an acceptable yield is achieved and unique problems have been seen and neutralized. This brings us to the high-volume situation.

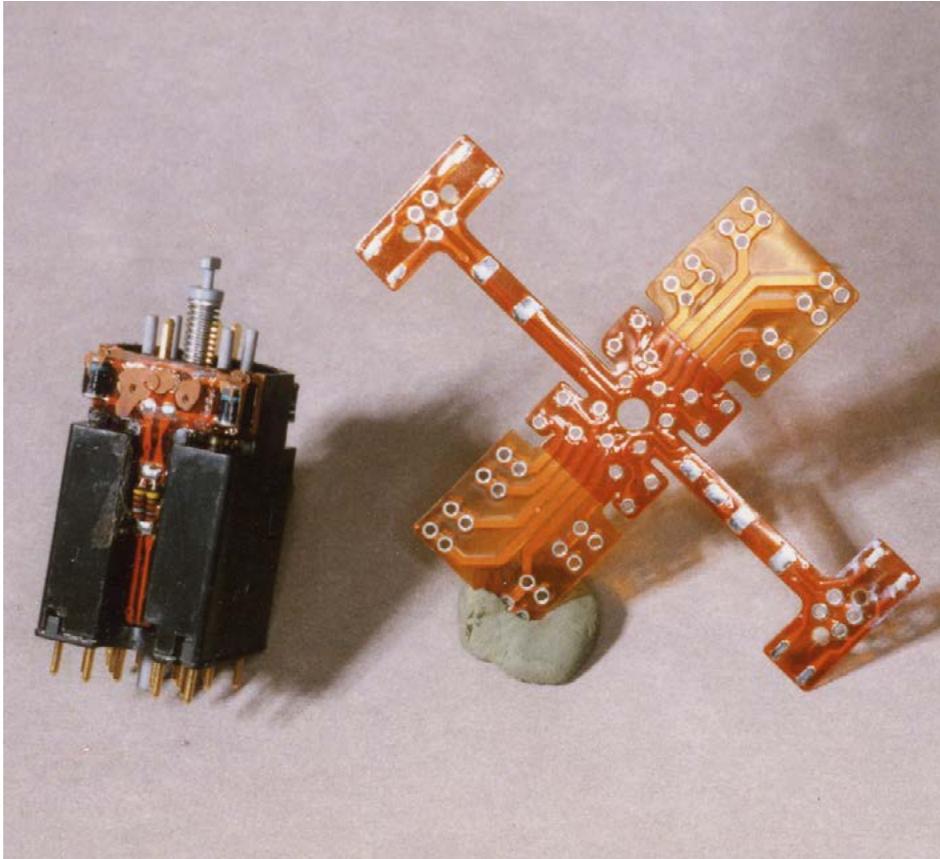


Figure 6: Relay circuit: FPC enables dense packaging. Relay on the left shows the FPC as folded/potted. The circuit is shown as manufactured on the right.

The raw materials of FPC production are manufactured, not natural. This brings in another layer of potential variation and out-of-spec products, along with latent defects like varying shrinkage in polymer films, out-of-date adhesives and other reactive chemicals, and so forth. Your vendor not only has his hands full controlling his own factory, but is exposed to variations anywhere upstream in his supply chain.

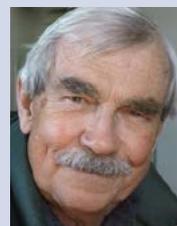
FPC has been historically over specified because it started out as a military component. Over specification, (i.e., specs that force the production to be “on the edge of state-of-the-art”) will rebound on you when yield drops. Your vendor is a partner and his problems are your problems. Set reasonable tolerances and inspection limits; it will help you.

Because FPC is so good at reducing production cost in dense electronic packages, it frequently appears in high-volume production. What happens there? Given a good, fully productionized design (i.e., one with rational tolerances and adequate room for uncontrollable variation in films and adhesives; well-set process conditions with functional limits; mature quality control procedures with their limits) FPC can be produced reliably at competitive cost.

### Summary

Keep in mind that vendor choice is more important in FPC applications than anywhere else. Building FPC involves chemical, thermal and mechanical processes, which means the FPC vendor has to be several times more skilled than other vendors with a grasp of much more technology.

Ever had a house built? Remember dealing with your contractor? FPC is also a custom-built product and this means you don't “buy” it, but contract for its manufacture sometime in the future. Price and delivery may be stated on the PO and embellished with boilerplate, but reality rules on the production line. Therefore, choose your vendor carefully. **PCB**

