I-Connect007

MAY 2018

PCB007 MAGAZINE

Connecting at the *Speed of 5G*

PCB007 MAGAZINE

Connecting at the Speed of 5G

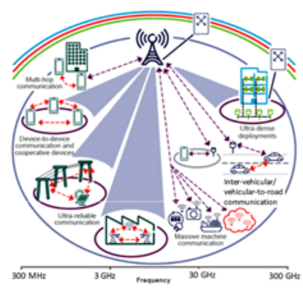
What truly defines 5G, as compared to 4G and 3G? As children say on road trips, are we there yet? Find out what is here, and what's on the horizon for the industry and the world when it comes to the dawn of the 5G era.

12 May the G Force Be With You
by Dan Feinberg

20 Experts Discussion: What Does 5G Mean to Materials and EDA Tools?
by the I-Connect007 Editorial Team

30 PCB Material Toolbox for Today's 3G and 4G Networks and Future High-Speed Needs in 5G
by Stig Källman with Happy Holden

38 Excerpts from Prismark's Presentation at CPCA 2018



PCB007 MAGAZINE

ARTICLE:

66 **CPCA 2018 Seminar Overview**
by Happy Holden

COLUMNS:

8 **5G—Generation after Generation**
by Patty Goldman

44 **The Velocity of Technology—What Does It Really Mean?**
by Jan Pedersen

52 **What's in your ET?**
by Todd Kolmodin

56 **Surface Preparation and Cleaning, Part 2**
by Michael Carano

60 **The Value of Coopetition**
by Steve Williams

82 **IMPACT 2018: We Need Your Voice in Washington, D.C.!**
by John Mitchell

SHORTS:

27 **One-Dimensional Material Packs a Powerful Punch for Next Generation Electronics**

42 **CEO Priorities Are Shifting to Embrace Digital Business**

59 **Laser Frequency Combs May Be the Future of Wi-Fi**

84 **AI Helps Soldiers Learn Many Times Faster in Combat**

DEPARTMENTS:

90 **Career Opportunities**
96 **Events Calendar**
97 **Advertiser Index & Masthead**

HIGHLIGHTS:

28 **Supply Line**
50 **MilAero**
64 **Markets**
86 **Top 10 from PCB007**

5G—Generation after Generation

Patty's Perspective
by Patty Goldman, I-CONNECT007

If you're like me, you've probably heard of 5G, but you may not understand what all the fuss is about. First, 5G simply means fifth-generation mobile networks. The best way to understand what 5G is about is to understand all the other Gs, like 3G and 4G (we rarely hear about the early Gs!). The analogy I understand best for mobile communications is this:

1G = analog (voice only)
2G = digital (includes text and pictures)
3G = video calling and data
4G = internet and video streaming
5G = everything connected to everything (4G on mega steroids and 1000x faster)

I found some other interesting explanations, including a video by Skyworks[1] called, "5G in 5 Minutes" that is worth watching. Their analogy of increasing highways is interesting because 5G needs to exist in full measure for truly autonomous cars and trucks to become a reality (or at least a safe reality—think about a self-driving semi on the road behind or beside you). In fact, several communications companies are planning on launching 5G networks later this year. Are we ready? Can we make the PCBs they will need? What does this mean to us in the PCB manufacturing world?

This Month's Issue

Now, if you really want to understand 5G better, start with Technology Editor Dan Feinberg's article. He begins with the very early mobile phones and takes you through today and beyond. He also points out the challenges such as bandwidth and the incredible amount of infrastructure that will need to exist to take full advantage of this technology and, again

SOURCE: SKYWORKS SOLUTIONS, INC.

to reach that autonomous car (and everything else) stage.

For our experts' discussion, we went right to the front lines of our industry, so to speak, namely the materials and EDA tools guys. Rogers' John Hendricks and Altium's Ben Jordan joined us for a conversation on the effect 5G will have on designers and builders of PCBs. That's right, building boards is not going to get any easier. And, as we've said before, if you aren't doing HDI and RF now, you will be…or you simply may not be.

That's right, building boards is not going to get any easier.

In our next article, Ericsson's Stig Källman presents what he sees as the necessary tools for making the complex PCBs of the future. He lays out material needs, focusing on all parts of the laminate as well as design and most importantly, understanding and specifying the material properties needed as opposed to a specific material itself.

Happy Holden alerted me to a presentation that Prismark made at the recent CPCA show in Shanghai. Several slides dealt with 5G which is nicely summarized in the next short article. The images are complicated but intriguing and worth studying. We appreciate that Prismark graciously gave us permission to use them as they help to get across the concept of 5G, plus there is also a nice summary of what PCB manufacturers can expect or need to be ready to accomplish.

Many pieces need to come together for 5G and one of those is or will be more sophisticated testing. This month, Gardien's Todd Kolmodin discusses connecting all CAT and CAM with CAT and CAR. Read on to figure out those TLAs for your connected factory.

As PCBs become more complex and the reliability requirements become more stringent, the need for precise and applicable industry specifications increases. Jan Pedersen, Elmatica, carries on the theme of testing, in this case discussing surface contamination, moisture sensitivity, and the importance of clear communications between designer and manufacturer.

Switching gears slightly, veteran columnist Mike Carano, RBP Chemical Technology, continues a discussion on surface preparation and cleaning that he began a few months ago. And Steve Williams, The Right Approach Consulting, brings to light the concept of "coopetition." Not a misspelling but a word combo that should be very meaningful to our industry—and something I have seen happen many times over the years.

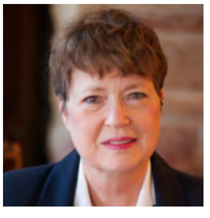
In March, Happy Holden participated in a seminar sponsored by the CPCA and I-Connect007. Seven presentations on the subject of automation were all geared towards PCB manufacturing. He has summarized it for us, along with some of the slides for illustration.

And last but not least, IPC's John Mitchell puts in a plug for the upcoming IMPACT Washington, D.C. 2018, happening May 21 – 23. I've said it before and I'll say it again, if you are a company executive you should be there to represent your company and the industry. Last year was the best year ever, with speakers and numerous meetings with senators, congressmen and top-level government officials from departments that are important to your business. I expect nothing less this year and believe me, there is never a better time than now to make your voice heard. Manufacturing is back in vogue and they are listening.

As we seem to speed through 2018, I can't help wondering what 6G is going to look like! Next month, back to some nitty gritty when we explore a manufacturing area: wet processing. See you then! (P.S.—do I have to tell you to subscribe to our magazines and newsletters again?) **PCB007**

References

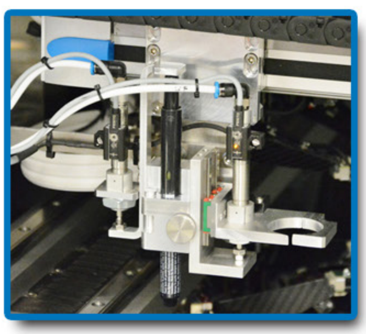
1. Skyworks' "5G in 5 Minutes" video.



Patricia Goldman is managing editor of *PCB007 Magazine*. To contact Goldman, click here.

Unrivaled Test Speed with Full Automation

Introducing the newly designed atg A8a with 8 test probes and a new high speed “lights out” automation for unrivaled throughput.



Highlights:

- Small footprint (6 square meters)
- Dual shuttle pick & place automation
- High accuracy combined with high test speed
- Pen or label marking option

Watch video

Get more info

atg Luther & Maelzer GmbH
Zum Schlag 3 • 97877 Wertheim • Germany
Phone +49-9342-291-0 • Fax +49-9342-395 10
sales@atg-lm.com • www.atg-lm.com

atg® LUTHER & MAELZER® an Xcerra company

Feature by Dan Feinberg
I-CONNECT007

We are about to begin the transition from the present cellular standard 4G LTE to the next generation, 5G. As in the past, most people will wonder, "What does 5G mean to me, and what is LTE anyway?" After all, if you can make your connection reliably and you can send and receive data at reasonable speeds, why should you really care? Many of you will not, and some will only care because the latest mobile device has become a status symbol; but all of us will gain a significant data communication speed increase when we get access to 5G networks and compatible devices, and our world will begin to change rapidly. If you are interested in the Internet of Things (IoT), you ain't seen nothing yet!

To get a better understanding of what 5G is going to mean, let's take a quick look back at the history of mobile communications.

In the '70s, if you wanted to communicate with someone who was not in your presence (and you were not near a land line), you had to use a mobile plain old telephone service (POTS) network. This service was first offered by AT&T in the late '40s and was called a mobile telephone service (MTS). These were push-to-talk systems; one person would hold in the microphone button and speak and then say "over" and then release the mic button, and the other person would have his turn. If you wanted to communicate from your car, you could try to get a mobile phone, but as each area had only very limited communications receiver/transmitters to communicate with mobile phone users, the number of devices it could service without the devices interfering with each other was extremely limited. This was basically mono communications (half-duplex) rather than cellular as we know it today. The waiting list to get mobile phone access was literally years long.

Of course, there was ham radio two-way communications as well as range-limited citizens band (CB radio); these also required taking turns to talk. I tried all of these. I tried to

put my name on the list for a mobile connection in the Washington, D.C. area where I lived at the time; the waiting list was so long there was a list to get on the list and the cost to use such a device was astronomical. I did have a ham radio license, but that was a hobby and you could only communicate with others who were ham radio operators. CB was similar, but much shorter range due to lower power and limited transmission frequencies.

I ended up doing what many who needed to have some level of mobile communications did at the time and that was get a pager or beeper (Figure 1). You had this small paging device and if your family or office needed you they would call a phone number and beep you and you would find a pay phone and call them to see what was up. Eventually, the paging device allowed you to receive a short text message but still only offered very limited communication options.

Figure 1: A pager from the '70s.

Things improved over the next few decades. Companies such as Motorola entered the arena and the full duplex voice (no pushing a mic button to speak) and cellular hand-off from tower to tower system was born.

The first true cellular networks or first generation (1G) became available in 1977 in Chicago. This revolutionary technology still used analog, but it seamlessly allowed the user to automatically switch from tower to tower as you traveled from area to area. In fact, one of my associates back then at DynaChem was one of the first to get his hands on a cellular phone. It was a black box the size of a cigar box mounted in the trunk of your car with a standard old-school telephone handset mounted on your dash. We were all envious (Figure 2).

Before major improvements could be made, the infant industry first had to have a frequency assigned—the cellular band, so to speak. It took

Figure 2: A mobile phone from the early '80s.

the FCC 11 years to approve the AT&T proposal and authorize commercial use of the requested 824 MHz band for cellular use. Once that happened, cellular networks began to bloom globally. The phones were large, not usually portable, analog and expensive to buy—typically a few thousand dollars. Costs were also quite expensive per minute of use.

By the end of the 1980s the rate of technological improvement had accelerated and in the early 1990s we had the arrival of two digital processes. There was the CDMA standard in the USA, and in Europe, the GSM standard. Improvements in battery and device design gave us the very first truly portable phones, although not portable by our 2018 standards. We now had the first digital cellular networks or second generation cellular 2G. Demand grew, and more and more cell tower sites were built. We now started to see the first truly portable devices (Figure 3).

Figure 3: One of the first portable cellphones.

In addition to the initial level of true portability, the tech improvements as well as going digital now allowed for the use of SMS texting over the GSM-based networks. Texting had arrived.

Just before the turn of the century, Japan's NTT started their first mobile internet service on the 2G network, but it was soon replaced with their launch of the world's first 3G network in October 2001. Many countries quickly followed suit, and over the next few years the USA and South Korea introduced their first 3G net-

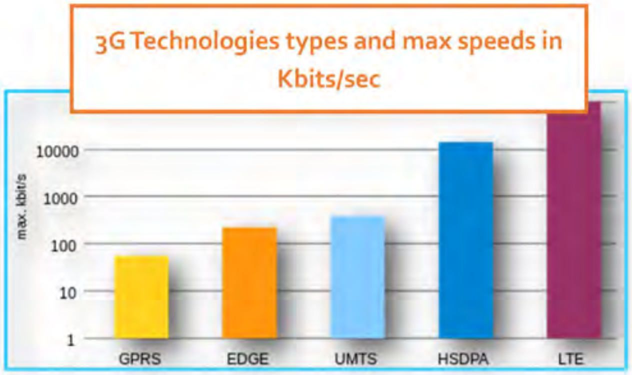


Figure 4: Different 3G technologies and their associated speeds.

works. Following shortly after that were the first European 3G networks in the UK and Italy, in 2003. While 3G was still being developed, several 2.5G services tried to bring older technologies up to speed; however, the lack of speed was the deciding factor, and while technologies like GPRS and EDGE provided improvements over standard 2G, they did not match the speed of newer 3G platforms (Figure 4).

3G really started to change the mobile phone landscape and the higher, more reliable speeds enabled transmission services such as radio, TV and data transfer for the first time. With 3G, browsing the Internet on a mobile device became possible without waiting an inordinately long period of time for a web page to load. And, of course, portable phones were getting smaller and lighter (Figure 5).

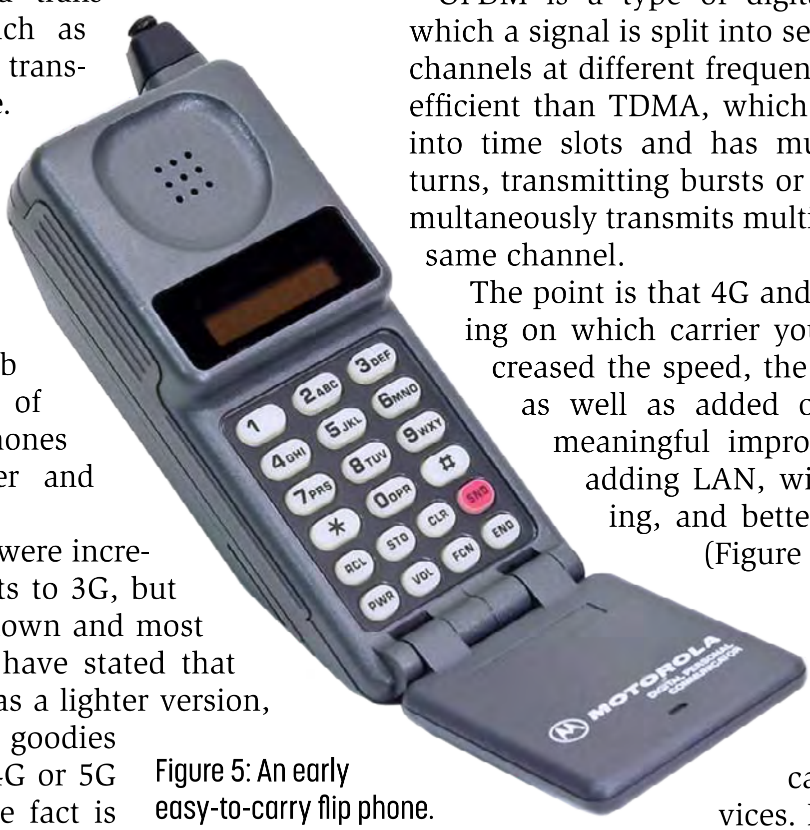


Figure 5: An early easy-to-carry flip phone.

As with 2G, there were incremental improvements to 3G, but LTE was the best known and most widely used. Some have stated that LTE meant that it was a lighter version, not including all the goodies of standard 3G (or 4G or 5G for that matter). The fact is that LTE stands for long term evolution and is used with GSM networks. It is generally much faster as long as the net being used is not overloaded. I once read a good description that said, "During rush hour in the city, back roads are sometimes faster than the freeway." So consider LTE as enabling you to take the uncluttered roads when necessary.

It seems that a new generation—a new "G"—has been introduced every 10 years or so. True to form, 4G networks came about in 2008 and phones were introduced that could take advantage of the new frequency bands and the higher data rates. According to the ITU, a 4G network requires a mobile device to be able to exchange data at 100 Mbit/sec. The older 3G networks, on the other hand, sometimes offer data speeds as slow as 3.84 Mbit/sec (Figure 6).

Per TechTarget, "Although carriers still differ about whether to build 4G data networks using Long Term Evolution (LTE) or Worldwide Interoperability for Microwave Access (WiMAX), all carriers seem to agree that OFDM is one of the chief indicators that a service can be legitimately marketed as being 4G."

OFDM is a type of digital modulation in which a signal is split into several narrowband channels at different frequencies. This is more efficient than TDMA, which divides channels into time slots and has multiple users take turns, transmitting bursts or CDMA, which simultaneously transmits multiple signals on the same channel.

The point is that 4G and 4G LTE (depending on which carrier you use) greatly increased the speed, the peak upload rate as well as added other modest but meaningful improvements such as adding LAN, wide area networking, and better error correction (Figure 6).

So here we are in 2018, and we are anticipating the first 5G networks and 5G-capable smart devices. It is expected that

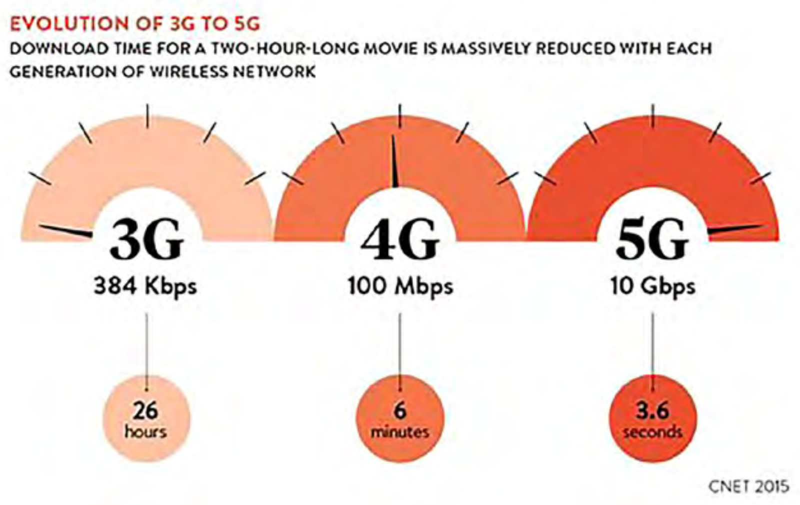


Figure 6: Comparison of speeds by generation.

the first 5G networks will launch by the year 2020. Verizon and AT&T have made advances and are already testing 5G networks. In fact, each of the four nationwide cellphone carriers—Verizon, AT&T, T-Mobile and Sprint—are developing 5G network technology. Chip designers and fabricators, including Qualcomm and Intel, are building processors and radios that enable 5G communications. And the major network equipment companies, including Nokia, Ericsson and Huawei, are building the backbone and equipment to support 5G. AT&T says it will start to roll out its first 5G network as early as late 2018, though virtually no one will be able to use it until 5G-compatible devices land on store shelves sometime in 2020—although it may happen sooner.

5G will give your new device a much speedier connection. Speeds up to 10 times faster than 4G are being targeted. Unlike the times when previous "Gs" were introduced, this time many of those that make up the target market actually do know what this means and are eagerly waiting for this next-generation technology.

A good example of what this will mean: You will be able to download a large file, something like an extremely high-resolution HD video/movie, perhaps with resolutions in the 8K range, in 30 seconds or less as compared to a six-minute download when using 4G (Figure 7). There will be virtually no latency—latency refers to how fast a piece of data takes to get to its destination—therefore virtually no lag time. Calling the portable devices using 5G "phones" is almost nonsense. Sure, you can talk on them but the 5G technology will enable the extreme level of communications necessary for autonomous driverless transportation and so much more.

The possible uses for 5G are massive; it will usher in truly connected cities where traffic lights, street lights, road sensors, vehicles, signs and a litany of other previously unconnected objects and structures come online and communicate with each other. That will

4G vs. 5G: Exciting Advances on the Horizon

	IMT-Advanced (4G)	IMT-2020 (5G)
Peak Data Rate	DL: 1 Gbps UL: 0.05 Gbps	DL: 20 Gbps UL: 10 Gbps
User Experienced Data Rate	10 Mbps	100 Mbps
Spectrum Efficiency	1 (normalized)	3X over IMT-Advanced
Peak Spectral Efficiency	DL: 15 bps/Hz UL: 6.75 bps/Hz	DL: 30 bps/Hz UL: 15 bps/Hz
Mobility	350 km/h	500 km/h
User Plane Latency	10 msec	1 msec[1]
Connection Density	100,000 devices/sq.km	1 million devices/sq.km
Network Energy Efficiency	1 (normalized)	100X over IMT-Advanced
Area Traffic Capacity	0.1 Mbpz /sq.m	10 Mbpz /sq.m
Bandwidth	Up to 20 MHz/radio channel (up to 100 MHz aggregated)	Up to 1 GHz (single or multiple RF carriers)

[1]Per 3GPP TR 38.913 (V0.3.0, Mar. 2016), 0.5 msec for DL and 0.5 msec for UL for Ultra High-reliability and Low-Latency communications (URLLC) and 4 msec for UL and 4 msec for DL for Enhanced Mobile Broadband.