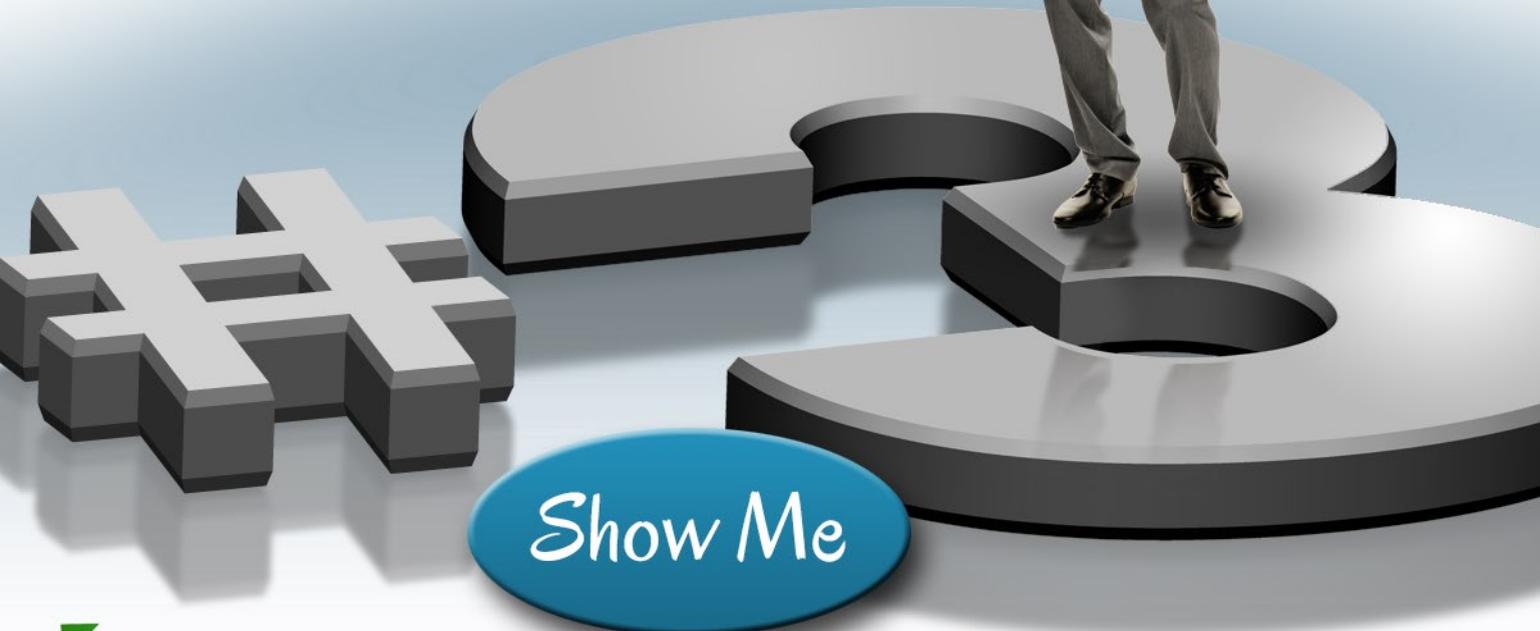


Thomas Stearns is a 57-year veteran of the FPC business and the holder of 23 patents. Stearns is the president of Brander Int'l Consultants, providing design, process and quality support in flex and rigid-flex circuitry. He may be reached at [thomasstearns@comcast.net](mailto:thomasstearns@comcast.net).

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# Achieving Fine Lines and Spaces: Part 2

by Michael Carano

OMG ELECTRONIC CHEMICALS

Achieving high yields with fine lines and spaces requires a good understanding of surface preparation methods. These include pumice and chemical cleaning. In essence, the surface profile of roughness plays a role in resist adhesion.

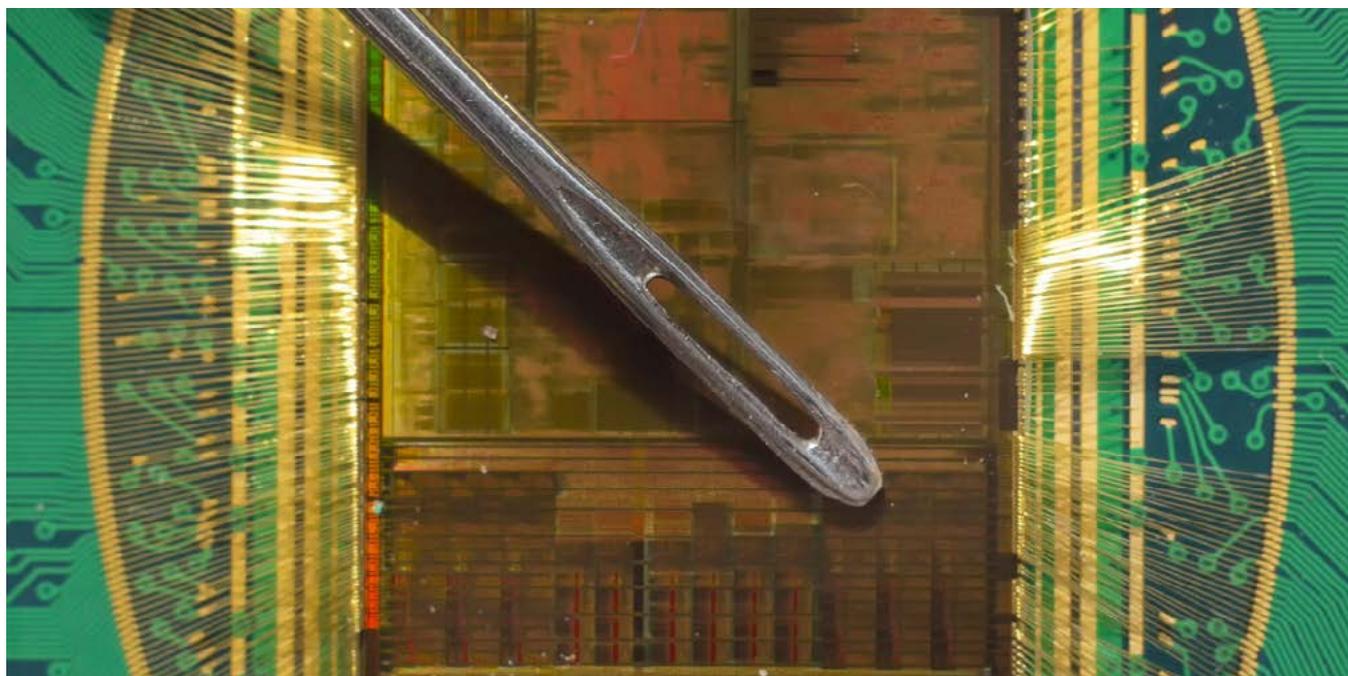
## Pumice vs. Chemical Cleaning

As someone who has frequently worked with PCB fabricators on a global basis, I must confess that surface preparation and imaging issues rank quite high on the list of yield loss. In previous columns, I have stressed the basic fundamentals. That is, understand what you are up against (which soils are on the surface, what are the interactions of the process parameters, etc.) in order to optimize yields. As stated previously, in order to minimize distortion and material stretching, mechanical methods of surface preparation are giving way to chemical clean-

ing. Copper foils and are also trending toward lower thicknesses in order to improve fine-line etching. Secondly, the need to improve impedance control with today's high speed electrical requirements is driving the implementation of low profile copper foil. These lower-profile foils are generally of a finer grain size, further impacting the ability to affect a surface topography sufficient to enhance photoresist adhesion. So let's first review the importance of surface topography and photoresist adhesion.

## Critical Surface Profile Parameters

I stated earlier that poor resist adhesion leading to defects such as opens or shorts, peeling and interfacial voids, are related to numerous issues including, surface preparation, characteristics of the copper foil, lamination parameters, and the formulation of the photoresist itself<sup>[1,2]</sup>. There are other causes of poor adhesion that



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are directly attributable to other factors such as developing and exposure. These causes will be explored in a future column. With respect to surface topography, I already stated that the randomness of the copper topography after surface prep is more beneficial than a unidirectional one seen with mechanical scrubbing. Pumice, aluminum oxide and chemical clean impart the random or multidirectional topography that we are concerned with. While that is a good thing, let's take a close look at critical profile or topographical parameters.