Source: Rysavy Research

Figure 7: Comparing 4G to the upcoming 5G. (Source: Rysavy Research)

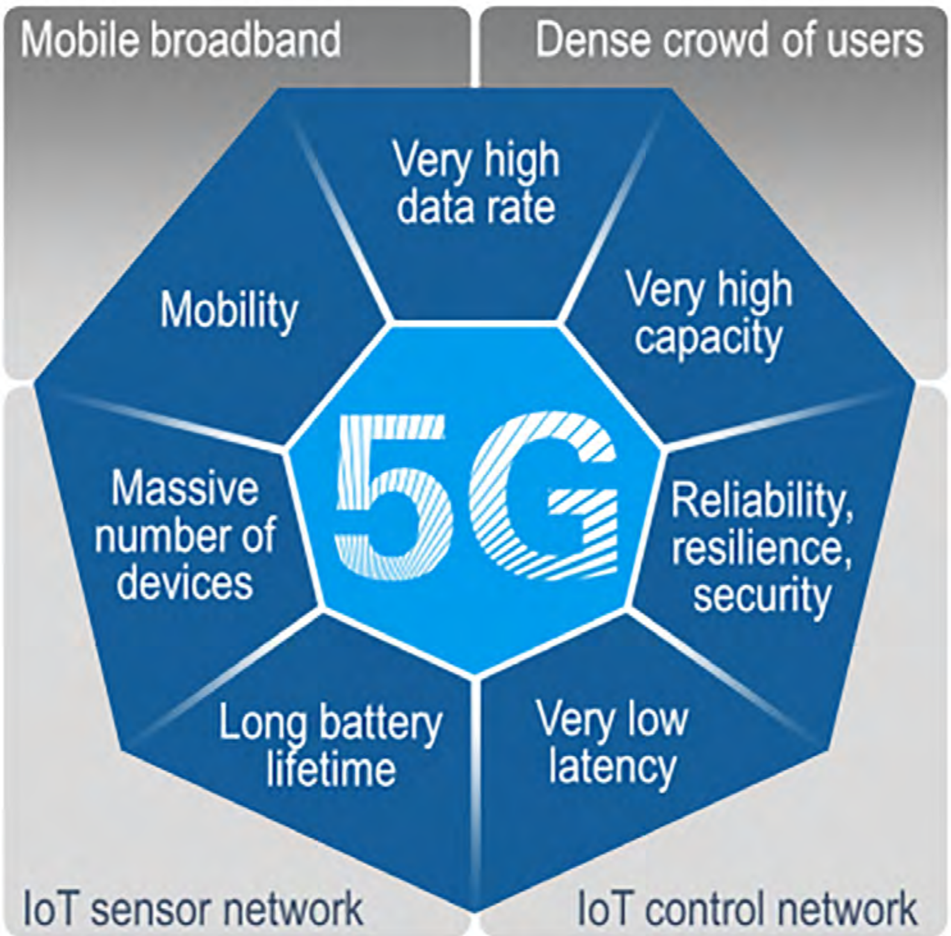


Figure 8: Advantages of 5G.

less companies will need to install thousands—perhaps millions—of miniature cell towers on top of every lamp post, on the side of buildings, inside every home and potentially in almost every room. Because of that, for the foreseeable future, 5G will complement 4G rather than outright replace it. In buildings and in crowded areas, 5G will provide a speed boost. But when you're driving down the highway, 4G could be your only option—at least for a while. Therefore, the next generation of devices may be hybrid 4G/5G.

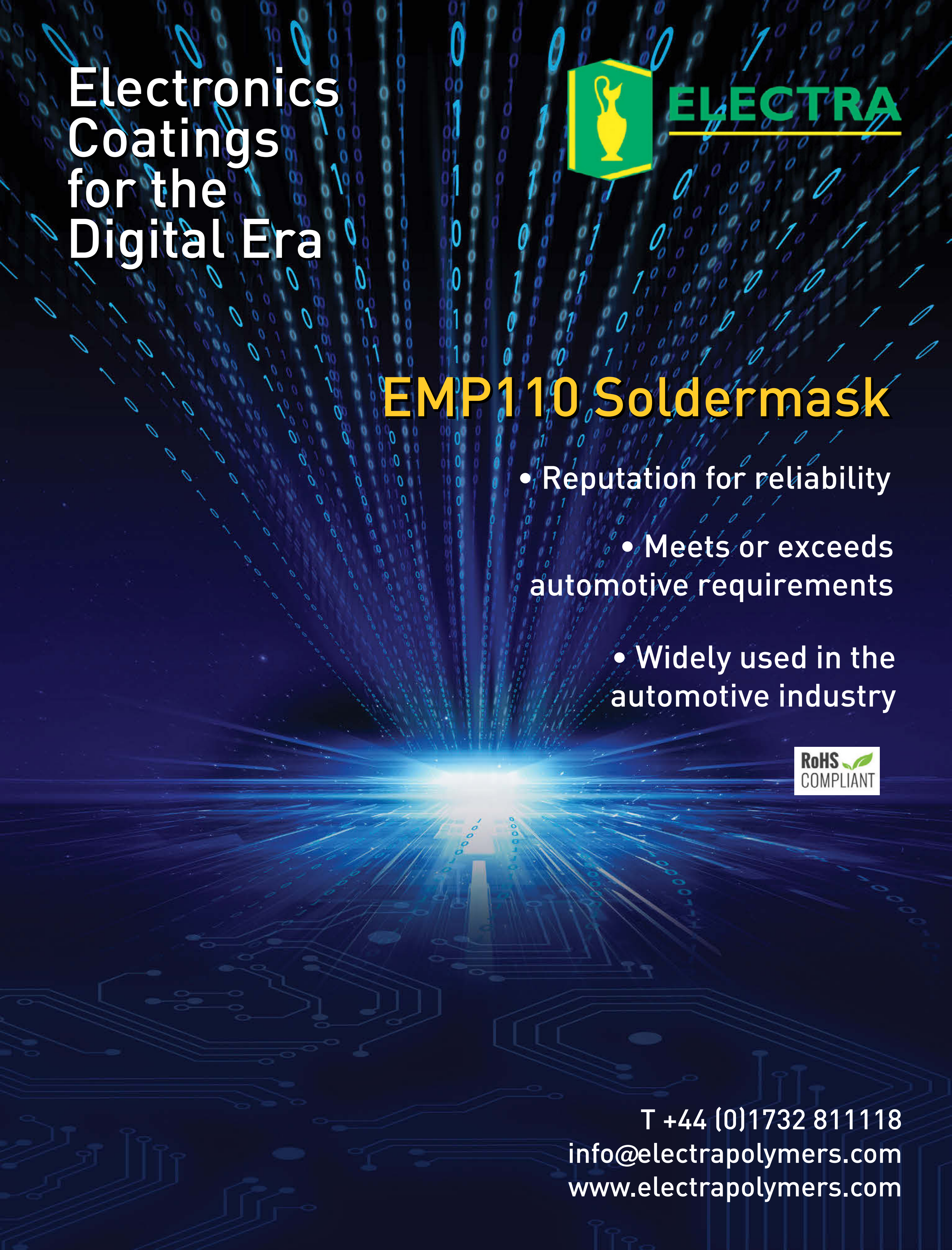
The research and development alone are costly and building out 5G networks will be wildly expensive—even for an industry accustomed to spending many billions of dollars on infrastructure costs. According to Barclays, rolling out 5G to the entire United States will cost $300 billion. One thing to consider is that if you want a new smartphone after 2018 you just may want to wait and stay up-to-date on what is to soon be available.

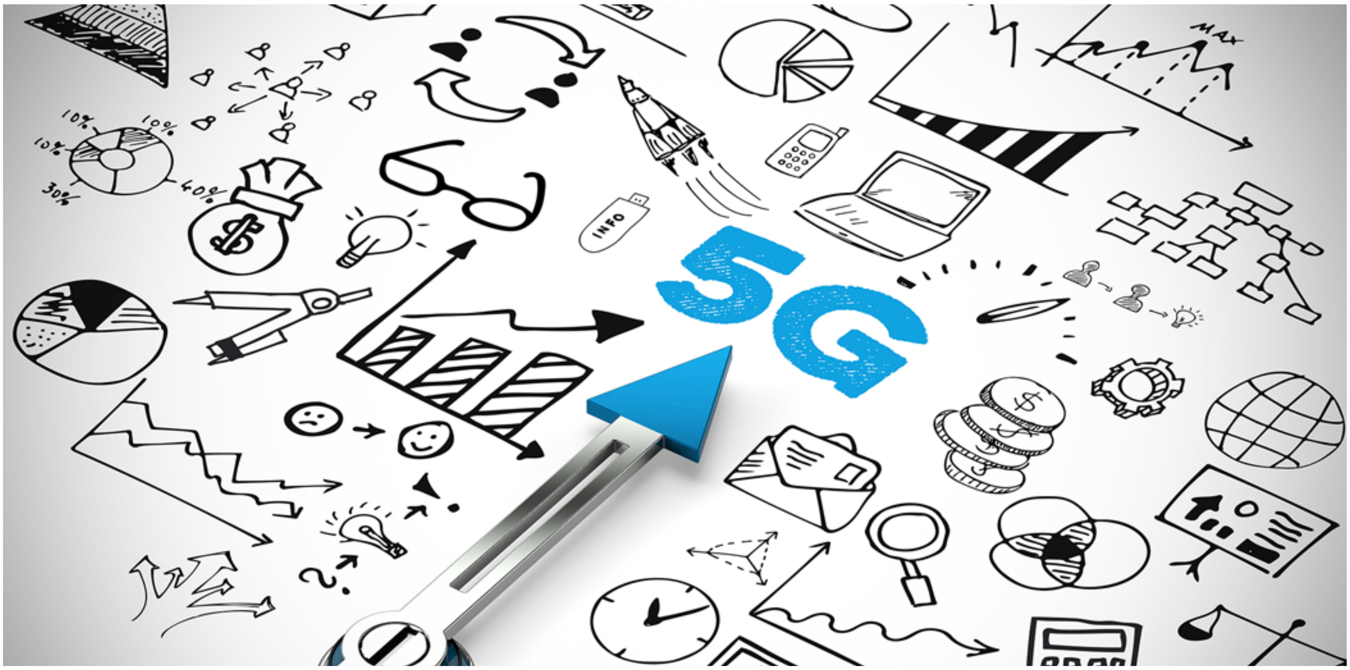
allow for far more efficient traffic flow, improve self-driving vehicle deployment, and allow for more intelligent route mapping—and in general make travel safer. Mix in the capabilities of 5G with virtual/mixed reality and the disruptions (good disruption in this case) are beyond the imagination of many. Surgeons will be able to perform surgery from anywhere there is a 5G connection, military commanders will be able to control their assets from any location, and on and on. Let your imagination run wild and wait 10 years and it will probably happen (Figure 8).

There are challenges, however. To accomplish all that, 5G will need to travel over super-high-frequency airwaves. Higher frequencies enable faster speeds and bandwidth. But they can't penetrate walls or windows, etc., like lower frequency waves can. Also, higher frequency transmissions weaken over long distances to a far greater degree. That means wire-

Just as with virtual reality, 3D printing, autonomous transportation, and other potentially disruptive technologies, you can be sure that we will continue to cover the progress of 5G, one of a number of approaching megatrends. **PCB007**

Dan Feinberg is the owner and president of FeinLine Associates Inc. and the technology editor for I-Connect007. To read past columns or to contact Feinberg, click here.


Electronics Coatings for the Digital Era
ELECTRA
EMP110 Soldermask
• Reputation for reliability
• Meets or exceeds automotive requirements
• Widely used in the automotive industry
RoHS COMPLIANT
T +44 (0)1732 811118
info@electrapolymers.com
www.electrapolymers.com



Experts Discussion: What Does 5G Mean to Materials and EDA Tools?

Feature by the I-Connect007 Editorial Team

Whether we're ready for it or not, 5G technology is coming. While many companies are waiting to see how we're all affected by this, PCB materials providers and EDA tool vendors have no such luxury. For this issue, we spoke with John Hendricks, market segment manager for wireless infrastructure at Rogers Corporation, and Ben Jordan, director of product and persona marketing for Altium, about the challenges related to 5G and what this means for PCB designers and fabricators.

Andy Shaughnessy: John, could you tell us a little bit about what you do at Rogers and your thoughts on 5G?

John Hendricks: Rogers Corporation manufactures high-frequency printed circuit board materials. I'm a market segment manager, and that means I have responsibility for the wireless infrastructure business, globally. It's my job to identify what we need to be doing to meet both current and future needs.

And 5G has some interesting challenges. If you look at it from the PCB material point of view, in the past there was not that much change as you went from 2G to 3G to 4G. Lots of other technologies developed very dramatically of course, but in the circuit board business, not a whole lot changed in terms of what was required from materials. And the simple reason for that was that, from a hardware point of view, there were just small differences in frequencies—700 megahertz, 900 megahertz, 1.8 up to 2.5, something like that. And a power amp still basically looked like a power amp, and an antenna still looked like an antenna.

5G is interesting because, as most people know, it's split into two areas; a much bigger area, at least in the beginning, is the sub-six gigahertz market. And then you have the millimeter wave, which is 28 gigahertz. The millimeter wave presents some very dramatic changes to the material requirements because of the much higher frequency, so materials must be much lower loss. They have to be much thinner, much smoother copper.

Down at sub-six gigahertz, there's not so much of a dramatic change in the electrical requirements of the materials, but one of the things that is happening is, perhaps not necessarily in the very first iterations, but certainly in newer designs that we see coming out on the horizon, there's a lot more integration between the antennas and the power components and the transceivers, and going forward even more integration with the high-speed digital parts.

So, you see much more complex multilayer printed circuit boards, and a lot more integration. You see these modular stacks starting to look a bit more like high-speed digital boards. And so, the manufacturability of the PCB becomes more critical, and the ability to make much more complex multilayer PCBs becomes more critical than it was from 2, 3 and 4G. I think that's how I would sum it up.

John Hendricks

Shaughnessy: Ben, why don't you tell us a little bit about yourself, then just give us a few thoughts on 5G.

Ben Jordan: Sure. My background is more digital than anything. I was an FPGA programmer before getting into the EDA space. For me, RF has always been this scary black box thing. And I know that 5G is going to affect many people, especially at the PCB design level. That's because those people don't necessarily have any knowledge or experience with doing RF PCB design or RF system-level design.

But the whole point of moving to 5G is to enable many thousands of additional devices to join the network, where the whole push for this from my point of view is so the Internet of Things could go to its next stage of evolution. There are going to be many thousands of devices needing reasonable bandwidth, a lot of them are going to be thirsty, and a lot of devices will have very, very small bits of information. So, if you read up on 5G, you read that there could be many hundreds of thousands of simultaneous connections from sensor arrays, or it will be used as a sensor network. Maybe the flagship consumer will still be mobile phones, but the same networks in our homes, in our streets, in our cities, are going to be 4G or 3G, will be completely saturated if all those different IoT sensors and services that we're dreaming up were to have to use those older technologies.

That's really what's driving this and what's pushing bandwidth to be increased to accommodate this. What do you do to increase bandwidth? You make much more complex modulation schemes, and you also must increase carrier frequency. So now with 5G we're going to be seeing in the millimeter wave, bandwidths up to 60 gigahertz, for example. What does that mean for PCB designers and people like me who don't know a lot about RF? It's kind of scary, if you think about it.

I think, to a large extent, we have been relying on our chip manufacturers, companies like NXP or Broadcom and Qualcomm, to come up with the goods in a very easy-to-consume sort of package, so that a lot of those materials and a lot of the RF signal pathways are contained on a chip, and the antennas are there. One of the good things about high frequency carriers is the sizes of the antennas can shrink. One of the other things about 5G is its ability to go peer to peer. Then various nodes on the network will be able to quickly negotiate direct links and communicate peer to peer and not require a base station all the time.

Some of those bottlenecks will disappear and it will become more of a true mesh. And in doing so, we can have lower power requirements because there's less signal strength required in many instances. So that can help with the hundreds or thousands of sensor arrays or other smart devices. In terms of PCB design, reducing power requirements can greatly simplify things. But it does increase other challenges for passing electromagnetic compatibility standards and certifications. That's going to be a huge challenge for a lot of the designers out there. And they'll have to learn more anyway, even if they're doing everything with a simple chip and a basic carrier printed circuit board, all the way to maybe a more specialized hub style device, like a tower or a node for aggregating connections.

Those boards are going to be the complex ones with exotic materials. But then hopefully the actual end-user devices will be simpler, because a lot more of the magic secret sauce will be on the chip, or in the package, or in the die. And in my mind, the problems are equally on the semiconductor companies as they are on actual board-level design engineers and PCB designers.

Shaughnessy: Right, they're supposed to start releasing commercial chips, this year and next, designed for 5G.

Jordan: I have a friend who is an RF engineer at a company that begins with Q. I was speaking with him just this morning, knowing I was going to join this discussion. And he said he's working on 5G right now, and it's very, very difficult for those guys doing the actual chip design and the analog front end. We'll see how well that goes.

Shaughnessy: One of the things that I've seen is that they're saying some of these are going to require much thicker boards. You know, they're going to demand thicker PCBs and they're going to have higher aspect ratios and it is going to be a lot harder for everybody, but harder for the fabricator to put these boards together.

John, have you seen that in your findings?

Hendricks: Yes, in truth we see a lot of people trying a lot of different solutions for the same type of problem. But there are some common threads that run through them, including a greater degree of integration that is leading to more complex, thicker PCBs. We're talking about boards that can be 10, 14, 16, 18, or 20 layers, which we wouldn't have seen in the past on previous generations of mobile communications or what have you. So yes, you do see that complexity, and you do see much more challenge on the PCB manufacturing side, and that's what I was referring to when I was talking about the stacks starting to look like more complex high-speed digital boards than they have in the past.

Shaughnessy: As far as materials go, is it going to require a whole different set of new materials?

Hendricks: I think that depends on whether you are talking about the sub-six gigs or the millimeter wave. The sub-six gigs can broadly work with the materials that are available today. What happens at 28 gigs and higher is that you start to require, for example, extremely smooth copper. What happens in the millimeter wave range is that as the materials become thinner, which is simply a function of the smaller wavelength, then it's more than just having to have just a low loss dielectric. The components of insertion loss on a microstrip circuit are both conductor-based and dielectric-based, and as you get thinner the copper component of that loss becomes more important. And that's driven primarily by the smoothness of the copper, because at very high frequencies you have the skin effect and the current travels along the bottom of the copper, so things like the copper foil roughness become more important. When you start having smooth copper, that means

What happens at 28 gigs and higher is that you start to require, for example, extremely smooth copper.

that you have challenges with copper bond and peel strength.

With the millimeter wave, you certainly start to foresee more material challenges than you see at lower frequencies.

Jordan: I think this really does tie into the CAD side as well, because if someone doesn't have a lot of experience and knowledge, we always say, "Work with your fabricator." A lot of fabricators are going to struggle with this stuff, and there will be a few leading-edge ones, and it might be more suitable for people working on 5G apps and design to work more with the materials company first than with the fabricator. I can foresee that we're going to need improved capabilities in layer stack planning, and maybe even some kind of simulation capability for things more around the mechanical limitations of layer stacks.

Ben Jordan

People already do thermal analysis on their circuit board designs, they do impedance control calculations and use 2D and 3D field solvers to make sure their layer stack is going to function as desired at RF and high-speed digital edge rates. But there's going to be an increasing number of people who have a great idea but don't know the mathematics or analysis techniques behind getting something to work with an appropriate layer stack that's affordable to manufacture.

With all those tradeoffs, on the CAD side, we need to introduce capabilities in layer stack planning that will help people making those tradeoffs and reuse known good layer stacks. Maybe it would be good for us to partner with a company like Rogers and come up with sample layer stacks that people can reuse. You know, if you build it this way, specify it this way, you'll have an easier time getting your design to production.

Hendricks: Sure. At Rogers, we have a two-pronged approach. We historically have very good and close links with microwave and RF engineers who tend to be the material specifiers at the higher frequency side of things. But going forward, because of the increased complexity of the boards, we also have a very strong technical service team that works very closely with PCB manufacturers and partners with them to help with design and the processing technologies. It becomes a triangle between the electrical designers, the manufacturers, and the material suppliers. We effectively have to work together.

Jordan: Collaboration is really the name of the game, isn't it?

Hendricks: Yup.

Patty Goldman: How often does that collaboration happen?

Hendricks: There's often this old-fashioned traditional approach where the electrical designer designs a PCB and then goes to a PCB manufacturer and the PCB manufacturer says, "I wouldn't have designed it that way." I guess there's always an element of that in it. We don't often have three-way partners or three-way meetings, but there is a set of three-way communications. We talk closely to the PCB manufacturers and the OEMs equally, basically.

Goldman: I asked that because we hear that so often on all sorts of different subjects that "if only they could let us know first and we could all work together it would be so much better."

Hendricks: Yeah. It never goes completely smoothly (laughs).

Stephen Las Marias: Do you think these 5G challenges will have an impact on the PCB assembly side?

Jordan: I think the issues with assembly remain the same for any kind of wireless technology. There's going to be DFT; it's going to create new problems and new opportunities, again because it's new physical connectivity and modulation schemes, and new rules from the FCC and CE and Europe and others, for making sure products don't cause problems. And all of that impacts assembly, in my mind anyway, because assembly is the first task of that final stage of production. The second half of that stage, which is done typically in the assembly process, at the end, is the test. And designing for test is going to have new challenges with 5G. I mean, how are you going to test that your devices are too chatty when it's supposed to be functioning and not using too much bandwidth on a network in a certain geographical region where there could be 1,000 other devices?

How do we test for that? And how do we design the PCB at those millimeter wave frequencies; the probe effect is going to be a huge problem. You know, the probe effect is that by measuring something you affect how it operates. So how do you measure? And that happens at those kinds of frequencies. So, the assembly houses are going to have to develop and buy new test equipment that's going to ensure these products pass muster. Not just functionally, but that they pass the rules. Maybe I have a naïve idea of that, but that's just my two cents on that question.

Las Marias: I think you're right, Ben. Thank you for that.

Shaughnessy: Happy, is there anything that we're missing? What do you think about the 5G?

Happy Holden: At Hewlett Packard, we typically would do testing for up to 800 gigahertz. When you're designing and building boards, and we have to measure something that's in 800 gigahertz, you have to be 10 times better. And so, RF design and RF materials were always a big headache, but that's where HP made a lot of money, because not too many people could build this test equipment. Now this kind of specialty, rather than being with the OEMs, is going to come down to common board fabricators and board assemblers that may not have the manpower, the equipment, the training or the knowledge. For a while there's going to be an elite few that will have mastered all these needs.

And then because of the opportunity and the prices, more people will jump in with more processes and more materials. But for the short term, this is a tough area. You know, I took a degree in electrical engineering, but because of the mathematics and field theory, I stayed away from Maxwell's equations. Unfortunately, it's coming that even digital is RF design, and you can't escape.

The only way to escape is to go optical; then you don't have to worry about it at all, because there are no magnetic fields. So, one of the alternatives may be that a lot of 5G may jump into the optical area, simply because of the inherent problems and shortages in the digital electronic area. I think that's what makes it an interesting subject. Going forward, there are an awful lot of challenges.

Shaughnessy: Right. It seems like you're just now getting to the point with millimeter wave where they can commercialize it for mainstream. I keep reading about people that have had a hell of a time with millimeter wave, but it seems like they've got it under control now.

Holden: UCLA demonstrated for us a millimeter wave chip that had only three connections, and it had replacement mechanical connectors. Because they were so directional that the transmit and receive had to be surface mounted on the edge of the PC board and you didn't need the wire or mechanical connectors because of the millimeter wavelength. A millimeter chip with its own antenna right off the die itself—and they're so small you can put quite a few on a wafer. Designing and the architecture of products, they change. The follow up, we're not using mechanical connectors with sockets or anything like that anymore.

Shaughnessy: John, is there anything you'd like to add?

Hendricks: I would just say that everything I've heard has been correct. The millimeter wave does present a lot of challenges, purely from the RF point of view, as has been pointed out. Millimeter wave is nothing new. Not even anything new in consumer applications because you'll see millions of 77-gigahertz radars being produced every year for the automotive industry now, and things like adaptive cruise control. So, from the RF point of view, it's not such a huge challenge. But people are developing new modulation technologies and all kinds of stuff that go with that, which is completely new.

From the PCB side of things, it's the complexity of the boards at those frequencies that's rather new. Even the 77-gigahertz radar is a relatively simple PCB, compared to some of the designs we are starting to see coming along in 5G.

The only other thing that I would point out is when we talk about sub-six gigahertz versus millimeter wave; it's going to be a long time before the millimeter wave really grows that quickly. The initial applications look more like fixed broadband access, and people are working on mobile applications at millimeter wave, so that is a lot more challenging. In the initial, let's say, five-year period, the vast majority of 5G designs are not going to be millimeter wave, at least in terms of production volumes. They're going to be down below six gigahertz.

Shaughnessy: Sounds like pretty interesting stuff. It sounds like it's going to make some little disruption, every step of the way. More change.

Hendricks: It's the one thing that never changes.

Shaughnessy: Well, I appreciate all of you joining us for this talk. I know you're all busy.

Jordan: You too, Andy. Thank you. PCB007

One-Dimensional Material Packs a Powerful Punch for Next Generation Electronics

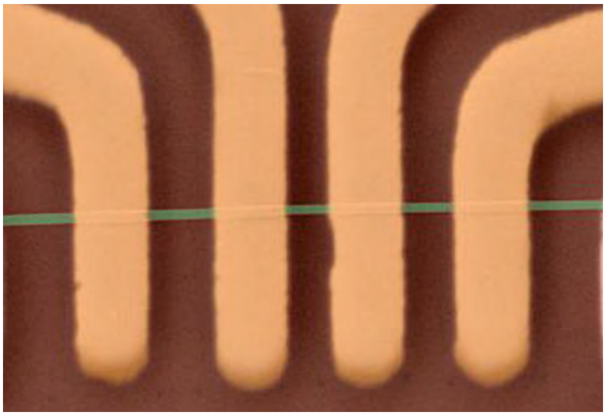
Engineers at the University of California, Riverside, have demonstrated prototype devices made of an exotic material that can conduct a current density 50 times greater than conventional copper interconnect technology.

As transistors in integrated circuits become smaller and smaller, they need higher and higher current densities to perform at the desired level. Most conventional electrical conductors, such as copper, tend to break due to overheating or other factors at high current densities. The advent of graphene resulted in a massive, worldwide effort directed at investigation of other two-dimensional, or 2D, layered materials that would meet the need for nanoscale electronic components that can sustain a high-current density. 2D materials consist of a single layer of atoms, while 1D materials consist of individual chains of atoms.

One can think of 2D materials as thin slices of bread while 1D materials are like spaghetti. Compared to 1D materials, 2D materials seem huge.

A group of researchers led by Alexander A. Balandin, a distinguished professor of electrical and computer engineering in the Marlan and Rosemary Bourns College of Engineering at UC Riverside, discovered that zirconium tritelluride, or ZrTe3, nanoribbons have an exceptionally high current density that far exceeds that of any conventional metals like copper.

The new strategy undertaken by the UC Riverside team pushes research from two-dimensional to one-dimensional materials—an important advance for the future generation of electronics.



Supply Line Highlights

Rogers Launches Low-Loss Laminates, Bonding Materials, and Foils ▶

Rogers Corporation is pleased to introduce a set of next-generation products designed to meet the existing and emerging needs of advanced millimeter wave multi-layer designs.

From Math to Marketing: Orbotech CMO's Worldview of the Industry ▶

Barry Matties met with Orbotech's corporate VP of Business Development and CMO, Lior Maayan, in Shenzhen and spoke about the next-generation processes currently challenging Orbotech's R&D team.

RTW IPC APEX EXPO: Bowman–XRF Equipment, New IPC 4552A Spec, and How They Go to Market ▶

Tom Leone, president, and Zach Dismukes, sales and support engineer from Bowman, discuss their XRF equipment, the new IPC 4552A spec, and how they go to market.

RTW IPC APEX EXPO: Ucamco's New Tools for Designers, Fabricators ▶

European Editor Pete Starkey and Ucamco partner Luc Maesen discuss Ucamco's newest solutions for PCB designers and fabricators, YELO (Yield Enhancing Layout Optimizer) and Communic8tor.

Trouble in Your Tank: Surface Preparation and Cleaning, Part 1 ▶

Surface preparation and cleaning are essential aspects of metal finishing and printed circuit board fabrication. It is critical that the engineer carefully evaluates these processes to determine the most effective way to optimize yields.

IPC APEX EXPO Boosts Uyemura's ENIG/ENEPIG Development ▶

Uyemura, the preeminent manufacturer of advanced chemistries for PCB manufacturing, received a significant boost for its two most important recent product developments at IPC APEX this year.

Hitachi Chemical to Build New Factory in Taiwan to Manufacture Laminate Materials for PWB ▶

Hitachi Chemical Co., Ltd. has decided to construct a new factory to manufacture advanced functional laminate materials for printed wiring boards (pre-preg and copper-clad laminates) in Taiwan.

RTW IPC APEX EXPO: Matrix Discusses Advanced Automation Equipment ▶

Matrix's Fred Long discusses advanced automation equipment for the PCB industry, including new cleaning technology for panels and dry film laminating equipment.

Rogers Introduces New Laminates for Base Station Antenna Applications ▶

Rogers Corporation has introduced two new products: AD300D laminates and IM Series laminates. AD300D fourth generation, commercial microwave and RF laminate material extends the capabilities of the successful AD300 product grade.

Don’t Let Your Temperatures Rise

Let ROGERS’ Thermal Management Solutions *Keep You Cool*

COOLSPAN® TECA Film • 92ML™ StaCool™ Laminates • ML Series™ Laminates & Prepregs

Heat can be damaging, especially when it is not managed. That’s why Rogers Corporation invested so much time and energy into creating an array of material-based thermal management solutions to keep heat rise to a minimum in printed circuits. From automotive circuits to LED modules to power supplies, ML Series laminates and prepregs effectively conduct heat away from the source, while COOLSPAN thermally & electrically conductive adhesive (TECA) materials enhance the thermal management of new and existing designs. And for that extra cooling edge, 92ML StaCool laminates feature a thermally conductive metal bottom plate to enhance the heat dissipation.

Product	Thickness	Thermal Conductivity (Z-Axis), W/mK	Thermal Impedance, C-cm2/W	Tg, C	CTE (Z-Axis), ppm/C		Dk, 1MHz	Df, 1MHz	Breakdown Voltage, kVAC	Flammability
					<Tg	>Tg				
92ML	8mils	2.0	0.52	160	22	175	5.2	0.013	>50	HF V-0

Don’t let your temperatures rise. Use Rogers’ thermal management solutions.

ROGERS CORPORATION

Advanced Connectivity Solutions

www.rogerscorp.com/acs

USA - AZ, tel. +1 480-961-1382
EUROPE - BELGIUM, tel. +32 9 235 3611

PCB Material Toolbox for Today's 3G & 4G Networks and Future High-Speed Needs in 5G

Feature by Stig Källman, ERICSSON
with Happy Holden, I-CONNECT007

Introduction

The material toolbox idea first came up when I saw the IPC appendix list for standard 1-ply stack-ups. The idea is to make a very simple bill of materials, specifications and notes, and possibly use the same prepreg/resin in the laminate and in the core.

This article will introduce the material toolbox concept by discussing seven important factors:

1. Standardization
2. Toolbox idea
3. Materials concerns
4. Technology drivers
5. Material needs
6. Future
7. Products

In the past, I came across many designers who wished to have the best specifications for impedance. They all start with specifying an impedance and conductor width that will make this according to their field solver. The conductor thickness is given as a constant due to plating or the base copper and the minimum requirement in the hole. This sets the requirement for certain material CCL and prepreg thicknesses. You may see this today in the material supplier's data sheets for many customers.

If you start with what has the largest input to the impedance in the PCB you will find that it is dielectric thickness and conductor width that contribute the most. Accordingly, I reflected on what could be used as a benchmark for robust design and found that the Big Mac tastes the same anywhere in the world. Not the best burger according to some, but it's my favorite as it's something I can relate to and recognize. If I could copy this into our design toolbox I would have a design that, with the right recipe, would re-

sult in impedance performance of the chosen stack-up that would be the same regardless of where it is produced.

The Big Mac Index[1] provides an estimate of a particular country's price level. It was first published the magazine *The Economist,* September 6, 1986. The index is based on McDonald's Big Mac, which is uniform all over the globe while domestically produced.

For Standardization

You must have a dedicated lane to follow depending on your product requirements. If you choose the mainstream, you have the most options and the lowest price—but the more specific the requirements, the fewer the options and the higher the costs.

Philosophy of Toolbox

The big benefit of standardization is that if you know the impact of the prepreg on the design and you know the impact of copper foil and its different roughnesses you then can understand the impact of PCB manufacturing process tolerances—both the one you can take as default but also how they affect your design and the manufacturing requirements you put onto it. Then you can start comparing differences and design suitable resin systems with your material suppliers.

The toolbox consists of three levels:

1. General properties as standard
2. Group of materials with the same properties (multiple source)
3. Specific supplier data (single source)

Material Concerns

When defining this we need to consider who in the supply chain controls the biggest impacts. We see it as follows:

Conductor width →PCB manufacturer
Conductor height → PCB manufacturer
Dielectric height → PCB laminate manufacturer
Dk/Df → PCB laminate manufacturer

By making the choice of specifying standard properties from production variations, the impact of Dk will be less important. Basically, if the tolerances of the dielectric are within IPC B/L (Class 2) and the conductor width for 0.1 mm conductors is +/- 0.03 mm, the impedance will be within 10% without need for measuring. If you choose to make a test board, measure the resulting properties and re-input into your field solver, the control will go to approximately 7%, without further measuring.

For the raw glass material there are a few sources in the world that make it. Many of the extra features with the material make it expensive due to the supply chain locations. Resin is made from oil, and that equals naphtha, a petrochemical product that is a mainstream raw ingredient for the whole industry. Here you must decide between either FR-4.0 (halogenated) or FR-4.1 (halogen-free) to start thinking of the resin's properties to fulfill its purpose and not over-design the requirements. This helped us a lot going from the 3G products to 4G with its increased requirement for speed. Here it was easy to copy the building blocks of the older stack-ups and reuse them in new materials with better properties.

Weave is important to choose from the cloths mostly produced, and the most produced also got the best tolerances and availability. Higher frequencies require thinner, spread-glass cloths.

Copper is produced by a few suppliers, each with their own treatments to reach the right properties. The most common are HTE, RTF and VLP (Figure 1). Unfortunately, there is no

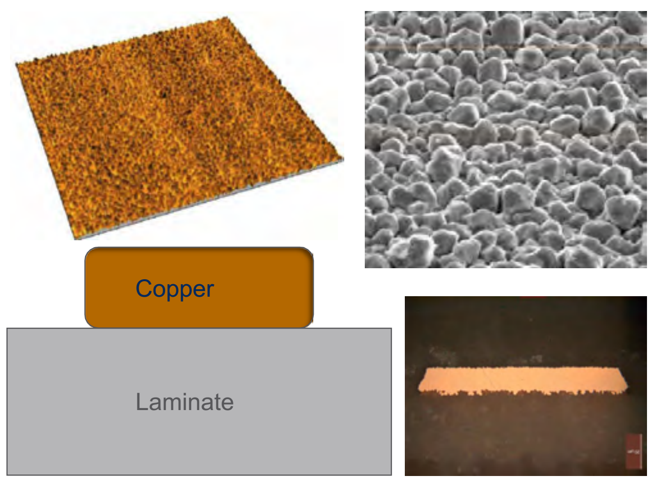


Figure 1: Copper treatment on the foil will affect not only speed and losses but also adhesion.

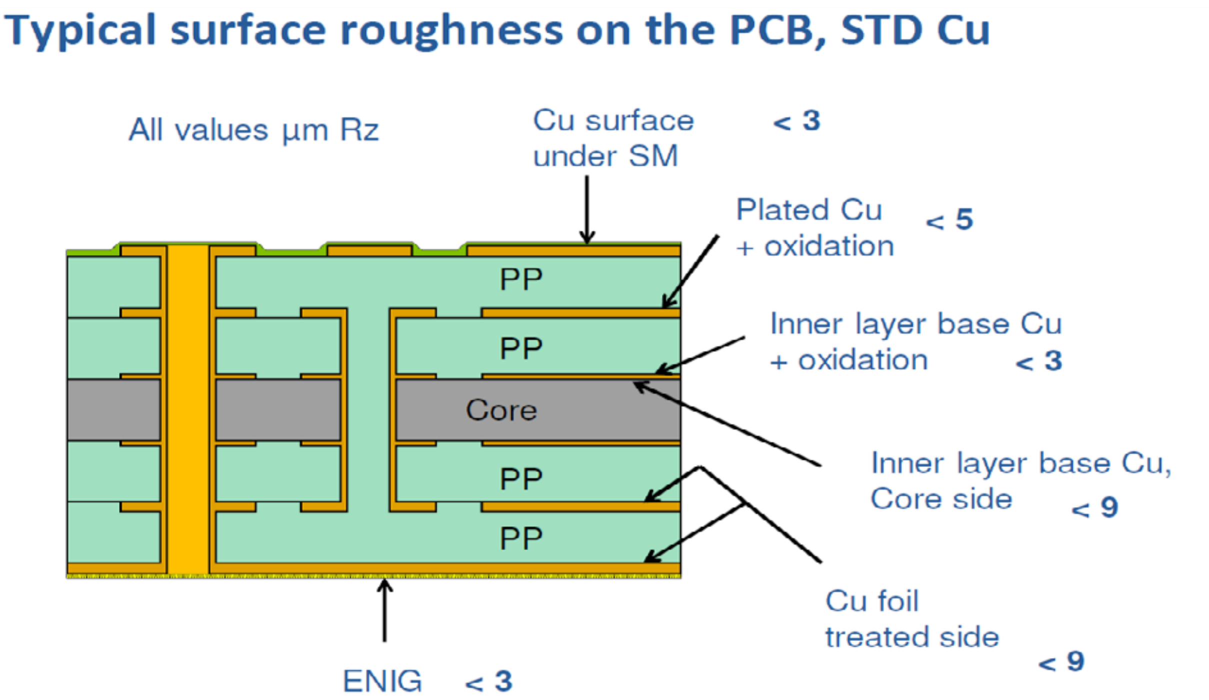


Figure 2: The copper roughness on a PCB can vary considerably, which is very important to electrical performance.

global standardization on the roughness of copper foil, so the same category can have different degrees of roughness on the same type. Important also to know is that the finished roughness may be changed during PCB manufacturing due to oxide treatment or oxide replacement chemistries used for adhesion. There is no sense in buying smoother copper on the resist side if it will be treated with black oxide. Figure 2 shows examples of this.

Technology Drivers

Cost effectiveness

Use the CCL and PP that is the most commonly produced as these are always available and have the best cost relations. Be cost-aware of how the material you use ranks itself as a cost index given by your PCB suppliers. Table 1 shows cost indexes for common pre-pregs. The cost of material in a PCB today averages 30% of the total cost, regardless of how cost-effective your PCB supplier's processes are. If they don't have good relations upstream with the material suppliers, you are not controlling the cost. Table 2 shows cost indexes for laminates.

Thickness Type* / mm	Cost index % HFFR
1080 / 0,07	1,00
1078 / 0,07	1,45 In toolbox but restricted
1067 / 0,07	1,47 Not in toolbox
106 / 0,05	1,43
2116 / 0,12	1,06
2113 / 0,09	1,16 Not in toolbox
1501 / 0,15	1,48
3313 / 0,10	1,60 In toolbox but restricted
7628 / 0,20	1,17

*Glass style

Table 1: Prepreg cost index averages from six PCB suppliers.

Thickness (mm)	Cost index % HFFR
0,050	1,31
0,063	1,23
0,076	1,07
0,100	1,00
0,127	1,03
0,150	1,10
0,200	1,11
0,250	1,34
0,300	1,41

Table 2: Laminate average cost indexes from six PCB suppliers.

Panel sizes

The material cost of making a PCB covers approximately 30% of the total value, so using a panel size that best fits the master sheet is essential. Then the PCB size becomes even more interesting because the process cost of making a panel can be set to one, and the individual price is then 1/n depending on how many PCBs you can fit on that panel.

Smaller features

As the density of the pattern gets higher and higher, the understanding of the copper thickness required for the different layers sets the limitations for miniaturization of the board. Also, the different materials' electrical properties make it possible to shrink the pattern.

Large format is key in 5G, especially for the lower frequencies where active antenna boards for beam forming can be as large as up to 800 mm (31.5 in.), which requires an even larger panel to be able to be produced.

Faster speeds

Serial links today go up to 28Gbit/s, but next generation mobile systems will require up to 56 Gbit/s so the individual selection of glass and copper foil properties is vital to success.

Warmer

Power consumption is essential to the performance and it makes the PCB warmer both as a heat source in components but also on antennas where some patterns get hot (>100°C). The material's behavior of not breaking down and changing its losses over time is important for a reliable product to prevent it from catching fire.

Environmental

Avoiding hazardous substances is important; using halogen-free materials where possible and choosing the halogen-free alternative when it's technically and commercially available is important.

PCB Material Needs

It is also important to share our current and future material needs to both the PCB suppliers and the laminate producers to be able to look for new cost-effective alternatives or increased performance.

It is and will be important to know all the material properties:

- Dk and Df
  - Dk and Df values over frequency (1, 2, 5, 10, 15, 30 GHz)
  - Dk and Df values over temperature (-40°C, +20°C, +100°C)
  - Measurement methods (e.g., IPC-TM-650 2.5.5.5, SPP, SPC, etc.)
- Copper surface roughness
  - Ra, Rz and Rq/RMS
- Mechanical properties of material
  - Flexural modulus
  - Flexural strength
  - Over temperature (-40°C, +20°C, +100°C)
- Break down voltage/dielectric strength

Current

Requirements that do not specify the PCB laminate names but rather the properties at certain conditions make the material suppliers aware of what we use today and in the future. Table 3 shows current halogen-free PCB material needs.

The future requirements are for materials with Dk of 3.5 and 3.0 that are also halogen-free and fully capable for making multilayers. However, for microwave designs a Dk of 1.0 (air) is preferable. It is also important that the material keeps its properties over frequency and temperature ranges of 1–30 GHz and from -40°C to +100°C, respectively. Table 4 shows future halogen-free PCB material needs.

Resin Development

You must start to collaborate with the PCB material suppliers on resin development and share your current and future requirements so these can be considered during the resin formulation steps. Today, developing a material in the range of a MEGTRON 6 or TerraGreen could take up to five years until it is commercially available to the market, especially if we add the PCB manufacturers' process learning curve and future UL approvals before we can start to use it in products.

Material Group	Dk	Df	Frequency [GHz]	Main Thickness [mm]	Thermal Conductivity [W/m/K]	CTE X and Y
FR-4.1*						
FR-4.1 high Tg	4.3 +/- 0.2	< 0.015	< 5	0.150 (6 mil) 0.114 (4.5 mil)		
FR-4.1 low CTE	4.3 +/- 0.2	< 0.015	< 5			10 ppm
FR-4.1 low Dk	3.9 +/- 0.1	< 0.015	< 5	0.114 (4.5 mil)		
Low Df, Dk and CTE	3.6	< 0.003	< 5	0.150 (6 mil)		10 ppm
Low Df and low Dk	3.6 +/- 0.1	< 0.003	< 5	0.508 (20 mil)	> 0.6	
Low Df and high Dk	> 6	< 0.003	< 5	0.508 (20 mil)	> 0.6	
Microwave	3.6 +/- 0.1	< 0.004	50	0.254 (10 mil) 0.127 (5 mil)		

Table 3: Current halogen-free PCB material needs. *FR-4.1 = HFFR4 (halogen-free).