In general, there are several key "profile" definitions to understand<sup>[3]</sup>:

- 1) Ra: arithmetic mean of departures of the profile from the mean line.
- 2) Rz: this is the ISO 10-point height parameter, basically the average height differences between the five highest peaks and five lowest valleys within the profile sampling length.
- 3) Rmax: maximum peak to valley height for an adjacent peak to valley pair measured within the sampling length of the profile.
- 4) Peak count: number of peaks and valleys per unit length. This is a good indication of overall surface areas.

While I do not subscribe hard and fast values for the above-defined parameters, the surface profile values provide a guide for adhesion as well as evaluation of different copper foil types and surface preparation methods.

As a guideline, I suggest the recommended profile values as listed in Table 1<sup>[4]</sup>.

Copper prepared surfaces that show  $R_a$  values in the range of 0.10–0.3 microns (Table 1) and  $R_z$  values of 1.5–3.0 microns are preferred to enhance photoresist lamination<sup>[5]</sup>. During dry film lamination, the action of the hot roll laminator coupled with the flow characteristics of the dry film aids in the bonding of the film to the micro-roughened surface. Copper surfaces that do not have a sufficiently rough profile fail to offer the surface area necessary to insure proper bonding of the dry film.

**Pumice vs. Aluminum Oxide**

Aluminum oxide ( $Al_2O_3$ ) jet scrubbing was first introduced by Ishii Hyoki (Japan). There are ample suppliers of the equipment and materials required for this type of surface preparation. However, it is important to differentiate between aluminum oxide and pumice. First, aluminum oxide does wear over the period of use. When the aluminum oxide "wears" the particles are less effective in roughening the

Profile Attribute	Profile Value	Note
Ra	0.1-0.3 microns	Arithmetic mean of the departures of the profile from the mean line.
Rz	0.8-2.0 microns	Average height difference between the five highest peaks and the five lowest valleys within the sample.
Peak counts/mm	22-30	Number of peaks and valleys per unit length.
Asperities/cm	900-1600	
Rmax	Varies—excessive peak to valley heights unacceptable	Maximum peak-to-valley height for an adjacent peak to valley pair measured within the sampling length of the profile.

Table 1.

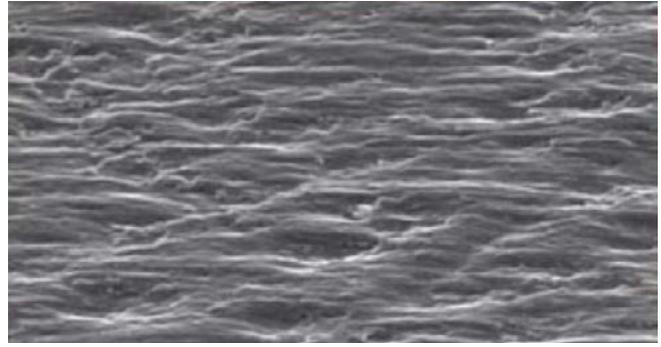
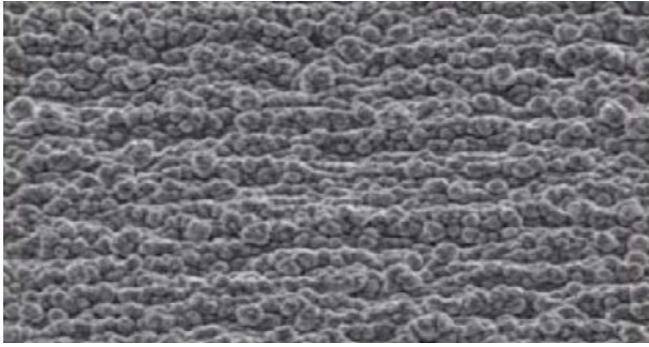


Figure 1: RTF or shiny or drum side of the foil that has been treated (l) and the standard shiny side (or drum side) untreated (r).

copper surface. So the fabricator must be diligent about replacing the spent aluminum oxide with fresh material.

Some fabricators resort to compressed pad brush pumice. While this method provides a multidirectional surface, there are issues with material distortion<sup>4</sup>. There are several good references on pumice and brush scrubbing available for further reading<sup>5,7</sup>. Regardless, be aware of embedded pumice residues. And be diligent with respect to applying sufficient rinsing to remove these residues prior to photoresist lamination.

**Alternative Copper Foils-Reverse Treat**

While not a recent development, RTF (reverse treat foils) is another means to improve photoresist adhesion. RTF is manufactured by the foil producers. Basically, the electro-deposition process is used to form the basic copper foil. The plating of the foil is carried out on a rotating drum in a copper plating solution. There are, of course, two sides of the foil. The drum side is smooth. The non-drum side is rough and thus what is typically used to bond to the resin. In the case of reverse treated copper foil, the foil receives a zinc treatment only on the smooth side (drum side), which is laminated to the dielectric. The rough, non-treated side serves as the bonding surface for the dry film. Because of its surface roughness, no mechanical or chemical roughening step is needed for dry film adhesion. This type of foil is also known as DSTF (drum-side treated foil). Figure 1

shows a comparison of the RTF or drum-side treated foil versus the standard copper foil (drum side but without treatment). **PCB**

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author, [click here](#).

Michael Carano is with OMG Electronic Chemicals, a developer and provider of processes and materials for the electronics industry supply chain. To read past columns, or to contact the

# Mil/Aero007 News Highlights



## Issues Continue to Plague

### RoHS Revision

Last week, IPC attended the EU Commission's final stakeholder meeting on the revision of the hazardous substance list under the EU RoHS Directive. As a result of the lack of consensus, the Commission will set up a working group to refine the methodology proposed to identify and assess the substances for potential restriction in electrical and electronic equipment.

### Calumet Earns Zero Non-conformance Nadcap Certification

The certification recognizes the company's world-class capabilities and focus on meeting the highest levels of quality assurance for products developed for the aerospace industry. Of the 290 PCB manufacturers in North America, Calumet Electronics is one of only 16 companies to meet the stringent requirements for Nadcap accreditation.