Material Group	Dk	Df	Frequency [GHz]	Main Thickness [mm]	Thermal Conductivity [W/m/K]	CTE X and Y
FR-4.1 high Tg	4.3 +/- 0.2	< 0.015*	< 15	0.150 (6 mil) 0.114 (4.5 mil)		
HDI PCB	< 3.6	< 0.005	< 40	Prepreg system		< 10 ppm
Antenna	~ 1		< 100	0.5 – 1.0		
Microwave	~ 3	< 0.002	< 100	Prepreg system		

Table 4: Future halogen-free PCB material needs. *Low variation on Df over temperature.

This time-consuming process needs to be sped up by interacting during the alpha and beta stages of the material testing so necessary modifications are done before launching it to market. Here again, the standardization of the building blocks comes in handy for the reusability of simulation data. Both electrical and mechanical properties need to be considered. Another consideration is the supply chain for the material, so it can be produced as locally

as possible and as close to the PCB manufacturers as possible to minimize transportation costs and environmental impact.

Future Topics and 5G Onward

To meet the speed requirements of transmission in copper, today's copper foil standardization by IPC seems rather old and there needs to be a way to describe the roughness in microns (preferable), rather than today's VLP, VLP2, and HVLP. You can make the list long and very complex to write a bill of material to purchase the signal integrity people want or desire.

- Copper foil standardization
  - Suggest three levels of Ra < 2 µm, < 5 µm, < 10 µm
- Today reference IPC-4562A, Table 3-1 (Table 5).
- Higher MOT requires new material and UL applications RTI/MOT 130 – 150°C
- Design constraints for CAF/thermal design/HW to HW

Foil Profile	µm	µin
S (Standard)	N/A	N/A
L (Low Profile)	10.2	400
V (Very Low Profile)	5.1	200
X (No Treatment or Roughness)	N/A	N/A

Table 5: Maximum foil profiles. (Source: IPC-4562A, Table 3-1)

We also follow with interest UL's introduction of the RTI/MOT of FR-15.1 (150°C) to increase the materials' temperature resistance. To accommodate greater densification of patterns, reliability of holewall-to-holewall capability (CAF testing) is needed, along with improved throwing power into through-holes on boards greater than 3 mm (118 mil) thick. The high-performing, low-loss multilayer materials must also meet the multiple lamination requirements, especially for any layer designs requiring more than seven lamination cycles.

Products

Many new products will result. Enabled by 5G, these include autonomous vehicles and virtual reality systems using goggles. In short, the IoT will touch everything we do. Even the Super Bowl and the Olympics of 2018 were involved in 5G experimentation. This makes it possible to imagine the future others have predicted and to do the things tomorrow that we dream of today. **PCB007**

References

1. The Big Mac Index, *The Economist*.

Stig Källman is Senior Engineer PCB with Ericsson in Kumla, Sweden.

Excerpts from Prismark's Presentation at CPCA 2018

Prismark Partners LLC presented a detailed report at the recent CPCA meeting and show in Shanghai, China, on the challenges and opportunities for the PCB market. Part of the discussion was on 5G and is excerpted here with permission.

5G promises exciting new capabilites. The objective is to achieve the following goals, although not necessarily all in the same device or use scenario: User data rates 10x faster, numbers of connections 10x greater, latency 10x shorter and battery life 100x longer. It enables new applications in virtual/augmented reality and artificial intelligence; ultra-dense connections mean massive IoT capability; among other things, autonomous cars can become a reality (Figure 1).

Realizing the full potential of 5G will require the use of new frequency bands. Cellular networks currently use frequencies be-

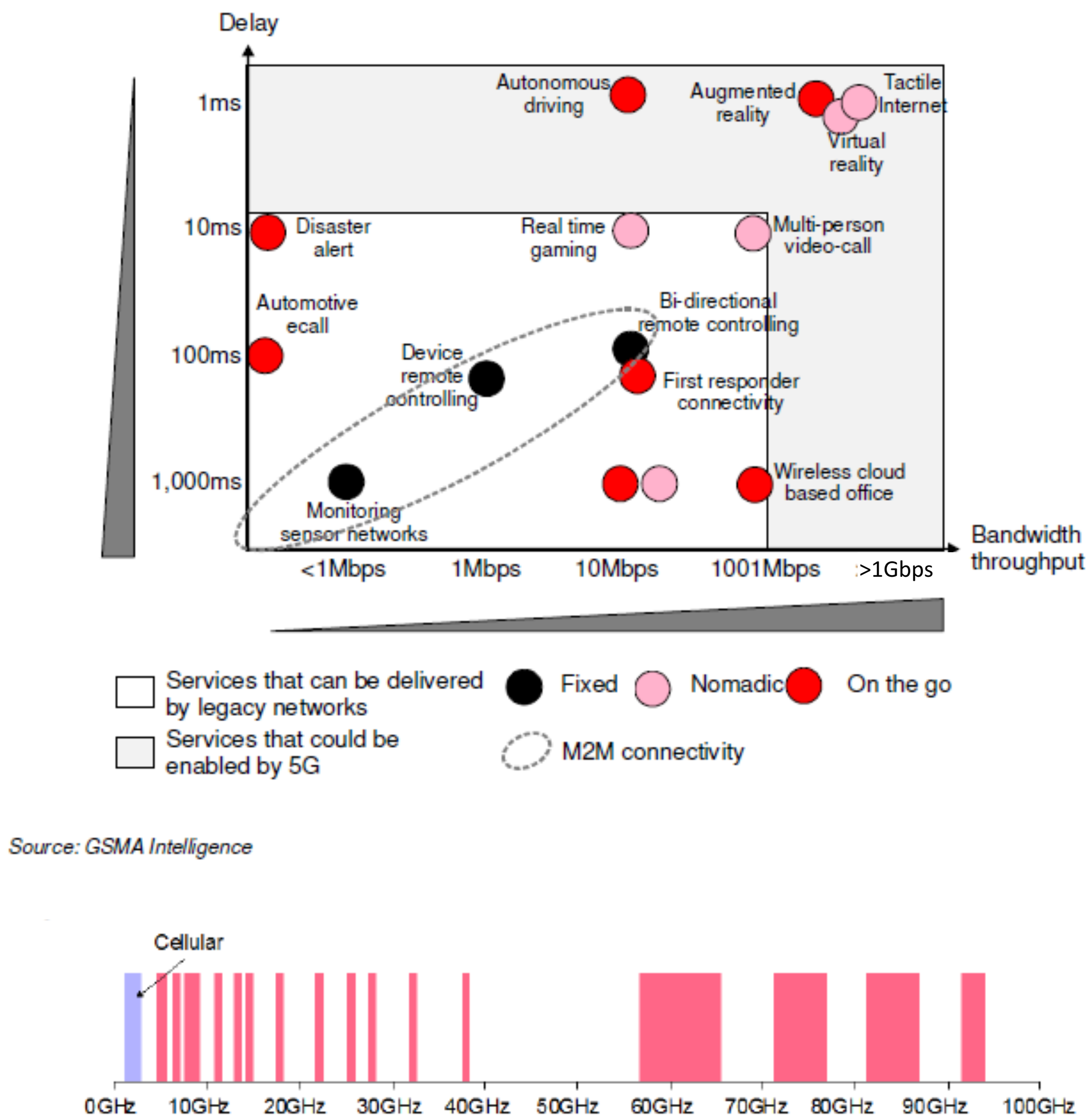


Figure 1: Higher data rates and lower latencies possible with 5G enable new services. (Source: GSMA Intelligence)


TRUST
THE EXPERTS
Industries serviced internationally: Automotive, LED, Mil/Aero, etc
Extensive global team of over 100 chemists
Worldwide solder mask market leader
Taiyo Holdings Co., Ltd. 64th anniversary
State-of-the-art products to the electronics, solar, lighting, display and printed battery industry niches
Reputation worldwide of proven performance, outstanding quality and extensive end-user acceptance
TAIYO AMERICA
Your Ultimate Solution
Phone [775] 885-9959 • www.taiyo-america.com • info@taiyo-america.com
in

low 3.5 GHz because these offer a good trade-off between performance and cost. Sub-1GHz frequency bands are particularly good for indoor penetration (going through walls), and as legacy standards are being phased out (starting already with 2G) these bands will be re-allocated to 4G and 5G.

Lower frequencies offer longer range and thus broad coverage at lower cost, but the available bandwidth is too limited to provide full 5G services. Extreme data speed and capacity can only be provided with wider frequency bands, and these are only available at much higher frequencies (> 20 GHz). Unfortunately, these higher frequencies also suffer from short range and higher costs; they are most useful for local high-traffic hot spots and backhaul services. In addition, WiFi already complements 4G/5G with higher data rates at short range, and the convergence of WiFi and cellular networks will continue.

5G commercial service will be starting in 2018 initially with fixed wireless, often at high frequencies (e.g., 28 GHz or 39 GHz). Mobile network deployments will gradually start by 2020 and sub-6 GHz will remain the most common frequency. Figure 3 illustrates high speed and high frequency applications.

PCB Market Opportunities and Challenges

The PCB market will continue to expand in the next few years. Prismark forecasts 3.8% growth in 2018 and 3.2% CAAGR from 2017 to 2022. Some of the key growth opportunities include:

- High-speed and high-frequency circuit boards for high data rate and RF applications such as automotive, 5G, AI, and others
- Fine line/space HDI and FPC boards; mSAP technology is fully recognized
- Fine pitch packaging substrates; < 5 µm line/space is desired
- Low loss materials, e.g., PTFE-like and LCP-like
- PVD processing technologies for fine pitch or special applications
- Processing automation and intelligent manufacturing

5G MARKET DEVELOPMENT

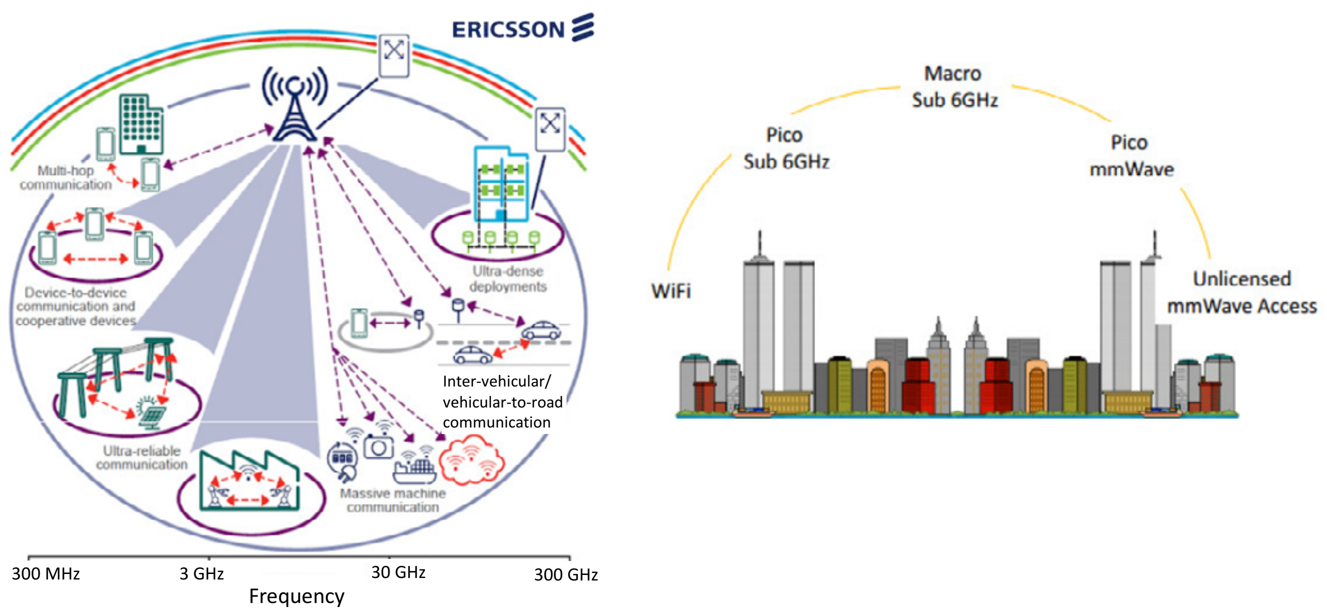


Figure 2: Mobile networks are being reconfigured to provide a wide range of services, and some require the use of new frequency bands. (Source: Ericsson)

Excellon

Manufacturers of precision Micro-Machining Solutions for over 50 Years

COBRA II

Hybrid laser system

689

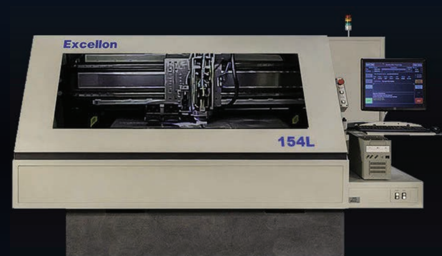
6-station precision drilling and routing system

HS-1L DS

Single-station, dual spindle high-speed system

136L

High accuracy and speed



154L

Large panel applications

HS-2L

2-station, high-speed

129

Single-station precision system

Move into the future with the latest innovations in Fabrication Technology from the Industry Leader!

www.excellon.com

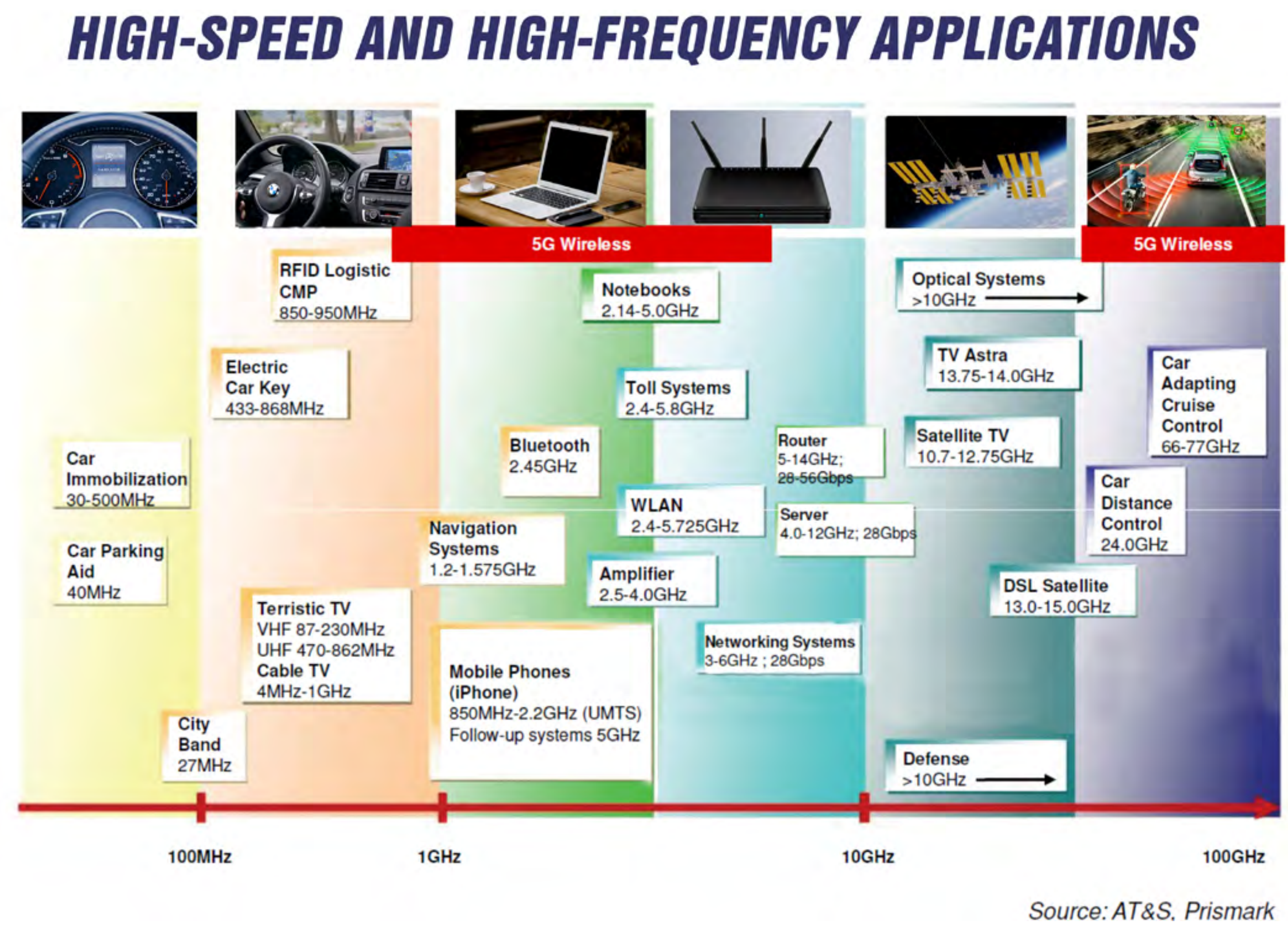


Figure 3: High-speed and high-frequency applications. (Source: AT&S, Prismark)

There are challenges, including:

- Uncertain demands, for example Bitcoin mining
- Concerns of over-expansion, especially in the rigid multilayer segment
- Unanticipated environmental regulations (recall RoHS and REACH)
- Raw material supply and cost (e.g., resin, glass, copper) could hurt profitability **PCB007**

CEO Priorities Are Shifting to Embrace Digital Business

Growth tops the list of CEO business priorities in 2018 and 2019, according to a recent survey of 460 CEOs and senior business executives in the fourth quarter of 2017 by Gartner Inc. However, the survey found that as simple, implemental growth becomes harder to achieve, CEOs are concentrating on changing and upgrading the structure of their companies, including a deeper understanding of digital business.

"Although growth remains the CEO's biggest priority, there was a significant fall in simple mentions of it this year, from 58% in 2017 to just 40% in 2018. This does not mean CEOs are less focused on growth; instead, it shows that they are shifting perspective on how to obtain it," said Mark Raskino, vice president and Gartner Fellow. "The 'corporate' category, which includes actions such as new strategy, corporate partnerships and mergers and acquisitions, has risen significantly to become the second-biggest priority."


Meet your new sales personal trainer.
Increasing sales isn't rocket science. We use proven methods to help you find the right customer, motivate your sales team, and increase your profits.
We've helped dozens of companies big and small improve their bottom line.
Learn how we can help YOU
207-649-0879
danbbeaulieu@aol.com
db MANAGEMENT GROUP

The Velocity of Technology—
What Does It Really Mean?

The PCB Norsemen
by Jan Pedersen, ELMATICA

Speed and Direction– Where Are we Going?

The subtitle of IPC APEX EXPO 2018 was "Succeed at The Velocity of Technology." What did IPC mean by this?

I have not asked the IPC staff what this phrase meant in real terms, but I have my own interpretation. For me, the velocity of technology has two components: speed and direction. The technology in electronics develops faster than ever. A user of mobile phones or computers may not understand the rate at which electronics changes, but if you see the development of components and the complexity of today's packages, you understand the speed.

Driving a car is probably one of the areas where the user comes in direct touch with the technology development. And we understand the speed when we see how fast we get new versions of smartphones and other gadgets. But in what direction are we going? We all know that size and weight reduction is good. We get more function into the same space. At the same time, we increase the functionality—a mobile phone today can do more than a desktop computer did some years ago. It has a better camera than the reasonably good full-size digital camera we still have in our drawers.

I am a PCB geek. For me, it is interesting to see how technology development has affected the PCB, and in which direction we move. How do we see the velocity of technology in PCBs?

(Almost) Born and Raised in a PCB Plant

I was born in a PCB plant outside Oslo in June 1958. Norway had no PCB factories at that time, so my father saw the potential and started to etch boards in a garage using silkscreened etching resist and ferric chloride etchant. The boards had to be used fast to avoid corrosion; we only had a simple lacquer to protect the copper.

Time went by and at 20-something I was set to lead a small PTH plant. We started to use photoimageable plating resist and infrared re-

IT-988G SE / IT-988G

IT-988G

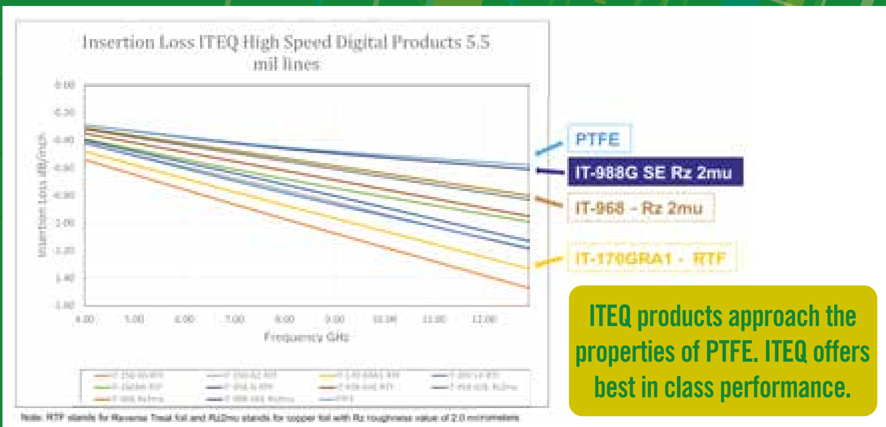
- Halogen Free
- Tg = 190° C
- Td = 405° C
- Dk = 3.46 @10GHz*
- Df = 0.0025 @10GHz*
- Available with low Dk Glass - IT-988G SE

IT-988G SE

- Halogen Free
- Tg = 190° C
- Td = 405° C
- Dk = 3.24 @10GHz*
- Df = 0.0014 @10GHz*

Ultra high speed > 56 Gbps per channel, NRZ (PAM2), PAM4 applications

Insertion Loss - Measured



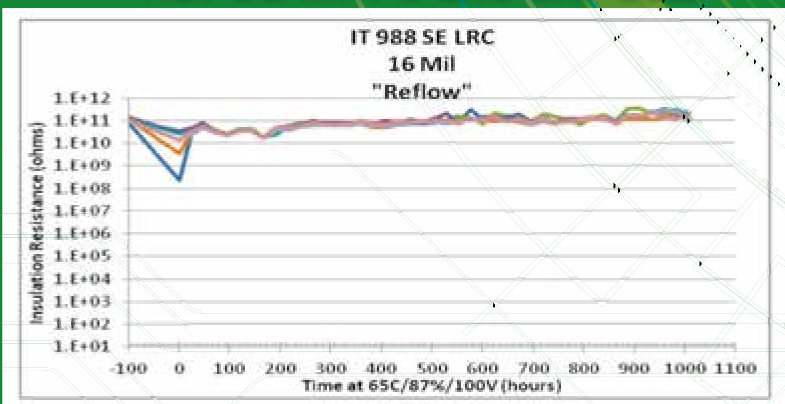
Sequential Lamination

7 Lamination cycle data

Lamination	DMA	DSC	TMA	T300 with CU	Solder Dip PCT: 1h @ 121℃	Td 2wt% / 5wt%
1	213	187 / 197	182	> 60	> 60	408 / 435
2	216	194 / 199	193	> 60	> 60	417 / 438
3	214	186 / 192	185	> 60	> 60	417 / 442
4	216	193 / 194	184	> 60	> 60	424 / 443
5	217	194 / 199	190	> 60	> 60	418 / 442
6	218	191 / 197	188	> 60	> 60	405 / 436
7	218	190 / 197	194	> 60	> 60	425 / 444

No thermal degradation observable after 7 lamination cycles

HDPUG MRT-6 LRC CAF Data



IT-988G SE

- High Tg / Lead Free / Halogen Free
- Ultra Low Loss Laminate & Prepreg
- 100G / 400G Solution
- Lower Dk (<3.24 @ 10GHz)
- Ultra low Df (<0.0014 @ 10GHz)
- Very Stable Dk-Df across frequency
- HDPUG MRT-6 - LRC and HRC passed all thermal requirements
- HDPUG MRT-6 - LRC and HRC passed CAF requirements

ITEQ has the leading solutions for High Speed Digital applications with the extremely cost-effective IT-170GRA1 and IT-968 to the ultra high speed IT-988G and IT-988G SE for the highest end designs beyond 56 Gbps.

*53% resin content

ITEQ

flow for tin-lead (those machines typically had a small fire every week). At that time, we had no RoHS, REACH or ISO 14000 or really any environmental awareness. I have some stories that are better told in more private circles.

In 1992, I joined Elmatica and during the '90s we saw some development of PCB technology but mostly just a slight miniaturization. Frankly speaking, the PCB technology itself has not changed that much today either. We still print and etch. We still drill, but we use a laser in addition to the mechanical drills. We still print solder mask, we still plate copper to achieve required thickness and through-hole connections. So, we have seen some changes, but not the speed or change of direction as in other technologies.

The velocity of PCB technology today is still, from my point of view, not at the same rate as we see in components. The introduction of smaller components has almost out-challenged the PCB. But only just. And, we are still in the same direction, so we cannot brag too much about the velocity of the PCB technology.

The introduction of smaller components has almost out-challenged the PCB. But only just. And, we are still in the same direction, so we cannot brag too much about the velocity of the PCB technology.

My First Meeting with IPC—the Giant

Before I go deeper into how I see the technology, I need to explain my connection with IPC. I attended my first IPC APEX EXPO in 2017. I was taken a bit off guard by how an unknown guy from Elmatica, a printed circuit broker up North, could be recognized by this ruler of electronics standardization. I looked at IPC as a giant with no empathy for the need of companies outside the USA, especially the smaller ones.

I was wrong. My experience with IPC is that all companies are welcome to contribute and have a voice, no matter the size. You just need to join a committee, have an opinion and raise your voice. I did just that. With good help from IPC´s Lars Wallin, I volunteered to be the chair of a new committee, the automotive addendum to IPC-6012D. Suddenly I had a voice in an organization, that from outside can look rigid and arrogant. What I found was an impressive group of engineers with an open mind to new ideas. Don't get me wrong, a standardization body shall be predictable and give stability. There are members who actively protect U.S. interests. But IPC is becoming more and more international, and I am a part of that. (I hope there are no hurt feelings.) So, with that background, how do I see the PCB technology and how can I contribute to the development?

Micro PCB—We Need to Talk

Today I also chair the medical addendum to IPC-6012 and IPC-6013. In the development of this standard, we have identified PCBs used in several applications such as implants and hearing-aids that have line widths, thickness, hole sizes and other features below current tolerances and limits in today's design, performance and acceptability standards. Imperfections in the material that are acceptable in normal PCB may cause application failures in these products. Where volume manufacturing of a standard PCB accepts a waiver of IPC´s test frequency requirements, suppliers of these micro PCBs must exceed the standard! Today, these PCBs are made to customer requirements rather than following the IPC standard. In the other far end we also fail to follow the standard, even for automotive and medical applications—and we all know it! We just don't talk about it.

Surface Contamination Testing—a Hot Topic

With this miniaturization, we also must meet new requirements for cleanliness and contamination test methods. IPC uses the term Cleanliness Testing in current standards. I call

it Surface Contamination Testing because we are not really talking about cleanliness, but to control contamination levels of the solderable surface. The smaller the solderable pads we have, the more we need to control the contamination level. And with increased variations in complexity and miniaturization, we may need product-related acceptability levels instead of a rigid standard level for all technologies.

This is a hot topic where the industry is in a need of an urgent development. While waiting for a better solution, my automotive addendum group have found a compromise that combines current test methods in a way that gives improved reliability and better control. We also see a development of new methods using non-solvent solutions that we believe will improve contamination testing in the near future.

Moisture Sensitivity Levels (MSL) for PCB

One direction of the velocity of PCB technology is increased complexity and density. With this increased complexity of the PCB, controlled humidity inside the boards is vital to avoid delamination and product failure. How do we control the moisture level inside the PCB and for how long can the PCB be kept in the assembly shop floor environment before the moisture level becomes a problem? Certainly, this depends on the base material's moisture absorption rate, and some materials like polyimides do absorb moisture at a rate that requires control.

Moisture sensitivity levels have been in use for components a long time, as described in J-STD001 but not for the PCB. Based on Elmatica´s internal MSL recommendation, I suggested at the 2017 IPC meeting and followed up this year with the result that the committee developing IPC-1601 will further develop and implement to the next revision of the standard. I believe this will be a valuable guide for users of PCBs with high moisture absorption levels.

Specifications–More Important Than Ever

Hand in hand with changes in the technology we must have precise specifications. Another unpaid job of mine (but a true pleasure and very exciting) is to chair CircuitData.

The other day, I received a PCB specification requiring me to follow IPC-610 Class 3, and with only fractions of a sufficient PCB specification. So, a time-consuming communication began. Hopefully, we will be able to deliver what the customer needs, but insufficient specifications make the process longer and more difficult.

To succeed with increased PCB options and complexity, a detailed and correct PCB specification is a must. The future is a digital specification file such as the open source CircuitData file in combination with an intelligent production file such as IPC-2581. Such files give much more information than the good old Gerber.

The Future

We cannot talk about the velocity of PCB technology without mentioning 3D printed circuits. I am following this from the sideline. 3D circuits including components will surely one day be a disruptive technology to the standard PCB, as we know it today with components soldered. That will be a new ballgame!

Even 3D circuits in the early stage of their life cycle, with the current PCB technology as I see it, will in the near future keep on following the same track towards miniaturization. What I call micro PCBs are today touching BGA substrate manufacturing and we need a term and a set of typical features that describes this group.

I also believe we will see an increased level of embedded technologies and complexity of mixed materials that will again challenge organizations like IPC to be up front with the development of standards. The changes we have seen over the last 10 – 15 years, unfortunately, have not been reflected by the standards at the same rate. The only way to improve the process of developing standards that meet the velocity of PCB technology is to participate.

Don't let the technology outrun you. Join in and take part in the exciting future of printed circuits. **PCB007**

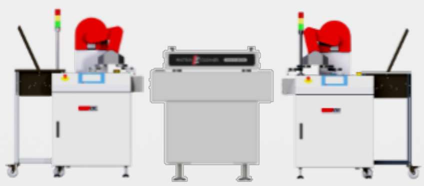
Jan Pedersen is senior technical advisor with Elmatica.

Advanced Copper Foil Expands Capacity with Enhanced Process Automation Tools

"ACF's manufacturing operation continues to expand capacity and productivity with increased automation. Material handling is a key issue especially for our growing sales of thin specialty copper foils.

With the EC24 Electrostatic Cleaner, we can maintain a clean manufacturing process to ensure that our customers get the best quality materials. Particles that were statically attracted to the copper surfaces have been completely eliminated by the new particle neutralizing technology in the EC24 Cleaner.

The system is such a success that we intend to fully automate the process with robotic handling equipment to provide a complete hands-free operation."



MATRIX E-CLEANER
MODEL EC24

ELECTROSTATIC TOUCHLESS PANEL CLEANER

Benefits

- Cost effective
- Panel thickness: 0.001" to 0.500" - Suitable for variety of applications
- No consumables
- Robust design with minimal maintenance - Low cost of ownership and designed to last > 15-20 years
- Options for particle removal

Applications

- Copper layers and panels before Dry Film
- Dry Film before Exposure or Direct Imaging
- Panels before and after Solder Mask
- Thin Films: PTFE, Foils, Flex circuit materials
- Before AOI
- Prepreg before packaging or layup
- Copper panels before packaging or layup
- Panels after drilling/deburring (removal of loose debris)
- Finished printed circuit boards before packaging

MATRIX
CIRCUIT BOARD MATERIALS

1-800-668-5447 • www.matrixusa.us

TORONTO • SANTA ANA • SANTA CLARA • CHICAGO

MilAero Highlights

The Vast Offerings in Laminate Technologies from TUC ▶

I sat down with George Hsin, chief strategy officer for TUC Worldwide, and Alan Cochrane, president of TUC North America to learn more about the company and their laminate products.

Rogers Unveils New Process Improvement Option for Flex Heater Dielectrics ▶

Rogers Corporation is pleased to introduce ARLON raPId polyimide substrates, an innovative solution for streamlining manufacturing and improving performance of flexible heater applications.

Interview with Dave Hillman: IPC's 2018 Raymond E. Pritchard Hall of Fame Award Winner ▶

A self-described "dinosaur" of the industry, Dave Hillman has been a steady force in all things solder-related at Rockwell Collins for 30 years.

Arlon EMD Achieves IPC's Qualified Product Listing Certification ▶

Arlon Electronic Materials, a specialty materials supplier based in Southern California, received IPC-4101 Qualified Products Listing Certification for all polyimide specification sheets.

Amphenol Invotec Awarded Cyber Security Certification ▶

As concerns about cyber security continue to increase, Amphenol Invotec is pleased to announce that it has been awarded the Cyber Essentials Plus certification.

Show & Tell: Corporate Awards Bestowed by IPC ▶

Every year IPC recognizes two companies that have made significant contributions to IPC and the electronics industry. This year's recipients were Northrop Grumman and Rockwell Collins, respectively.

TTM Technologies Completes Acquisition of Anaren ▶

TTM Technologies Inc. announced that it has completed its acquisition of Anaren, Inc. The combined company had pro-forma 2017 revenue of $2.9 billion.

Microtek Laboratories China Completes First U.S. IPC-4101E Validation Services Test Program ▶

Microtek Laboratories China has completed the first qualification testing program for IPC-4101 Validation Services for a U.S. manufacturer of copper-clad laminates and prepreg.

Lockheed Martin and Cobham Team to Develop Next Gen Jammer Low Band for U.S. Navy's Electronic Warfare Aircraft ▶

Lockheed Martin and Cobham are joining forces for the Next Generation Jammer Low Band (NGJ-LB) competition to replace the U.S. Navy's ALQ-99 tactical jamming system currently on the E/A-18 Growler aircraft.

What's in your ET?

Testing Todd

by Todd Kolmodin, GARDIEN SERVICES USA

With all the buzz around automation, paperless operation, and integrated processes, it's time to think about how the connected systems work within an electrical test department. We are all familiar with computer-aided design (CAD) and computer-aided manufacturing (CAM), but with electrical test we can also add computer-aided test (CAT) and computer-aided repair (CAR).

Back in the '80s, Bob Whitehead, of Electronic Packaging Company in Dallas, Texas, coined the phrase "The 4 Cs" with his vision of an integrated electrical test platform. Although Bob is no longer with us, I'm sure he would smile to see that his vision has grown even further than perhaps he imagined. As many of us can remember back in the day, ET was nothing more than a couple drilled plexiglass plates, some one-inch pins and a universal single-sided test machine capable of "self-learning," a "known good board," and then testing of the subsequent product. There was even the learn-comparison avenue for which you had no known good board and learned one from the lot, and then compared the rest to the learned board. It worked well for the time being unless the entire lot was bad. Bad board learned, all bad boards the same, the machine said "pass." This would be a dangerous concept today to be sure.

So, what's in ET today? Self-learning is a thing of the past in most cases, thank goodness. The fixture testers have evolved from the original single side, single-density versions to double density, quad density and even octal density! They can test by pre-programmed data sets, provide data logging, serialization, print bar codes, and even process the product automatically.

This is where computer-aided test (CAT) really shines. In ET today, orders can be processed simultaneously on multiple machines

ENEPIG has *(at last!)* reached its ***ultimate*** performance potential!

- Uniquely flexible and stable electrolytes, with Talon electroless/alloyed palladium phos
- Lowest make-up and operating costs
- Pure palladium formulation available
- Reduction-assisted TWX-40 plates up to 8 µin of gold, with no nickel corrosion or deposit porosity

UYEMURA USA

www.uyemura.com

North America’s Leading Experts in Final Finishes, Via Fills, Acid and Electroless Coppers, Immersion Silver and Tin; also MEC Surface Treatments and Auruna Gold Electrolytes.

Corporate Headquarters: 3990 Concours, #425 • Ontario, CA 91764 • ph: (909) 466-5635

Tech Center: 240 Town Line Road • Southington, CT 06489 • ph: (860) 793-4011

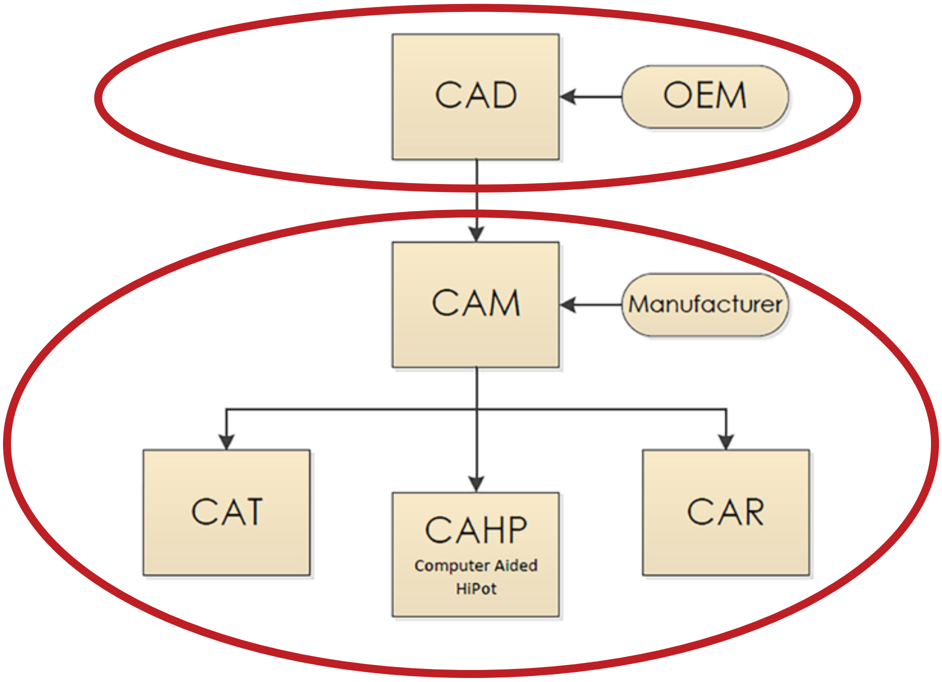


Figure 1: Connected systems within an ET department.

with floor ERP systems tracking results from any given machine. Serial number, operator, parameters, and yield can all be captured seamlessly. Between fixture testers and flying probes, the flying probes can work with the fixture testers to verify non-conforming product. This keeps the fixture testers running and not waiting to troubleshoot each board. The probers can validate if the defects are real from the fixture testers and pass the product with errors that are deemed false. This is done by the test floor integration process where data fault logs are captured, the board receives a serialized bar code, and the flying probe reads that barcode. It then reads the fault data and performs a retest based on the same CAM data used at the fixture tester. Conforming boards can automatically be marked as well.

Continuing the process, passed boards receive a passed tag while non-conforming product will receive a fault tag, complete with barcode. This fault data is also captured. We move now to CAR. The product moves to the repair/troubleshooting area where the bar codes can be read, and the fault locations presented on a screen for easy translation to the board itself. It can be quickly determined whether the board can be reworked, or the fault requires unfavorable disposition (scrap). From here, reconciliation of the order from all facets of the ET operation can be completed. Pass/fail reconciliation, serialization, and final inspection can all be achieved.

So, we can see that the computer and automation age has hit ET as well. Many processes in ET are no longer the manual, tedious processes of the past. Still, the entire manufacturing theatre relies on the OEM to begin the process via CAD. Then the full integrated process of CAM through CAR exists under one umbrella. Even now, the once manual HiPot (dielectric breakdown) test has evolved to automated options. Flying probes are now able to automatically perform the tests that once were the tasks of a single operator. Although an operator is still required for the machine, the tedious movements of probes to different pairs and waiting for the test is now automated.

So we see in Figure 1 that, although CAD (OEM) is still the first attribute, manufacturing including the functions of ET are all in the connection equation. **PCB007**

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

Surface Preparation and Cleaning, Part 2

Trouble in Your Tank

by Michael Carano, RBP CHEMICAL TECHNOLOGY

Some type of cleaning and surface structuring is required in virtually every step of the printed circuit manufacturing process, from preparing the raw laminate for etch or plating resist to final assembly board cleaning before shipment. In this edition of "Trouble in Your Tank," I will attempt to cover most of the general cleaning problems that can occur in any of these steps and, where possible, any problems unique to a specific manufacturing step. Many cleaning procedures are tightly integrated within certain manufacturing processes, such as plating, and may also be covered in other columns or feature articles.

This section is divided into two categories: mechanical cleaning surface preparation and chemical cleaning. However, this is only a general presentation. More details with chemical and mechanical cleaning will be covered in future columns.

One should make a clear distinction between the method of surface preparation and the nature of the surface alteration affected by such a method. The mechanical method of brush scrubbing changes the topography as well as the chemical composition of the surface (e.g., removal of oxide, chromium, etc.). On the other hand, the mechanical method of jet-pumice scrubbing restructures the topography with little or no abrasion of copper. The chemical composition of the surface stays very much the same, except for the removal of loosely held oxide and some redistribution (e.g., of chromium from conversion coatings into deeper layers of the surface). A chemical surface preparation method such as

Integrate QA Solution

Because everyone's QA needs are just a little bit different.

Integrate is a fully customized solution, and no two contracts are exactly the same. No matter what size customer you are, we can tailor AOI, testing, final inspection, or a combination of all three services to fit you. And you only pay for the product that actually passes quality assurance, not on panels produced or tested.

Find out if our Integrate solution is right for you!
www.gardien.com/why-integrate

GLOBAL FOOTPRINT
WITH A LOCAL PRESENCE

30+ YEARS
EXPERIENCE

30 YEARS OF PCB
INDUSTRY EXPERIENCE

alkaline cleaning will change the chemical nature of the surface by removing organic contaminants, but will not affect the topography, whereas a persulfate etch will change both.

In general, surface preparation is done to assure good adhesion of metal, dielectric, photoresist, or soldermask to the prepared surface, although avoiding excessive adhesion could also be the object. Take the example of surface preparation before dry photoresist lamination. One can measure the surface profile of the copper surface using the technique of profilometry. This technique measures changes in the structure or profile of a surface. The data collected gives information such as[1]:

Ra—Arithmetic mean surface roughness: Arithmetical mean of the sums of all profile values.

Rt—Total height of the roughness profile: Sum from the height Zp of the highest profile peak and the depth Zv of the lowest profile valley within the measured length (ln).

Rzi—Maximum height of the roughness profile: Sum from the height of the highest profile peak and the depth of the lowest profile valley within a sampling length.

Rz (max)—Maximum surface roughness: Largest of the five Rzi values from the five sampling lengths "i" over the total measured length.