### Murrietta Earns MIL-PRF-50884 for Flex & Rigid-flex PCBs

Albert Murrietta, COO and co-owner, announces that his company has achieved full qualification for military flex and rigid-flex boards by achieving certification to the MIL-PRF-50884 standard. The company is now one of a few in the nation offering a full turnkey solution, from design through final assembly, for military-certified PCBs of all types.

### Viasystems' Shanghai Facility Earns AS9100 Certification

"The AS9100 certification is evidence of our commitment to ensure that our quality and manufacturing systems are equipped to provide the high-quality products demanded by our customers," said David M. Sindelar, CEO.

### Stress is the Culprit in Tin Whisker Growth

"We're convinced it's got to be stress from the intermetallics that causes them to form," said Eric Chason, professor of engineering at Brown University. "When you put tin on copper, there's a reaction when copper is shoved into the tin, which causes whiskers to pop out."

### Robotics Industry Set for Strong Growth

"The robotics industry is looking into a bright future," stated Dr. Shinsuke Sakakibara, IFR president, on the occasion of the publication of the study World Robotics 2013: Industrial Robots. "In 2013, global robot sales will increase by about 2% to 162,000 units.

### Global Man-Portable Military Electronics Market 2013 - 2023

This report is the result of SDI's extensive market and company research covering the global man-portable military electronics industry. It provides detailed analysis of both historic and forecast global industry values, factors influencing demand, the challenges faced by industry participants, analysis of the leading companies in the industry, and key news.

### 3D Printing: The New Frontier?

3D printing is ready to revolutionize space travel. ESA is paving the way for 3D-printed metals to build high-quality, intricate shapes with massive cost savings.

### Next-generation Robotics Program Secures \$38M in Funds

The National Science Foundation, in partnership with the National Institutes of Health, U.S. Department of Agriculture, and NASA, has announced new investments totaling approximately \$38 million for the development and use of robots that cooperatively work with people to enhance individual human capabilities, performance, and safety.

### Global Markets for Satellite Technology

Satellites are self-driven objects or vehicles placed in predefined orbits around the earth for communication and monitoring purposes. This report identifies and forecasts the potential for telecommunication components, modules, and devices in satellite technologies.

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# Phototools, Part B

by **Karl Dietz**

KARL DIETZ CONSULTING LLC

Phototools are either silver or diazo. The objective of this column is to familiarize you with diazo phototools. Less common, and more expensive, are chrome-on-glass phototools. Diazo phototools are transparent even in the darker, unexposed areas and they come with a characteristic amber color.

Photospeed is one characteristic feature of phototools. Laser plotter films have a relatively high photospeed. By contrast, diazo films, which are exposed by contact printing using a silver film to define the pattern, are much slower.

Diazo films are usually positive working. A negative working film reproduces a black line on a clear background as a clear line on a black background. A positive working or duplicating film reproduces a black line as a black line.

Diazo films have some properties that make them uniquely suited for use as phototools that must be visually registered to boards. The diazo phototool is visually transparent, with the image a light yellow color, to allow easy regis-

tration to a pre-drilled board. Yet, that image is opaque to the ultraviolet radiation to which the photoresist is sensitive. Also, the surface of a diazo phototool is significantly tougher than the gelatin used in silver halide films, making it more resistant to the handling a phototool receives during a production run.

Figure 1 shows the structure of a typical diazo film used for phototooling. It is somewhat simpler in appearance than the silver halide structure, but the chemistry is no less complex. It is in the sensitized layer that the image is formed. This layer contains four major constituents dispersed in an acrylic binder:

- Light-sensitive diazonium salts
- Dye couplers that react with the diazo salts during development to form the image
- A preservative to prevent the diazo salts and couplers from reacting before development
- A small amount of matte in the matted versions





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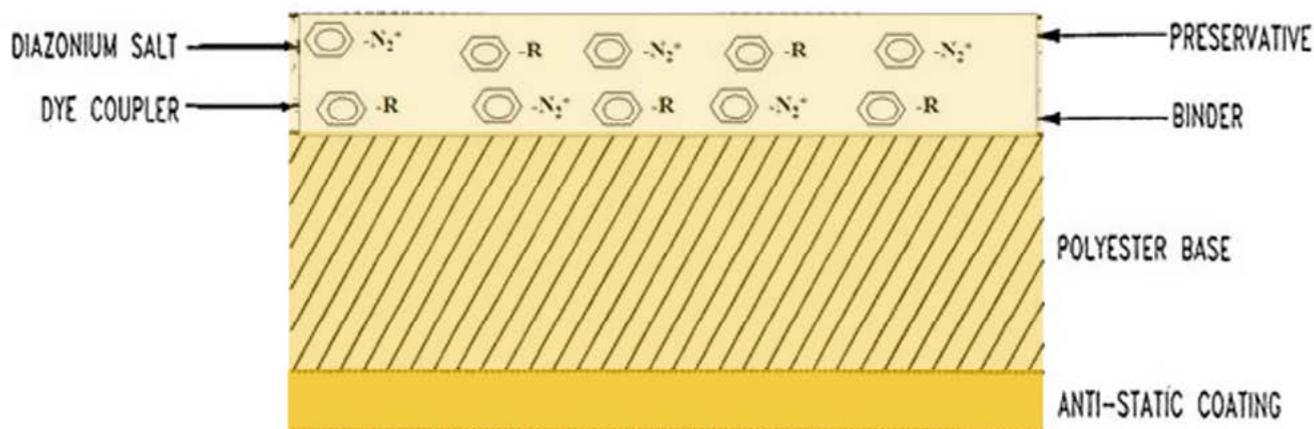


Figure 1: Structure of a typical diazo film.

The sub-coats used in diazo consist of materials different from those used in silver halide films, but the purpose is the same: to provide adhesion between the base and the coated layers. As with silver halide films, the base material most commonly used is polyester due to its strength, clarity, flexibility, durability, and dimensional stability. The anti-static backing helps to minimize dust and dirt pick-up due to static electricity. Again, this drawing is not to scale. When using a 7 mil (175  $\mu\text{m}$ ) thick base, the total thickness is about 7.2 mils (180  $\mu\text{m}$ ).

The light-sensitive component of a diazo film is the diazonium salt (Figure 2). It is an organic molecule that contains two nitrogen atoms in the cation portion of the salt. As we discuss how the diazo system works, keep in mind that this is a positive working system; where the film is exposed there will be no dye image. This

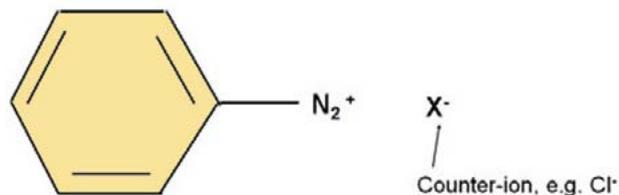


Figure 2: Diazonium salt.

is unlike the negative working silver halide system in which a black image is formed where the film is struck by light.

When exposed to nearly ultraviolet radiation, the diazo molecule is broken into inactive, colorless compounds (phenol, nitrogen, and an acid (Figure 3). The amount of exposure is as important here as it is in the silver halide sys-

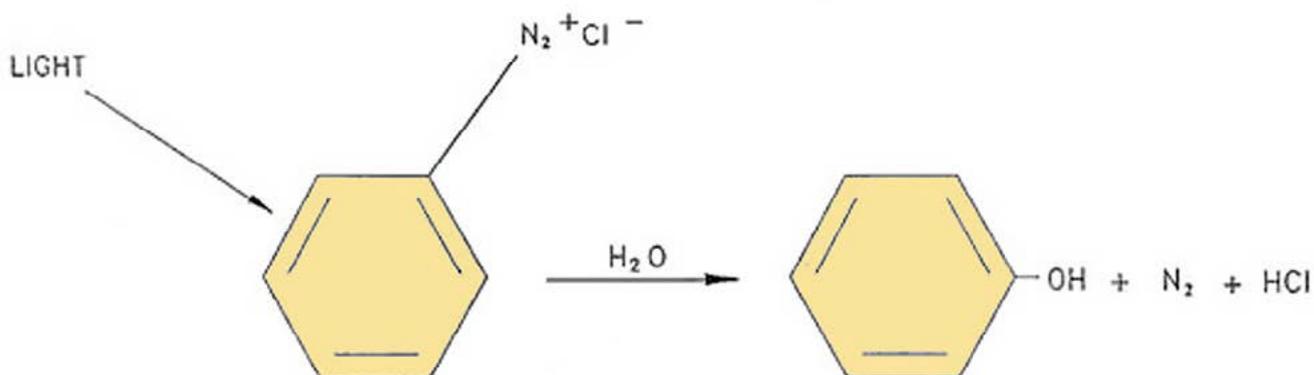


Figure 3: Diazo exposure.

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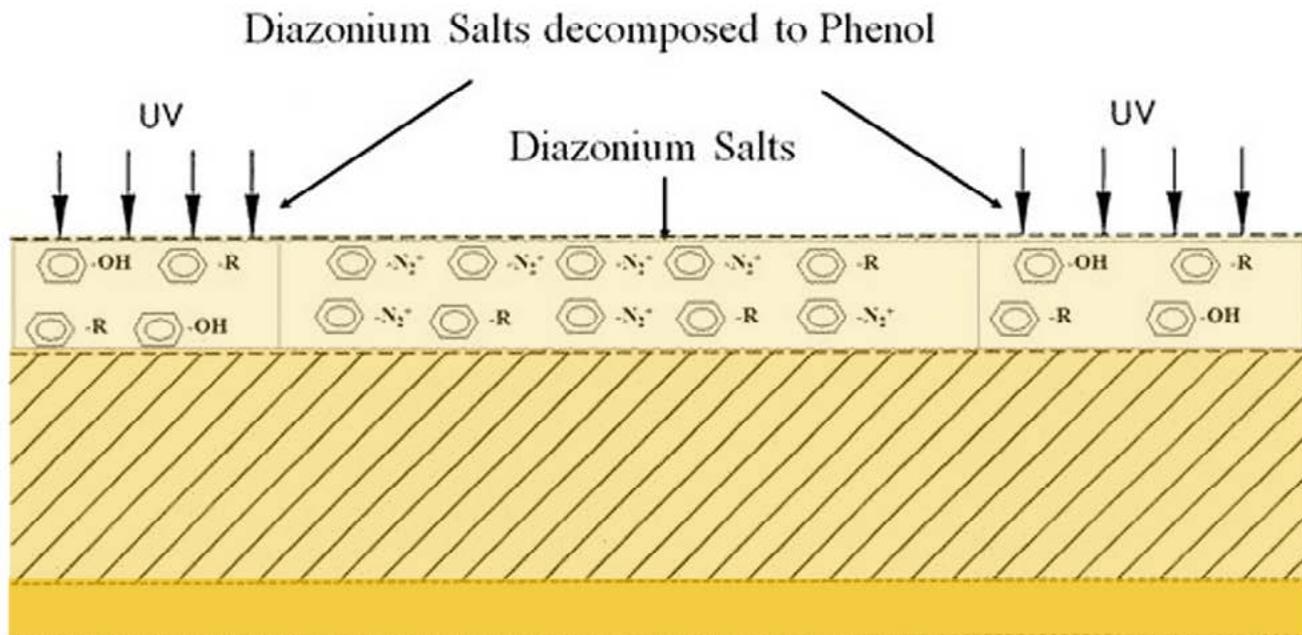


Figure 4: Diazo cross-section after exposure.