Rz—Surface roughness depth: Mean value of the five Rz values from the five sampling lengths over the total measured length.

One must be careful about encountering differential etching. This occurs when spots of organic residues have not been cleaned from the surface of the copper. One common source of these residues is epoxy or pre-preg dust that can deposit on the copper.

In addition, the overall surface roughness of the material is often contributed by the glass fabric styles and thicknesses. This is especially notable since the industry has moved to thinner core materials and thinner copper foils. Be prudent when working with these thinner materials as mechanical surface preparation may stretch thinner materials. In contrast, while chemical cleaning will not stretch the material, excessive copper removal may impact signal conductivity. Excessive copper removal or an overly roughened surface will impact signal integrity resulting in insertion loss at high frequencies.

Several types of copper foil are used today. The two main categories are electrodeposited (ED) foil and rolled annealed (RA) foil. And within each of these categories are several variations. As an example, there are several foil types within the ED category. These differ based on the extent of the copper pro-

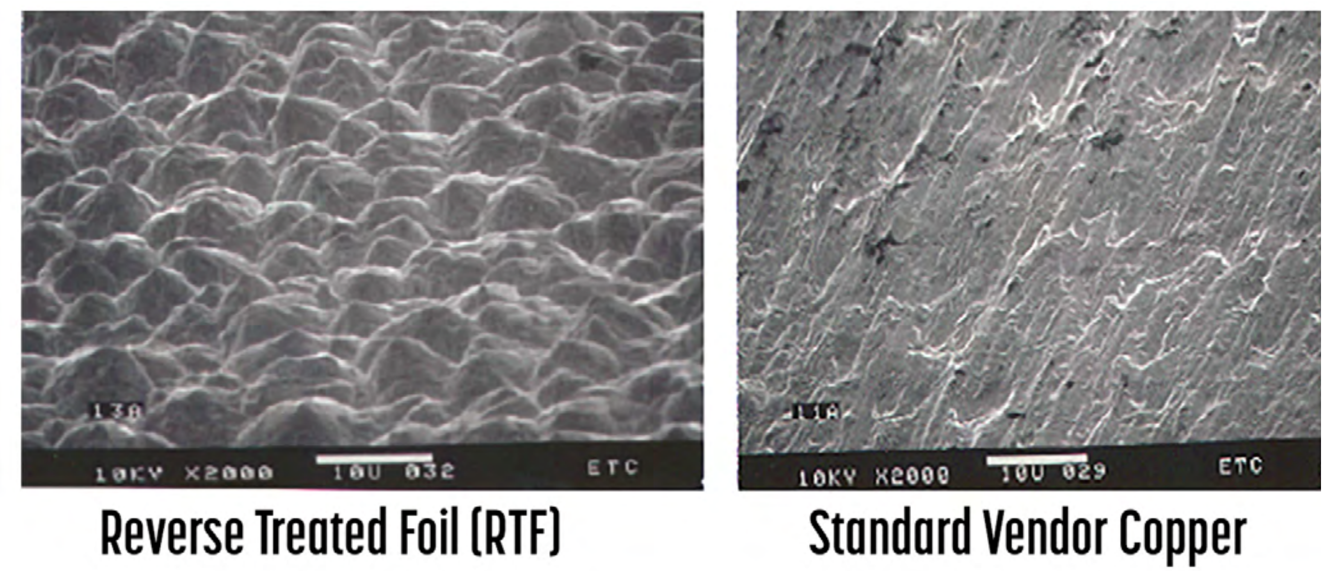


Figure 1: Comparison of RTF to standard ED copper foil.

file. In addition, during the past several years, low profile ED copper foils have been introduced with an enhancement known as reverse treat. Essentially, the shiny side of the copper foil (also known as drum side) has been treated with material to enhance the bond of the photoresist to the copper foil (Figure 1).

It is important to note that if one employs RTF foil, there should be minimal if any microetching or scrubbing of the RTF. Any aggressive etching or cleaning will negatively impact the topography one is paying for with RTF. It is suggested however that an alkaline cleaner followed by an acid cleaner (to remove the chromate conversion coating) be used. One must still have a clean copper surface to facilitate resist adhesion. **PCB007**

References

1. Mitutoyo website.

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

Laser Frequency Combs May Be the Future of Wi-Fi

Wi-Fi and cellular data traffic are increasing exponentially, but unless the capacity of wireless links can be increased, all that traffic is bound to lead to unacceptable bottlenecks.

Upcoming 5G networks are a temporary fix, not a long-term solution. For that, researchers have focused on terahertz frequencies, the submillimeter wavelengths of the electromagnetic spectrum. Data traveling at terahertz frequencies could move hundreds of times faster than today's wireless.

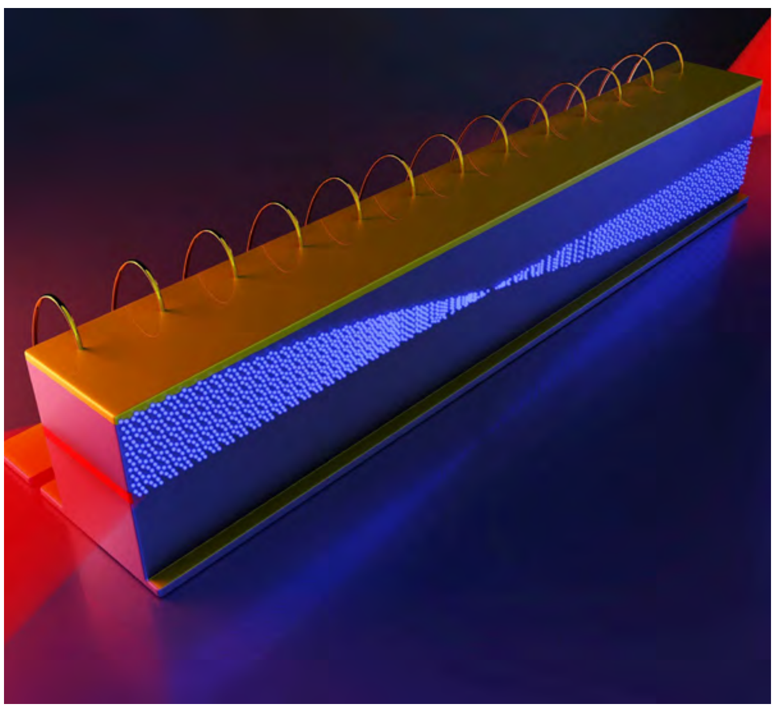
In 2017, researchers at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) discovered that an infrared frequency comb in a quantum cascade laser could offer a new way to generate terahertz frequencies. Now, those researchers have uncovered a new phenomenon of quantum cascade laser frequency combs, which would allow these devices to act as integrated transmitters or receivers that can efficiently encode information.

"This work represents a complete paradigm shift for the way a laser can be operated," said Federico Capasso, the Robert L. Wallace Professor of Applied Physics and Vinton Hayes Senior Research Fellow in Electrical Engineering and senior author of the paper. "This new phenomenon transforms a laser—a device operating at optical frequencies—into an advanced modulator at microwave frequencies, which has a technological significance for efficient use of bandwidth in communication systems."

Unlike conventional lasers, which emit a single frequency, these emit multiple frequencies simultaneously, evenly spaced to resemble the teeth of a comb. Today, optical frequency combs are used for everything from measuring the fingerprints of specific molecules to detecting distant exoplanets.

This research, however, wasn't interested in the optical output of the laser.

"We were interested in what was going on inside the laser, in the laser's electron skeleton," said Marco Piccardo, a postdoctoral fellow at SEAS and first author of the paper.



The Value of Coopetition

The Right Approach

by Steve Williams, THE RIGHT APPROACH CONSULTING LLC

As our industry continues to evolve and shape-shift, printed circuit board manufacturing continues to shrink through consolidations and attrition. Unfortunately, this trend will most likely continue, albeit at a slower pace than over the last decade. In what has truly become a global economy, partnering with world-class suppliers is mandatory, and excluding a sub-set of this dwindling supply base because they also happen to be in a crossover business will severely hinder this effort.

Coopetition

Although I cannot take credit for coining this buzz word that combines "cooperation" and "competition," I have embraced the concept and believe it is good for our industry (the term coopetition was coined by Ray Noorda, the founder of Novell). I have noticed a clear movement in our industry away from the arch-enemy mindset to a more collaborative methodology, in other words, complementary v. competitive relationships. The value proposition to the customer in this scenario is providing world-class technology and service at a competitive price; the "protect our trade secrets" mentality just won't work anymore. And if we are really being honest, there are not many trade secrets in our business any longer (if ever any existed).

Coopetition is not a new concept; the most visible example of everyday usage can be found in the realty industry. Frustrated at manually scouring competitive listings when they did not have a property that met the customer's needs, the industry banded together and formed the MLS (Multiple Listing Service). This allowed them to expand their services to customers and capture a portion of the market that they otherwise could not serve. Isn't that last statement what our business is all about?

Other examples are retail and fast food; most have figured out that they will attract more overall customers by geographically locating stores where their competition is

(i.e., malls). They realize that they cannot meet every customer need, but with a proximity to many competitors that collectively can, they will get more customers than they would receive at a discrete location. To paraphrase my high school classmate Andy Rooney, "Did ya ever notice there is a Burger King within a stone's throw from most McDonalds?"

Two Schools of Thought

Collaboration with suppliers, customers and firms producing complementary or even the same products can lead to expansion of the market and the formation of new business relationships. There is one school of thought that sees business strictly as competition, where doing business is like waging war and one can't win unless someone else loses. Another school sees business strictly as cooperative, utilizing teams and partnerships to succeed. But business really is both cooperation and competition: Coopetition. Figure 1 depicts a graphical representation of the "Coopetition Web" that defines this model.

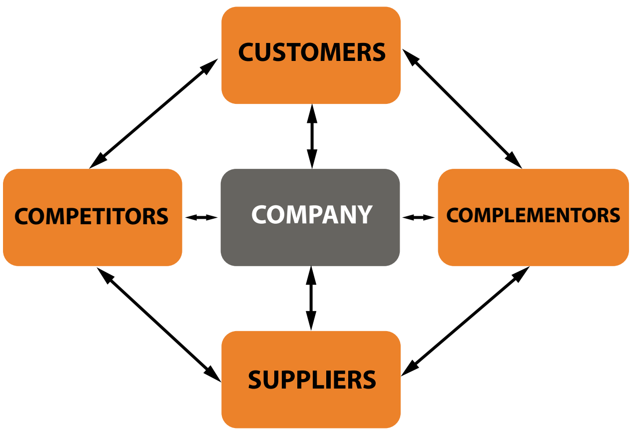


Figure 1: The coopetition web.

Blurred Lines

During a recent visit to another client, senior management stated that 35% of their revenue is derived from customers who are also competitors! That is truly a remarkable number, one that causes this supplier absolutely no concern or threat. I personally believe that the recent recession may have taught us a collective lesson, one that has a lot to do with this paradigm shift. A simple way to describe this relationship is to think of it as such: If a customer values your product/service more when combined with another's, this is coopetition. If a customer values your product/service less when combined with another's, this is competition.

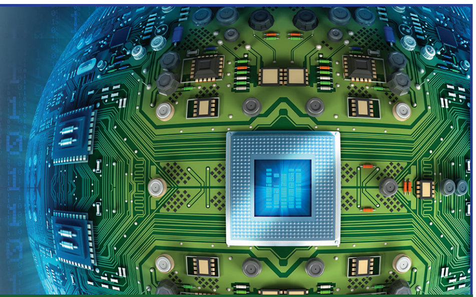
Competitors are a key part of both our micro and macro economy. Competitors offer choices, bring new ideas and improvements to markets, help educate customers, and drive improvement within our own organizations. Every business must coexist with competitors, so the choice becomes whether to treat them as enemies or selectively as colleagues. At the end of the day, competitors have a single unifying goal—they all want more business. While debating this point, a friend recently told me, "There are only so many pieces of the pie to go around." I argued that you can always make more pies. Market share has an interesting way of redefining itself so that there is always enough pie for all.

The Hadco Example

In a prior life running global sourcing for a large contract manufacturer, my largest and best PCB supplier was Hadco. One day, Hadco was purchased by Sanmina, and word came down from on high that we had to move $20 million of business just because Sanmina was a competitor. This short-sighted thinking created more problems than it solved; but this was a different time in the industry. Refusing to use a world-class supplier was akin to throwing the proverbial baby out with the bath water.

Of course, prudence is the operative word. I am not suggesting throwing caution to the wind with an open-kimono naiveté, as there will always be the occasional predatory wolf and sheep situation. However, with a certain degree of trust and diligence in partnering with the right organization, strategic advantages can be attained on both sides. **PCB007**

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



ITI & IPC Conference on Emerging & Critical Environmental Product Requirements

June 4 • BOSTON, Massachusetts
June 6 • CHICAGO AREA, Illinois
June 8 • SILICON VALLEY, California

It is a continuing challenge to stay current on global environmental regulations and issues such as:

- The EU Circular Economy Strategy
- EU RoHS exemptions
- REACH regulation registration and enforcement
- China and Southeast Asia environmental restrictions
- The Toxic Substances Control Act (TSCA)
- California Green Chemistry Initiative

That is why IPC and ITI are again joining forces to help keep you ahead of the curve and connect you with leading industry speakers, update you on the latest trends and offer networking opportunities at the **2018 Emerging & Critical Environmental Product Requirements Conference**.

This conference will provide anyone who is responsible for keeping their organization in compliance with environmental regulations the tools they need to comply with legal, regulatory, and customer requirements.

Register today and stay ahead of the curve on the changing state of global environmental regulations!

For more information, contact **Ken Schramko**, IPC director of government relations, at **KenSchramko@ipc.org**.

Electronics Industry News and Market Highlights

NAND Flash Prices Continue to Decline as the Slight Oversupply Continues in 2Q18

The NAND Flash market has witnessed a slight oversupply in 1Q18. The growth momentum remains weak in 2Q18 although the demand increases. It is expected that the slight oversupply in NAND Flash market will remain and the prices will continue to decline.

EPTE Newsletter: Consumer Electronics in the Bathroom

DKN Research is the world's leading engineering firm specializing in microelectronics and packaging. We review business trends, dissect new electronic products, and provide state of the art technology. Advancements in electronics now extend to the bathroom, in particular, the toilet.

Trump Administration Proposed to Apply a 25% Tariff on 1300 Chinese Products

The Trump administration published a list on April 4, 2018 of 1300 Chinese exports and proposed to apply a 25% tariff on these products.

Breakthrough Made in Atomically Thin Magnets

Cornell researchers have become the first to control atomically thin magnets with an electric field, a breakthrough that provides a blueprint for producing exceptionally powerful and efficient data storage in computer chips, among other applications.

Scientists Discover a Link Between Superconductivity and the Periodic Table

Scientists from Moscow Institute of Physics and Technology and Skoltech have demonstrated the high-temperature superconductivity of actinium hydrides and discovered a general principle for calculating the superconductivity of hydrides based on the periodic table alone.

U.S. Trade Tensions with China Hit Fever Pitch

Following through on his 2016 campaign promise, President Trump is implementing trade policies that buck conventional wisdom in Washington, D.C. and among U.S. businesses.

OFFSET "Sprinters" to Pursue State-of-the-art Solutions for Second Swarm Sprint

DARPA's OFFensive Swarm-Enabled Tactics (OFFSET) program envisions future small-unit infantry forces using small unmanned aircraft systems (UASs) and/or small unmanned ground systems (UGSs) in swarms of 250 robots or more to accomplish diverse missions in complex urban environments.

CPCA 2018 Seminar Overview

Article by Happy Holden
I-CONNECT007

I had the good fortune to speak at a seminar sponsored by the CPCA and organized by the China Team of I-Connect007 in Shanghai on March 22. This full-day seminar was on one of today's hot topics, "Automation in PCB Manufacturing." Seven talks were given:

1. "Planning More Automation (of HDI) In Your Factory," by Happy Holden, I-Connect007
2. "The Benefits of Deploying Robots and its Application in Manufacturing," by Wen-Tao Bao, Universal Robots
3. "Whelen PCB as an Example of Industry 4.0," by Jochen Zeller, AWP
4. "HANS Lasers in PCB Fabrication," by Guo-Dong Chen, Han's Laser Inc.
5. "Using Raw Data to Develop an Intelligent Manufacturing Solution for Process Control," by Les Sainsbury, Xact PCB Ltd.
6. "Essential Process Control of Automated HDI," by Happy Holden, I-Connect007
7. "Whelen PCB—A Case Study of Full Automation and Zero Effluent," by Happy Holden, I-Connect007

First Presentation

I started off the seminar with a keynote on automation technology and strategies. Automation has been employed in manufacturing since the early '80s and pioneered by the automotive industry and the Computer and Automated Systems Association of the Society of Manufacturing Engineers (CASA/SME). CASA has publicized the strategy and called it CIM—computer-integrated manufacturing.

CIM has seven key areas of focus:

1. Computer-aided design
2. Group technology
3. Manufacturing planning and control
4. Robotics
5. Automated material handling
6. Computer-aided manufacturing/process control
7. Computing technologies coordinating all of these

After going over some slides on understanding the activities and application of CIM, including integration of "Islands of Automation," I landed on the CIM-directed modernization plan as seen in Figure 1. This is the blueprint for automation and consists of six phases:

1. Environment assessment
2. Program strategy
3. Conceptual design
4. Detailed design and requirement specifications
5. Deployment of design
6. Implementation and execution

Phase 4 is the most important step, as it defines the requirements definition (RD). The RD requires a planning methodology, and I went over the method of benchmarking human and machine activities for mechanization and systemization (data and information) for each process workstation for the entire manufacturing process. The definitions of mechanization and systemization are seen in Figure 2 and capture all the labors of production workers and automated machines and their information. By defining each workstation (the present), the incremental improvement in mechanization and systemization can be planned (the future), as seen in Figure 3.

I went on to further define mechanization in PCB fabrication and the dimensions of systemization including modern networking and application software developed to integrate purchased software into PCB equipment. The use of the SEMETECH GEMS/SECS II protocols from the IC wafer fabrication industry provided a useful model to follow.

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

Figure 1: The six phases of a CIM-directed modernization plan.

MECHANIZATION CLASSES

A	Manual	Actions conducted by human with simple tools	0 - 9% by machine
B	Semi-manual	Actions conducted by human with complex tools or machines, some activities part of the hardware	10 - 25% by machine
C	Machine assisted	Actions conducted by machine with many tasks done by tools or machines	26 - 50% by machine
D	Human assisted	Actions conducted by machine with many tasks done by humans	51 - 75% by machine
E	Semi-automatic	Most actions done by machine with human in a monitoring or supervisory role	76 - 98% by machine
F	Fully automatic	All actions done by autonomous machines with minimal or no human role	99 - 100% by machine

SYSTEMIZATION LEVELS

1	Manual information collection	Set parameters, record past occurrences – documents (reports) produced at a later time	0-9% collected by computers
2	Batch computer/ human collection	Actions conducted by human with complex tools or machines, some activities part of the hardware	10-24% collected by computers
3	Online computer/ human collection	Actions conducted by machine with many tasks done by tools or machines	25 - 49% collected by computers
4	Real time computer/ machine	Actions conducted by machine with many tasks done by humans	50 - 74% collected by computers
5	Dedicated supervisory control	Most actions done by machine with human in a monitoring or supervisory role	75 - 98% collected by computers
6	Fully auto gateway/ network control	All actions done by autonomous machines with minimal or no human role	99 - 100% collected by computers

Figure 2: Mechanization and systemization definitions and classifications.

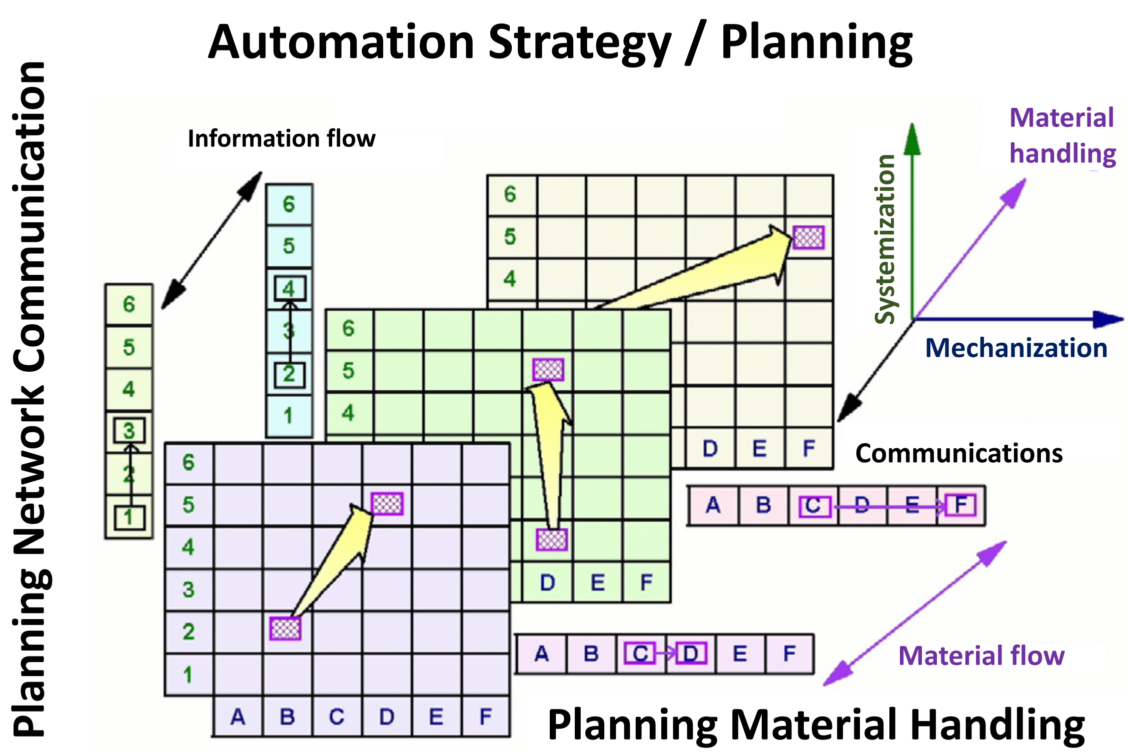


Figure 3: Automation strategy and planning visualization for PCB work centers.