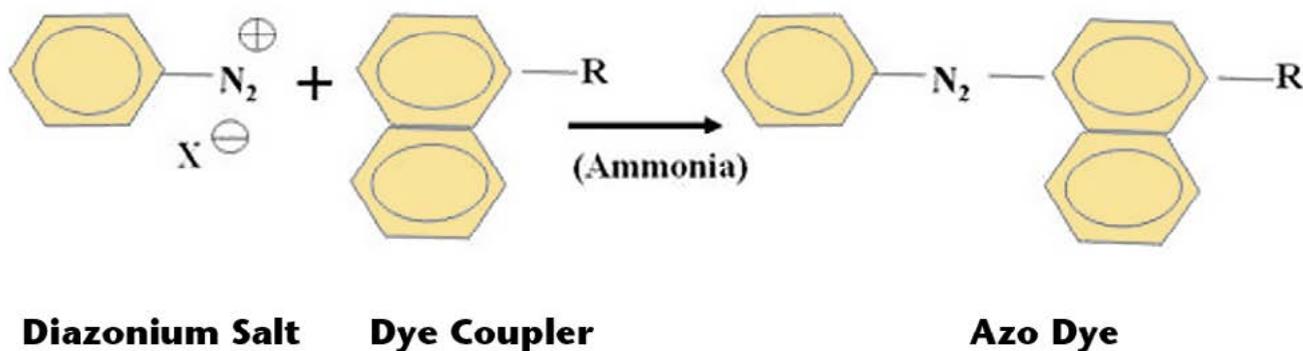


Figure 5: Dye formation during development.

tem, but the effects of incorrect exposure are somewhat different. If your original is negative appearing, too much exposure yields lines (clear areas) that are too fat and may reduce the background density. Too little exposure will produce lines (clear areas) that are not entirely clear. To help establish the correct exposure, place a 21-step exposure guide over a clear area of your original and make a diazo reproduction. When the exposure is correct for most applications, the step tablet will be reproduced with a clear

Step 2 and a “ghost” density on Step 3. Fine-line applications may require slightly less exposure than this. For very critical applications, use a microscope to ensure that the line width on the diazo reproduction is the same as that on the silver original.

Using a cross-sectional diagram (Figure 4), one can see that where the film was exposed the diazo salts have been destroyed. The film must now be developed in a relatively simple one-step process.

During development, the film is heated and exposed to ammonium hydroxide vapors (Figure 5). The ammonia destroys the preservative in the sensitized layer, allowing the remaining diazo salts to react with the dye couplers. At least two dyes are formed. One absorbs blue light and forms the transparent yellow image that we can see. The other dye is invisible to us but absorbs the ultraviolet radiation used to expose resist. Development should be done in a commercial processor designed for diazo development producing phototools. The temperature controls should be set so that a temperature strip placed on the sensitized side of the film reads 140°–160°F (60°–70°C). Temperatures higher than these should be avoided to prevent distortion of the polyester base. All diazo phototools should be passed through the processor at least twice. Some older processors require three passes or more to achieve complete development.

After development, there is a stable dye image in unexposed areas and clear film in the

exposed areas. No other processing steps are required. Diazo films are not easy to overdevelop. However, too little development will yield phototools that appear to have sufficient density but lose density with time or after exposure to high intensity ultraviolet. **PCB**

### Acknowledgment

Information provided by my friend and former colleague Robert Seyfert is gratefully acknowledged.



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

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

## VIDEO INTERVIEW

# Gardien Delivers Integrated Bare Board Test Solutions

by Real Time with...productronica 2013



Heiko Henrich, MD of Gardien Europe, explains how bare board testing throughput can be increased by a factor of 7 when the Acceler8 scanner is integrated with the G60 flying probe system. He also describes how the inScan final inspection system delivers a more consistent performance than can be achieved by a human inspector.



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# ENIG and the Plating Process

by **George Milad**

UYEMURA

Electroless nickel immersion gold (ENIG) continues to gain market share due to its versatility in a wide range of component assembly methods including solder fusing, wave soldering and wire bonding. The ENIG finish provides a highly solderable flat surface that does not tarnish or discolor. It has a long shelf life and the precious metal topcoat provides excellent electrical continuity. The nickel serves as a barrier against copper diffusion and prevents copper contamination of the solder during wave soldering and rework operations.

## The ENIG Plating Process

The plating of ENIG is a complex multi-step process. Each process step is carefully designed and must be well understood and controlled to produce the desired end product.

These can be broken down into the following:

1. Preparing the catalyzed surface for Ni deposition
2. The Ni deposition step
3. The gold deposition step

### 1. Preparing the Catalyzed Surface for Ni Deposition

The objective is to form a thin immersion uniformly distributed palladium catalyst layer on the copper surfaces to be plated with nickel. Nickel deposition is specific to the catalyzed surface. Nickel will not initiate or deposit on non-catalyzed surfaces like soldermask or laminate. The uniformity is important so that the nickel will initiate at the same time on all areas of the copper surfaces to be plated. This will give rise to an even nickel deposit with no crevices or protrusions in the final plating. An even nickel deposit is not susceptible to corrosion during the gold deposition step.

Achieving a uniformly catalyzed surface be-



gins with bringing a pristine copper surface to the catalyst bath. A pristine copper surface is one that is free of oxidation, organic contaminants, neutral (charge-free) and fairly smooth (low profile).

The copper surface coming to the ENIG line in most cases follows the application of soldermask. This involves cleaning and roughening the copper surface, the application of a photo-imagable mask, tack drying, imaging, developing and curing. Attention to the details of processing soldermask is paramount to achieving the desired ENIG deposit. The proper adhesion between the mask and the copper surface must be secured. After development there should be no organic residues left on the pad surfaces, and the side wall should be straight with no signs of negative or positive foot. This is particularly important if the design includes soldermask defined pads. This surface is then subjected to the ENIG pre-treatment process steps. Pre-treatment involves a series of steps, namely cleaner, micro-etch and acid pre-dip.



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### IMPACT 2014: IPC on Capitol Hill

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### IPC Europe High Reliability Forum

Düsseldorf, Germany

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### IPC TechSummit

Raleigh, NC

October 28–30

### International Printed Circuit and APEX South China Fair (HKPCA and IPC Show)

Shenzhen, China

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The cleaner serves a series of functions, the detergent component removes soils and organic residues (fingerprints), the acidic component removes oxidation and the surfactant present wets the surface. A properly wetted surface will help dislodge any entrapped air in the narrower vias. Vibrating the parts in the cleaner bath is recommended for high-aspect-ratio holes and small vias. Vendor recommendations of make-up, bath life, operating temperature and dwell time, should be followed. Good rinsing should follow the cleaner.

The micro-etch removes a layer of surface copper and modifies the surface topography. The proper choice of micro-etch can effectively reduce the profile of the copper surface that was previously roughened to ensure proper solder-mask adhesion. Peroxide/sulfuric based micro-etch is the preferred choice here. Usually 30–50 μins of copper is removed. This should be monitored and maintained. Vendor recommendations of make-up, bath life, operating temperature and dwell time, should be followed. Good rinsing should follow the micro-etch.

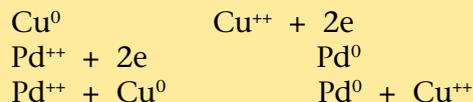
The micro-etch is a strong oxidant and must be completely rinsed off. Failure to rinse off all micro-etch residues particularly from small holes will interfere with the immersion (charge transfer) based palladium catalyst deposition. A heated sulfuric post dip is recommended here. This step helps in removing any traces of oxidant trapped in small holes. This again is followed by rinsing.

This is followed by a catalyst pre-dip (a room temperature sulfuric acid bath). The purpose here is to eliminate the drag in of rinse water that would dilute the acid content of the palladium catalyst, remove any traces of oxidation from the previous rinse step and to acidify the surface before introduction into the catalyst bath.

If all the above is adhered to, the copper surface now has a low profile, is organic residue free, oxidation free and more importantly, charge neutral.

The catalyst bath lays down the foundation on which the nickel and eventually the gold will deposit. The bath is in most cases composed of palladium sulfate in a sulfuric acid low pH medium. Here the Pd ion in solution will be reduced to Pd metal at the expense of copper

metal (the substrate) that is oxidized to the Cu ion. This is an immersion reaction and is based on electron transfer, where a metal ion higher up in the electromotive series will displace a substrate metal lower in the series.



Any residual charge on the Cu substrate will interfere with the electron transfer and could prevent the Pd from immersing on the copper. Residual charge occurs from localized side reactions involving a galvanic setup. An example is dissimilar solutions in close proximity like entrapped oxidant in a small via adjacent/connected to the pad to be plated. Under those conditions the partial charge on the adjacent pad will not allow the immersion/deposition of the Pd ion and will eventually give rise to skip plating in the Ni deposition step. Nickel will not plate on a non-catalyzed copper surface. Proper rinsing is important after the catalyst bath to ensure no drag in of Pd into the electroless nickel bath.

### The Electroless Nickel Bath

This is a well understood multi-component bath. The primary constituents are nickel sulfate as the source of nickel and sodium hypophosphite (hypo) as the reducing agent. The latter supplies the electrons needed to reduce the nickel ion to the nickel metal. The hypo reaction also produces phosphorous and the by-product orthophosphate. The phosphorous is incorporated in the electroless nickel deposit. The buildup of the orthophosphate byproduct in bath determines the life of the bath. The nickel deposition reaction requires a specified temperature (between 175 and 185°F) and a weak acidic pH.

In addition, a series of other important proprietary constituents have a direct effect on the quality of the nickel deposit:

- Stabilizers, which slow down the reduction by co-depositing with the nickel
- Surfactants, which reduce surface tension in order to reduce pitting and or staining

- Complexing agent, which are necessary to increase phosphite solubility and also to slow down the reaction speed, and are not co-deposited into the resulting alloy
- Accelerators, which are added to overcome the slow plating rate imparted by complexing agents
- Buffers (most complexing agents perform double duty as buffers)

Different vendors or suppliers may use different ingredients to achieve the goal of a uniform deposit with an optimized deposition rate and achievable/reproducible operating conditions. In addition, they package these ingredients together or separately to achieve the desired ease of management of the plating process.

The nickel bath requires good management as it is a dynamic, ever-changing bath. The nickel and the hypo are consumed during the deposition; in addition there is a buildup of the byproduct orthophosphate. The pH of the bath must be controlled within a narrow range. It is necessary to replenish those ingredients that are being used up. This is best achieved by a controller that will automatically replenish the desired components as well as maintain the pH. The controller monitors the nickel concentration using continuous spectrophotometric analysis and controls the replenishment of the nickel as well as all the other ingredients. The other ingredients like hypo, etc., are added in proportionate amounts based on the nickel concentration.

Most suppliers mix their proprietary ingredients with the nickel sulfate or with the sodium hypophosphite, so they are replenished accordingly. Certain suppliers package these components separately and are able to better control their introduction back into the bath. This becomes particularly important when starting the bath after a prolonged shutdown; these ingredients may be added without the need of controller replenishment. Controller replenishment can only be triggered by consuming the nickel and hence the requirement for dummy plating in the case of pre-mixed proprietary components.

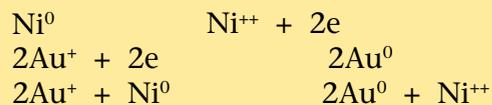
The nickel deposition is initiated on the palladium catalyzed copper surface. The amount of

catalyst introduced into the bath has a direct impact on initiation and uniformity of the plated deposit. The bath loading range specified by the supplier must be adhered to for consistency of product.

The orthophosphate buildup will determine the life of the bath. The bath life is measure in terms of metal turnovers (MTO). One MTO occurs when the equivalent of the weight of nickel in the original makeup is plated. For example, if a 200-liter bath is made up at 5 g/L nickel, the total weight of nickel in the bath is 1000 g. The plating of 1000 g in this case will constitute 1 MTO. This can be easily kept track of based on the volume of nickel concentrate added back to the bath. As the bath ages the orthophosphate buildup will impact the rate of deposition; adjustment to the nickel concentration and to pH based on MTOs will maintain the rate of deposition. Supplier recommendations for bath life based on MTOs must be adhered to. Exceeding the recommended dump schedule will compromise the nickel deposit and render it susceptible to corrosion.

### The Immersion Gold Bath

The gold ions in solution in this bath will pick up electrons and be reduced to the gold metal. The electrons are supplied by the oxidation of the nickel substrate. The nickel metal is oxidized to the nickel ion releasing the electrons for the gold reduction:



The main ingredient in the gold bath is the gold salt, potassium gold cyanide. Other critical components are complexing agents and buffers. The bath runs at a high temperature (180–190°F). Most commercially available immersion gold baths run a pH in the range of 4.5–5.5. Newer gold baths are designed to run at a neutral pH (6.8–7.2); these baths are less corrosive to the nickel substrate. The bath clearly builds nickel over time and that eventually becomes the bath life determining factor. The bath is very sensitive to metal contaminants like low ppm copper. Copper content must be

monitored periodically and action taken based on supplier recommendations.