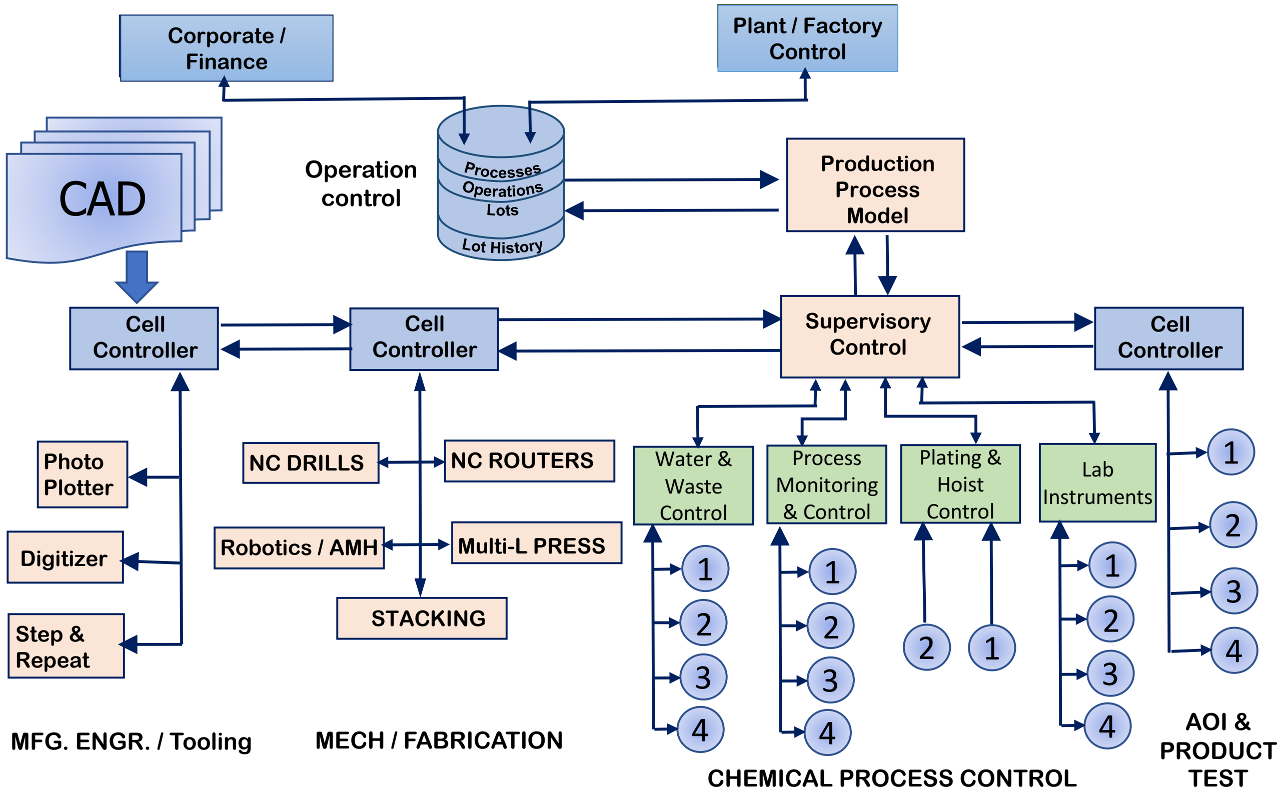


Figure 4: CIM/CAM system hierarchy of supervisory computers for HP's automated PCB fabrication facility.

I finished off the talk with an example of PCB fabrication automation at Hewlett-Packard, an example of Industry 3.0 CIM. The supervisory systems are shown in Figure 4.

Second Presentation

The second talk was by Wen-Tao Bao of Universal Robots and emphasized the increasing use of robots in the electronics industry in China. Growth of robots and their applications have increased steadily since 2001. Electronic assembly is one of the fastest growing markets for robots in China, but automotive is quickly becoming the largest application. UR has three articulating arm robots (Table 1), popular for PCB fabrication and assembly.

	UR3	UR5	UR10
Load (kg)	3 kg	5 kg	10 kg
Precision (mm)	+/- 0.03 mm	+/- 0.03 mm	+/- 0.03 mm
Reach (mm)	500 mm	850 mm	1300 mm
Weight	11 kg	18.4 kg	28.9 kg
Power Usage	100 W	150 W	250 W

Table 1: Three models of Universal Robots used in electronics manufacture.

Bao then showed examples of the usage of these three models of robots that included light assembly, electronic packaging, custom soldering and welding, automotive assembly, parts assembly/handling and the assembly of these UR robots. He concluded with an example of the ease of programming this type of intelligent robot.

Third Presentation

The third talk was by Jochem Zeller of AWP Group, a worldwide company specializing in horizontal wet processing, materials handling and automation, and copper etchant recycling. Zeller showed an overview of the large number of different PCB equipment handling and processing equipment that they design and supply (Figure 5).

As an example, Zeller highlighted a recent project for Wurth Elektronik, in Germany, where they automated the entire solder mask process using custom barcode readers to control legend, solder masking and curing. The bulk of his slides were about the new expaniNEMI MEPTEC SMTA Surface Mount Technology Association

Medical Electronics Symposium 2018

May 16 & 17

University of Texas at Dallas • Dallas, TX

SMTA, INEMI, and MEPTEC have joined forces to again host this international conference, focusing on advances in electronic technologies and advanced manufacturing, specifically targeting medical and bioscience applications. Our last conference attracted about 200 attendees and more than 30 exhibitors. In prior years, MEPTEC's and SMTA's conferences were held in Phoenix, AZ and Milpitas, CA, respectively, drawing technology experts, entrepreneurs and service providers that work in this niche technology space. Typical applications within this space involve implantable defibrillators, neurostimulators and drug delivery, interventional catheters, pillcams, ultrasound transducers, hearing aids, biosensors, microfluidics, wireless communications, as well as future diagnostic and treatment solutions that may use stretchable electronics, microelectromechanical systems (MEMS) or nanoelectromechanical systems (NEMS). ◆

TECHNICAL COMMITTEE

General Chair:
Chuck Richardson, iNEMI

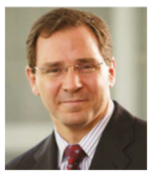
Technical Chairs:
Don Banks, Abbott
Peter Tortorici, Ph.D., Medtronic Microelectronics Center

Dock Brown, DfR Solutions
Dale Lee, Plexus Corp.
Glenn Robertson, Processes Science Incorporated
Nicholas Leonardi, TechDirect Consulting
Gary Tanel, Libra Industries

REGISTRATION SPECIAL
Four Registrations for the Price of Three!

KEYNOTE SPEAKERS

Sensorizing and Connecting Medical Devices
Cory Forbes, CTO
Nypro



Robotic Surgery: Where Are the Opportunities?
Kemp H. Kernstine, Sr., M.D., Ph.D.
Division of Thoracic Surgery
UT Southwestern Medical Center

Sensors for Medical Applications: Unlocking the Value
John Burnes, Medtronic Technical Fellow
Director of Implantable Core Teams
Cardiac Patient Monitoring and Diagnostics
Medtronic

Multiple Track Topics Include:

■ **TRACK 1:**
Designs, Components and Assembly for High-Density Medical Electronics Solutions

■ **TRACK 2:**
Next Generation Microelectronics for Changing Healthcare Markets

Sponsorship Opportunities and Exhibit Spaces Available

REGISTER TODAY AT SMTA.ORG/MEDICAL

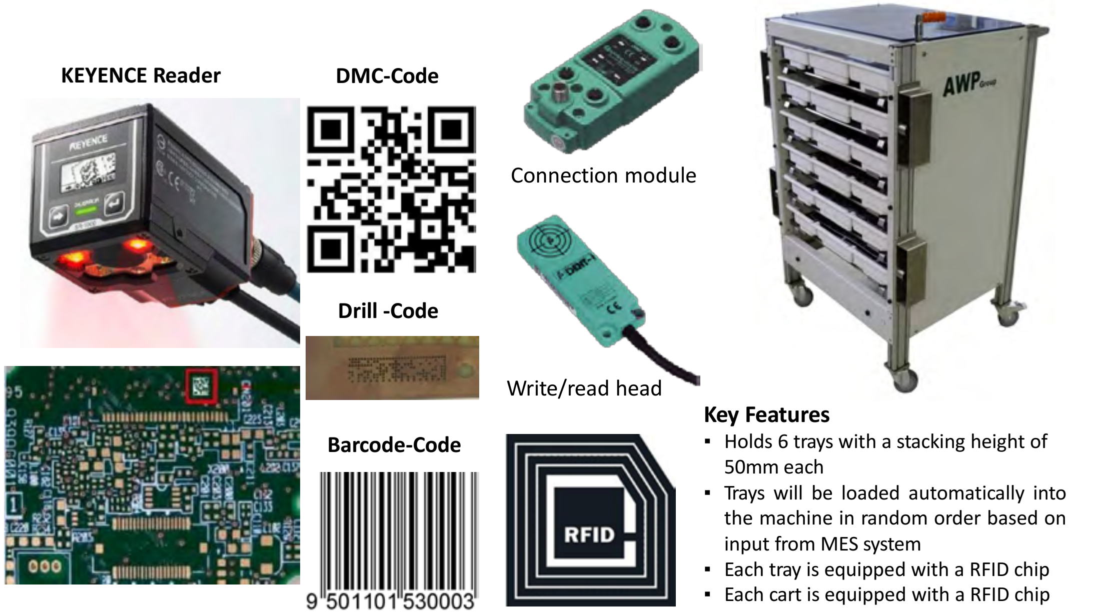


Figure 5: The special KEYENCE reader capable of reading the three different barcodes employed on PCB panels and materials (in process) and the RFID used on the material handling trays and carts.

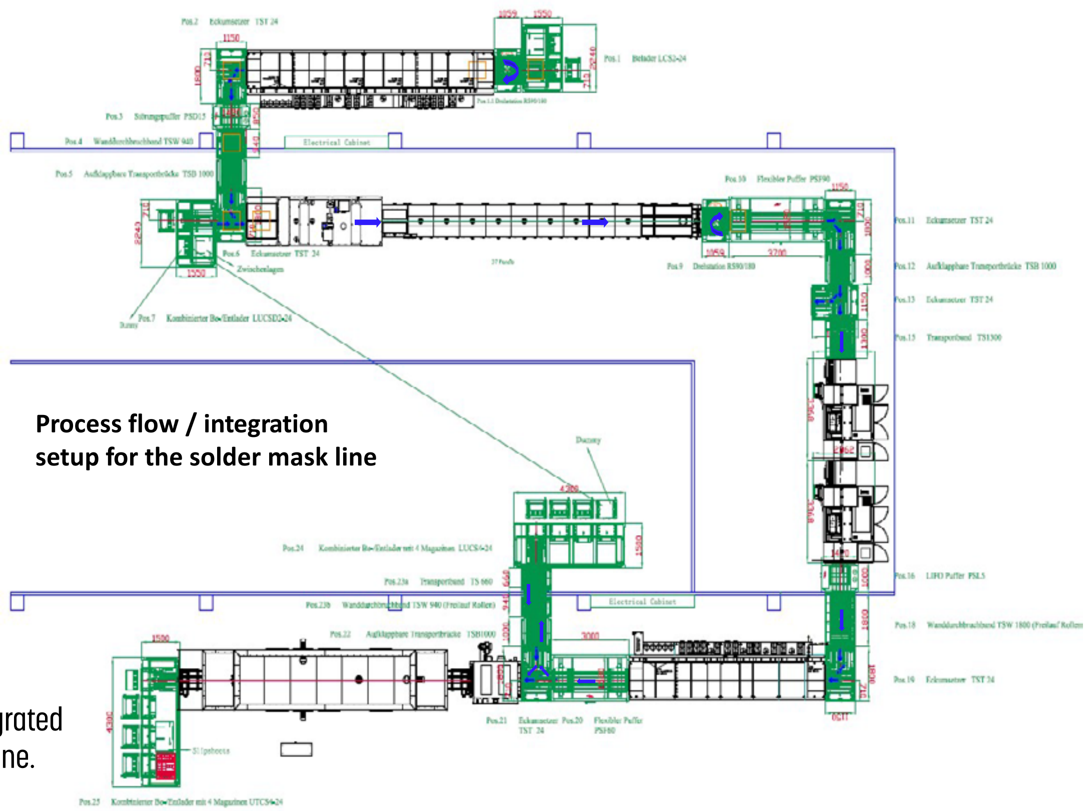


Figure 6: Integrated solder mask line.

sion of Whelen's multilayer facility in New Hampshire. This is the most automated PCB fabrication facility in the world and famous for its "Green Plus Lean" manufacturing strategy. He went on to illustrate the automation they supplied:

1. Integrated solder mask line (Figures 6, 7, 8, 9)
2. Fully automated inner layer line with automatic materials retrieval (Figure 10)
3. Fully automated multilayer layup and solder mask final cure (Figure 11)
4. Automatic stacking/destacking for

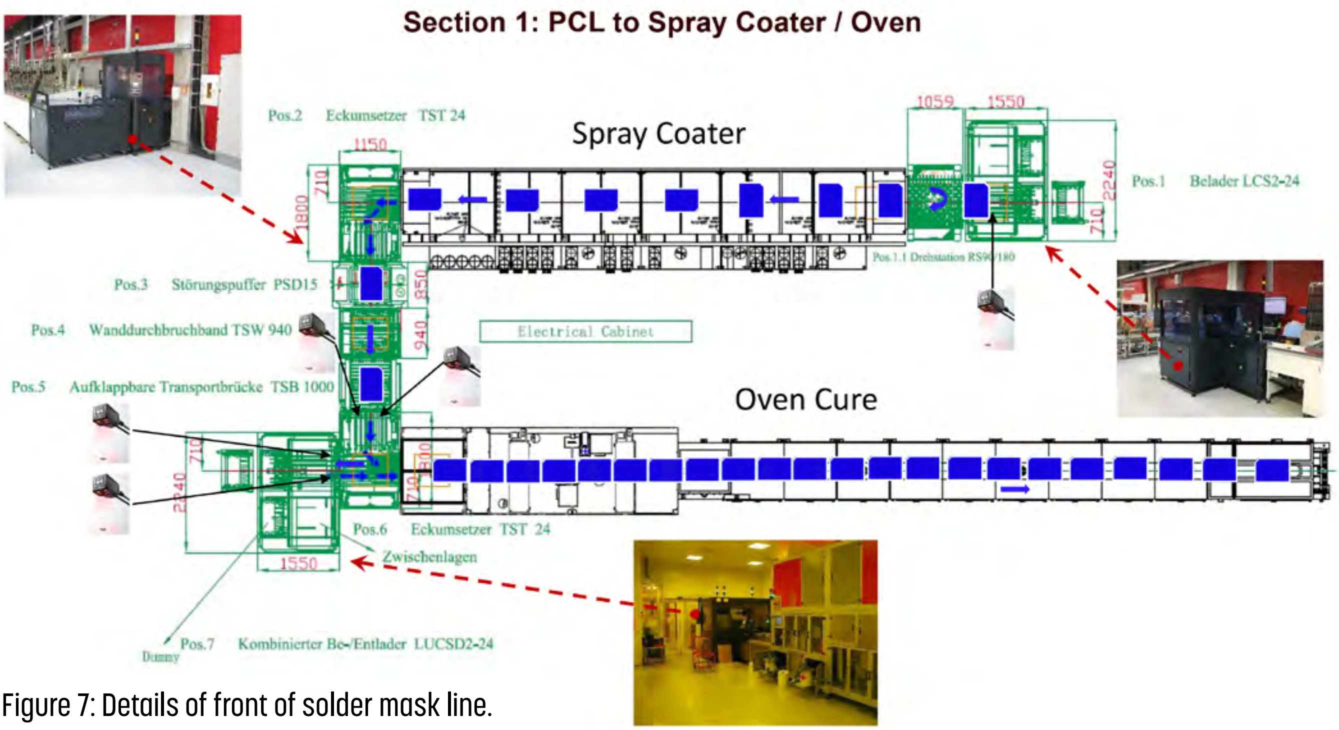


Figure 7: Details of front of solder mask line.

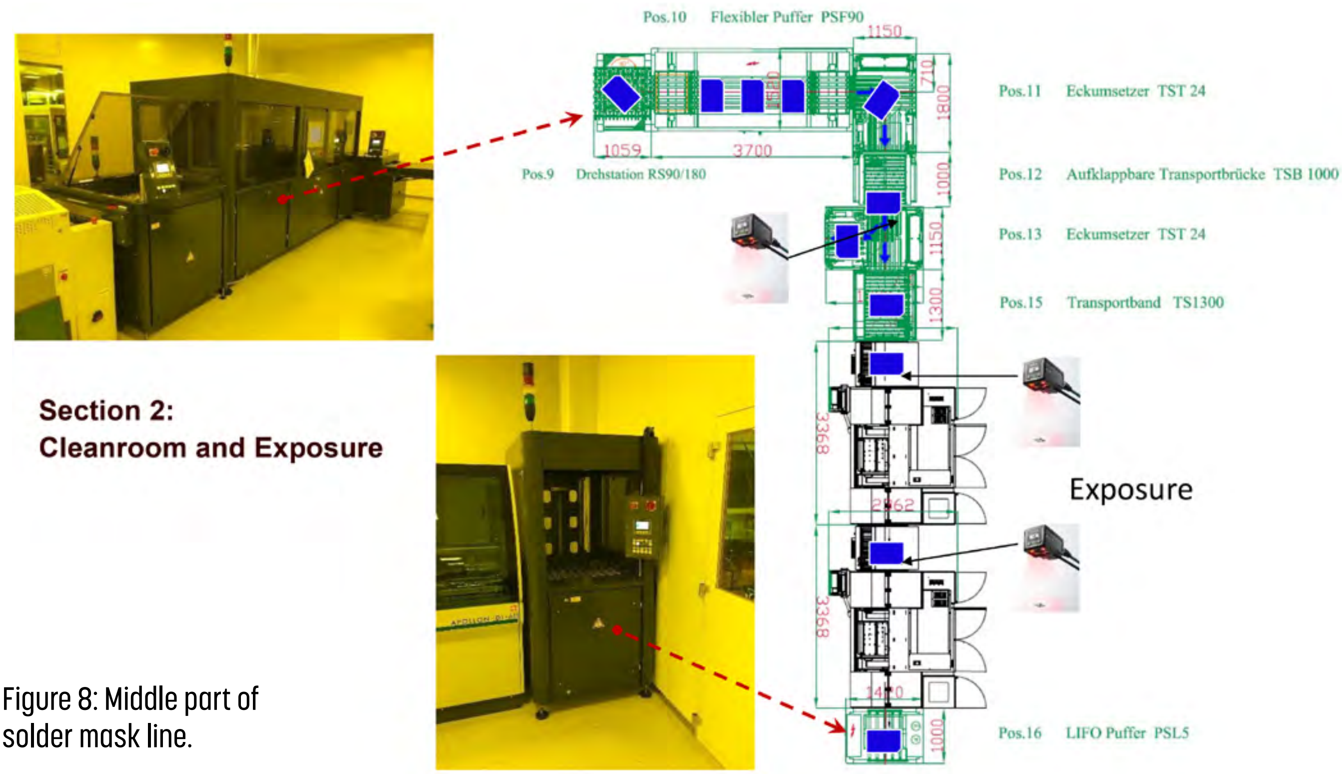


Figure 8: Middle part of solder mask line.

drill/router area (Figure 12)

5. The fully integrated horizontal Atotech plating area (Figure 13)

The new Whelen facility is now running final startup panels alongside of the current automated facility. Commercial operation is expected to begin in late this spring.

An informative interview with the principals of AWP and Whelen's Alex Stepinski, conducted at productronica 2017, and published in the January 2018 issue of *PCB007 Magazine*[1].