Different commercially available gold baths run a gold content of 2.0 g/L. Newer baths are now designed to run at a gold content of 1.0 g/L, and some run as low as 0.4 g/L. It is critical to run the gold bath within the specified range for gold concentration. Running the bath below the lower limit renders the bath more corrosive and nickel may be released into the bath without the full complement of gold being plated out. This would compromise the ENIG deposit and could have an adverse effect on solderability. Running the bath beyond its designed bath life will adversely affect the performance of the bath as well as the final deposit.

Supplier recommendations of analysis and replenishment, operating conditions and bath life must be adhered to for consistent results.

The ENIG line is one of the most complex chemical lines in a board shop. It requires a good understanding of how the process works

and what are the critical parameters that must be maintained. The ENIG line has little tolerance for deviations, particularly regarding extending the bath life of any of the process steps. Shops that have good engineering and documentation of the manufacturing process coupled with a dedicated experienced ENIG operator and backed by a capable analytical laboratory run defect-free ENIG day in and day out, producing a consistent product that meets customer requirements. **PCB**



George Milad is the national accounts manager for technology at Uyemura International Corporation. Milad is the recipient of the IPC 2009 President's award, current chair of the IPC Plating Committee and a permanent member of the Technical Activities Executive Committee of the IPC. Contact Milad at [gmilad@uyemura.com](mailto:gmilad@uyemura.com).

## VIDEO INTERVIEW

# The German Market for PCBs: Automotive and Industrial

*by Real Time with...productronica 2013*



Ventec's Thomas Michels gives an overview of the market for PCBs in Germany, dominated by automotive and industrial sectors. Michels describes how Ventec has recognized the substrate requirements for LED vehicle lighting, with a range of high-thermal-conductivity IMS materials.



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# TOP TEN

PCB007  
News

## PCB007 News Highlights This Month

### ① **Schweizer Electronic Reappoints Board Members**

The Supervisory Board of Schweizer Electronic AG has reappointed Board Members Dr. Marc Schweizer and Nicolas Schweizer until 2018. Their contracts were previously ending in July 2015 and March 2016, respectively.

### ② **Endicott Interconnect Now i3 Electronics**

The company has completed a successful transition to i3 Electronics, Inc. from Endicott Interconnect Technologies. The sale to i3 Electronics closed October 31, 2013. The company appreciates the patience and the support that employees, customers, and suppliers have provided during a challenging 2013.

### ③ **IPC: PCB Book-to-Bill Ratio Falls Due to Sluggish Growth**

"A combination of slower order growth and shipments that exceeded bookings in August and September brought the book-to-bill ratio below parity to 0.98," said IPC's Director of Market Research Sharon Starr. "Although year-on-year shipment growth in the North American PCB industry is still negative, it has been moving in the right direction."

### ④ **Multilayer Technology Named Jacobs' 2013 Subcontractor of the Year**

Multilayer Technology has been selected as the 2013 Subcontractor of the year by Jacobs Technology. This award from is the result of a partnership between Jacobs Engineering, NASA-JSC, and Multilayer Technology.

## 5 Despite Regulations, Lead Usage Continues to Grow

Companies in the electronics industry have spent billions in recent years to remove lead from solder, ensuring that the few ounces of this toxic metal on a printed board don't leach into water supplies. Though regulators are attempting to curtail lead usage, it's growing by approximately 5% per year.

## 6 Viasystems Upgrades, Opens New Facility in Anaheim, CA

Viasystems Group, Inc., a leading provider of complex multilayer PCBs and electromechanical solutions, has announced the opening of its new North American PCB Technology and Manufacturing Center in Anaheim, California.

## 7 IPC: Printed Electronics Gains Momentum

The PE industry continues to expand rapidly. Nearly every week, companies are announcing positive steps that demonstrate solid growth. For example, Optomec, a global supplier of additive manufacturing systems for 3D printed metals and PE, reported a 100% increase in bookings compared to the first half of last year.

## 8 TTM Announces Retirement of Kenton Alder; Posts Q3 Loss

The company has announced that Kenton K. Alder, TTM's CEO, will retire effective January 1, 2014 and that its Board of Directors will appoint Thomas T. Edman, currently the company's president, as its next chief executive officer.

## 9 Dragon Circuits: Old Company; New Name & Ideas

Raj and Gunny Babaria acquired North Texas Circuit Boards and began rebuilding the failing company. After shedding a few long-time employees and investing in new equipment, the two say they are ready to make Dragon Circuits into a twenty-first century technology company.

## 10 Kyocera Raises Forecasts Amid PCB Firm Acquisition

Kyocera Corporation has reported net sales of 699.66 billion yen (\$7.14 billion) for the first half of fiscal year 2014, up by 15% from the same period last year. Profit from operations reached 58.2 billion yen (\$594 million), up by 124.8% from the first half of fiscal year 2013.

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# EVENTS

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For the iNEMI Calendar of Events, [click here](#).

For a complete listing, check out *The PCB Magazine's* full [events calendar](#).

## **HKPCA & IPC Show**

December 4–6, 2013  
Shenzhen, China

## **International Printed Circuit & Electronics Assembly Fair**

December 4–6, 2013  
Shenzhen, China

## **Semicon Japan**

December 4–6, 2013  
Chiba, Japan

## **Austin (CTEA) Expo and Tech Forum**

December 5, 2013  
Austin, Texas, USA

## **BELEX**

December 5–8, 2013  
Bursa, Turkey

## **International Electronic Components Trade Show**

January 15–17, 2014  
Tokyo, Japan

## **Electronix R&D Japan**

January 15–17, 2014  
Tokyo, Japan

## **Electrotest Japan**

January 15–17, 2014  
Tokyo, Japan

## **Material Japan**

January 15–17, 2014  
Tokyo, Japan

## **NEPCON Japan**

January 15–17, 2014  
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## **Automotive Electronics Expo**

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**PCB007 Presents**



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## Next Month in *The PCB Magazine:* Surface Finishes

What is the last thing the fabricator puts on the PCB and the first thing the assembler sees? The surface finish—the critical interface between the PCB and the assembly process.

What to choose and how to specify it? What are the performance requirements? What conditions will the finish experience during the assembly process, and what conditions will it have to endure during the expected life of the assembly?

See the January edition of *The PCB Magazine* for answers to these questions and more!