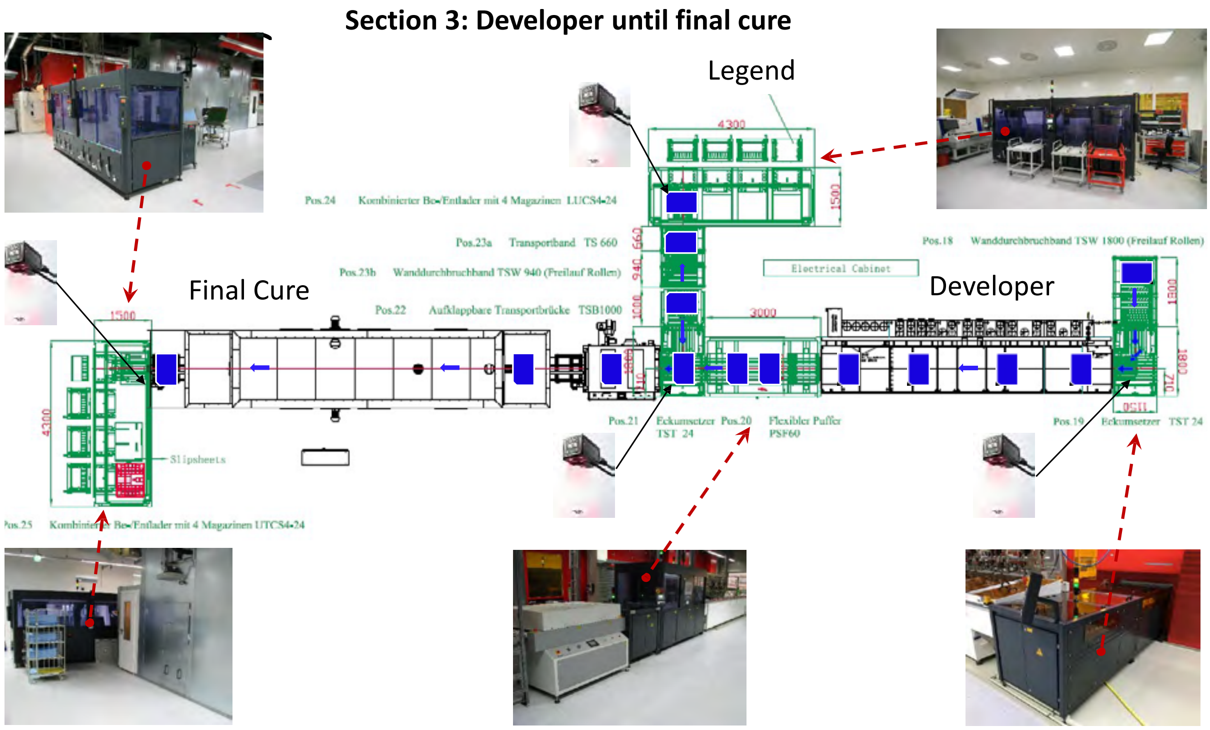


Figure 9: Legend and end of solder mask line.

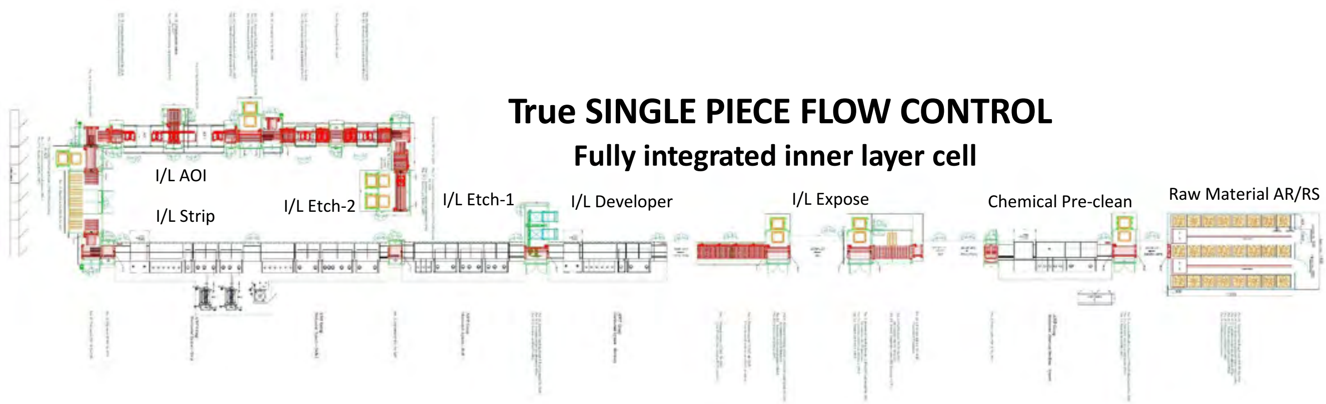


Figure 10: Inner layer processing line including automated materials warehouse and AS/RS.

Fourth Presentation

The fourth talk was by Guo-Dong Chen of Han's Laser, who spoke about the various models of Han's UV and CO_2 laser drills. Their models come as either auto-load or robot load/unload. These drills are tied into the facility's MES computer system and have several recipes that can be downloaded.

Fifth Presentation

Next was Les Sainsbury of X-Act PCB Ltd. His company specializes in software and processes to measure and improve process control for PCB fabrication. In this case, for Whelen, they supplied the software to measure and integrate registration data from various sources to control drilling and direct exposures. In general, they utilize a modular implementation to establish proof of concept and demonstrate their business value:

- Allows use of existing capable equipment
- Application-focused data control and communication systems
- Strengthens existing infrastructure
- Does not require a new factory
- Is achievable in the short term

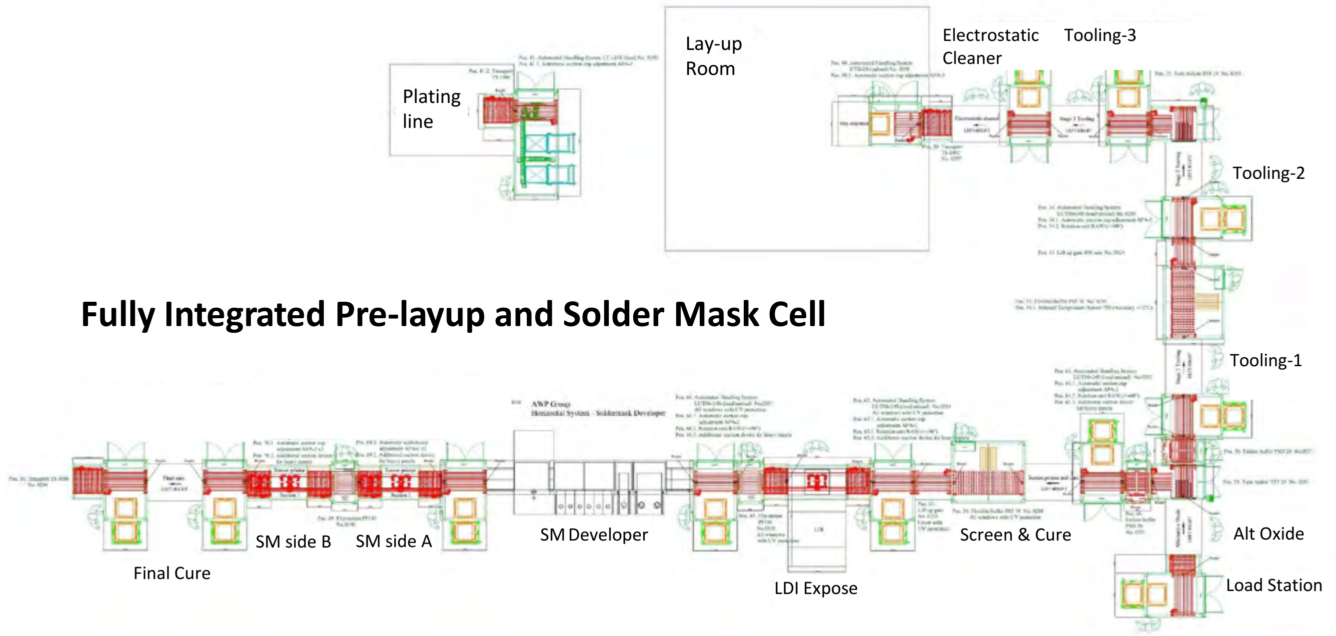


Figure 11: Integrated multilayer layup and lamination prep and the final cure for solder mask.

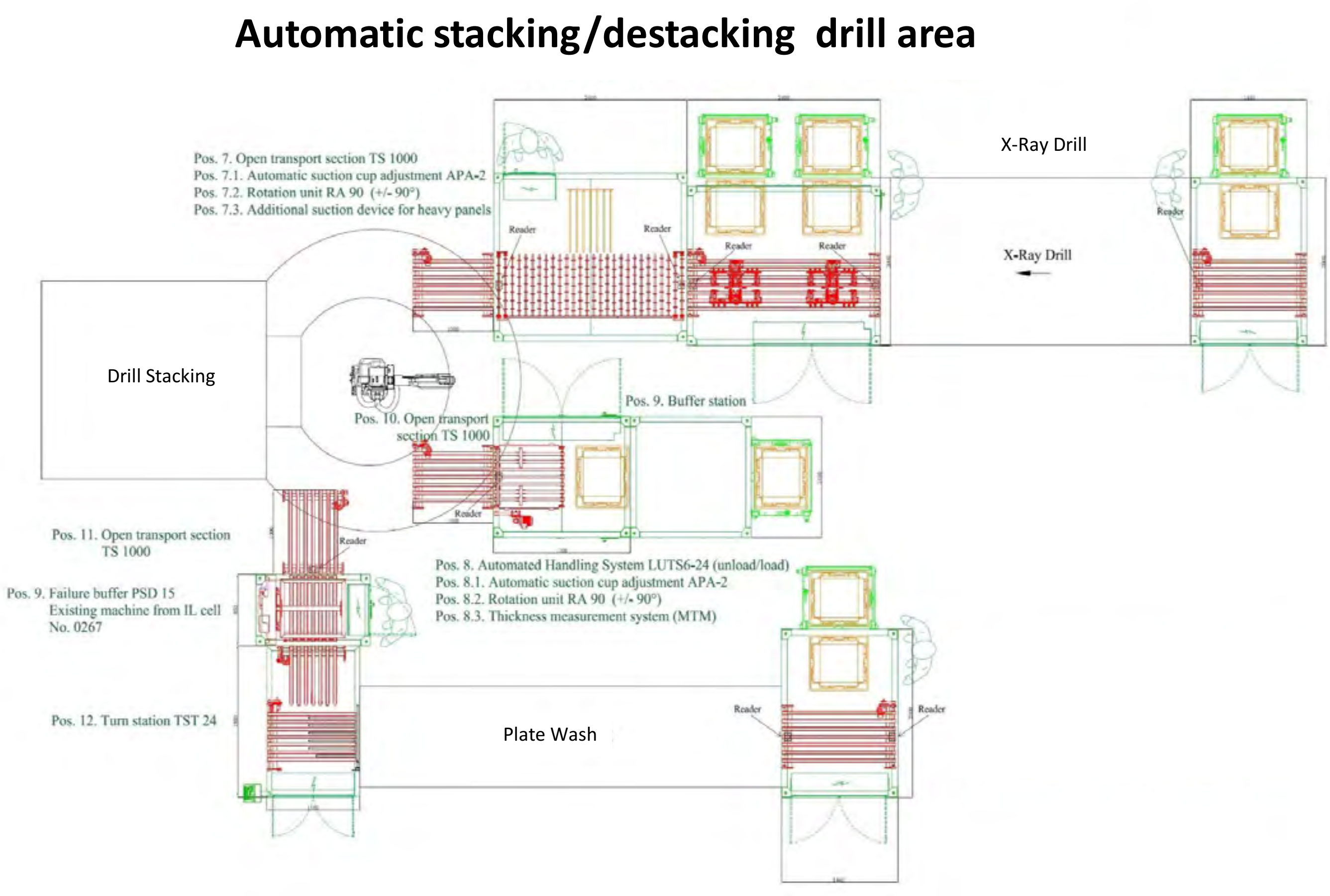


Figure 12: Drill/router area stacking and destacking.

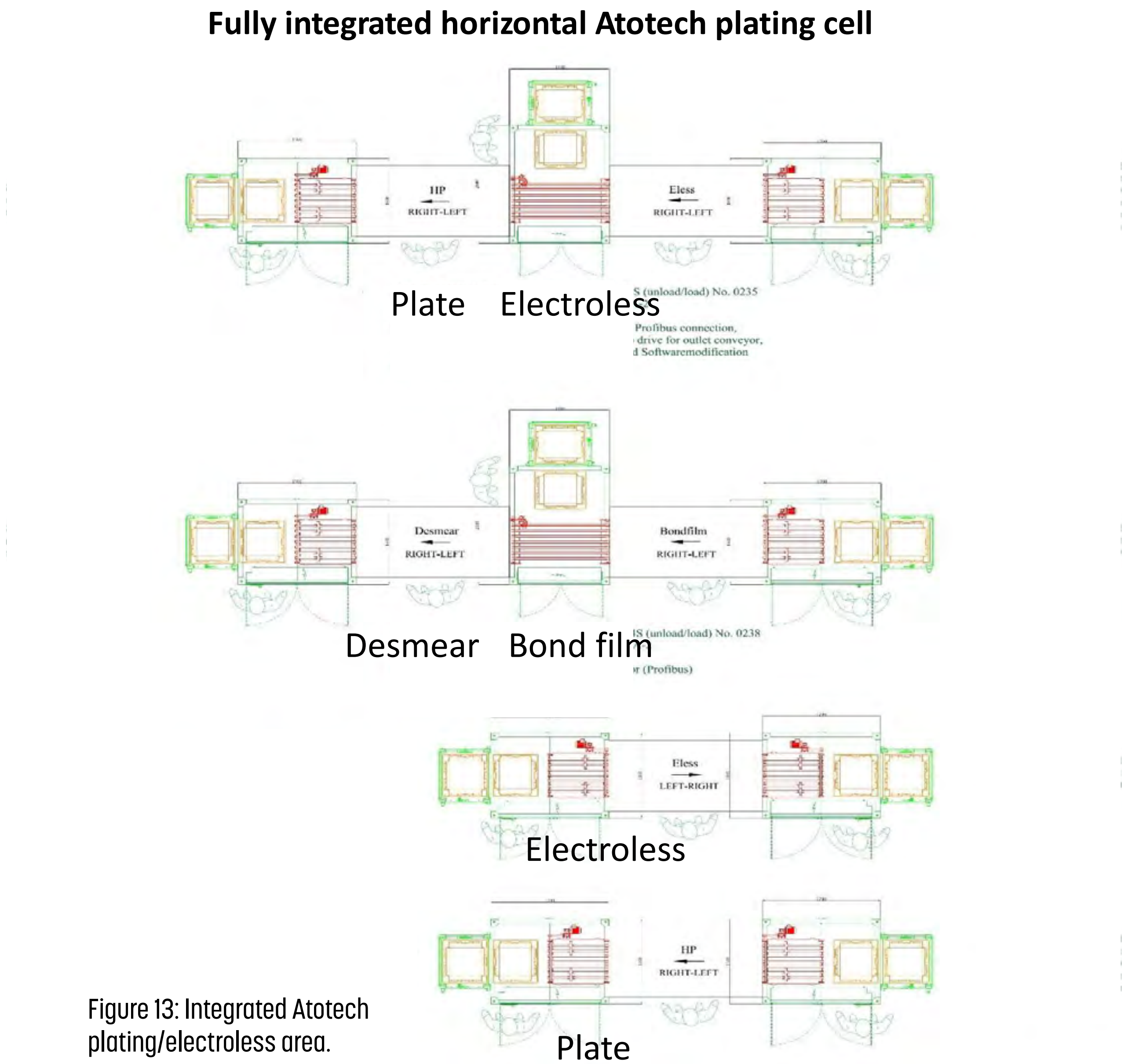


Figure 13: Integrated Atotech plating/electroless area.

Sainsbury reviewed the role of data in the Smart Factory Initiatives. His example is the current Whelen green factory. This takes disconnected data from various factory sources including:

- Pilot batches
- Cross-section analysis
- Look-up tables
- X-Ray drill optimizers
- Coordinate measurement machines
- AOI inspection

It is collected and analyzed to correct for scale errors or misalignment of layers within the panel and adjust the drill program for minimum mis-registration. This process is shown in Figure 14.

Analysis of X-ray data is seen in Figure 15. In addition to the AOI data of innerlayers and lamination effects, these measurements allow for compensation of drilling program and direct digital exposure. Coordinated analyzed data leads to better control actions and future results, as seen in Figure 16.

Sixth Presentation

The sixth presentation of the seminar was on "HDI Chemical Process Control and Analysis" given by myself. This is a favorite topic of

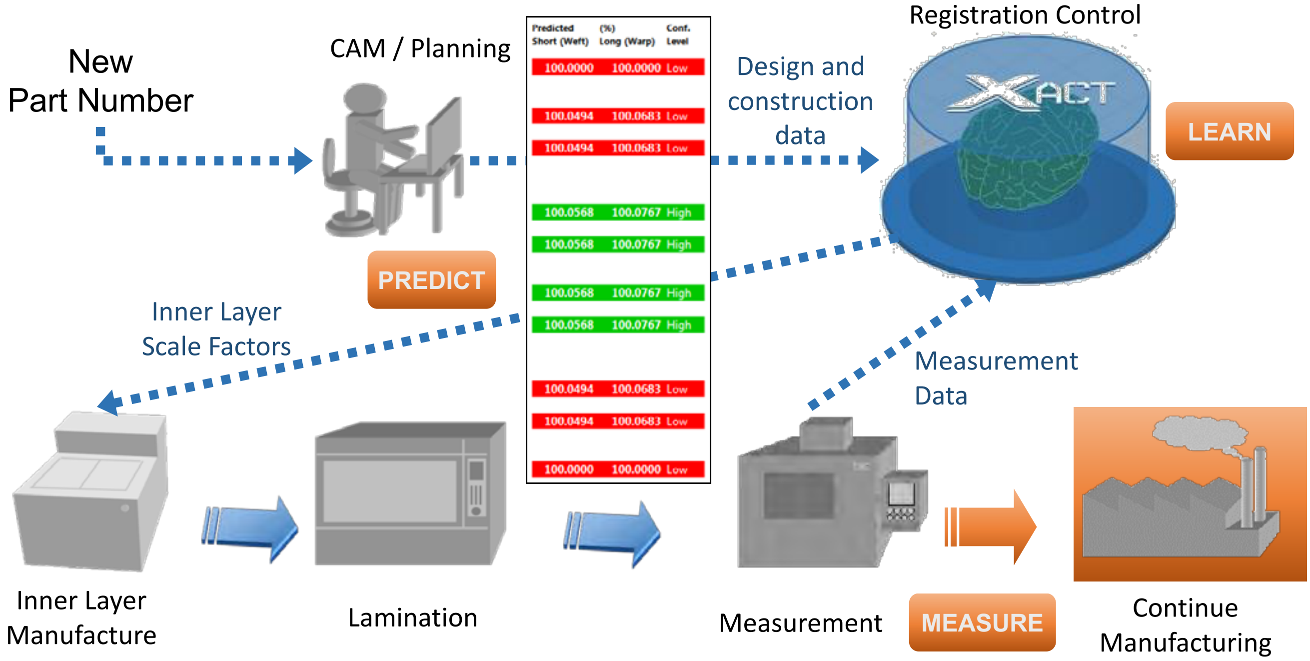


Figure 14: In registration control we see how these steps are applied in a smart manufacturing process.

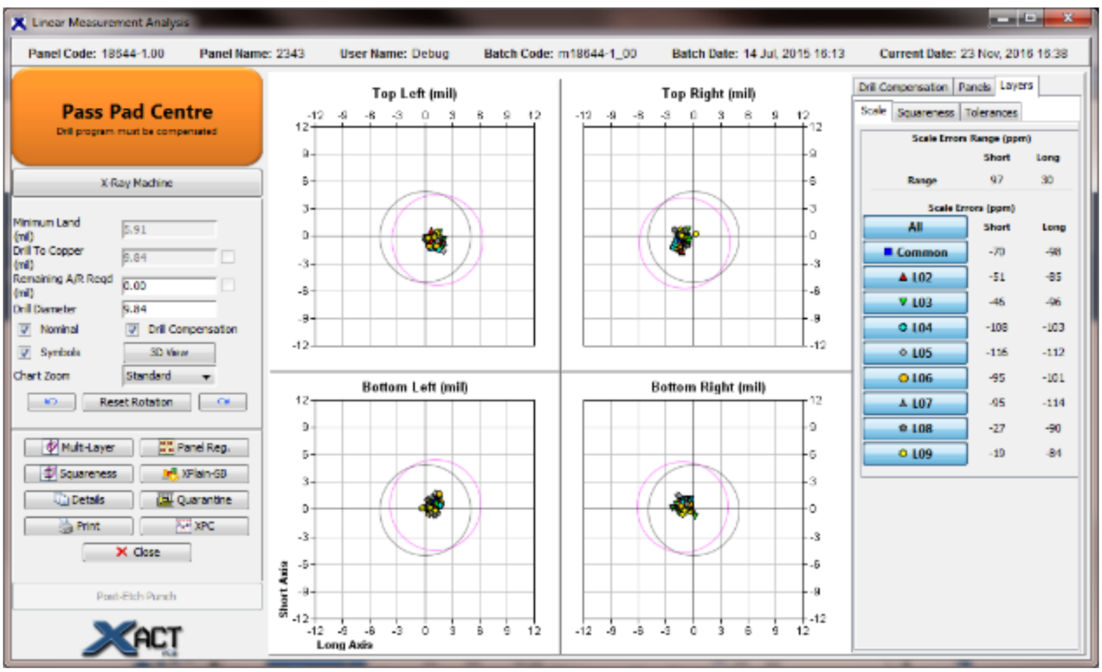


Figure 15: Analysis of X-ray drill data for improvement in registration.

mine and I covered it in detail in last month's issue of *PCB007 Magazine*[2]. I reviewed the methods of chemical analysis for typical PCB processes with emphasis on better control and continuous analysis, which can lead to a 30% cost savings on chemicals. More importantly, it can lead to higher product yields, especially for rapidly changing processes such as HDI.

Seventh Presentation

The last presentation of the seminar was another of mine, "Whelen PCB—A Case Study of

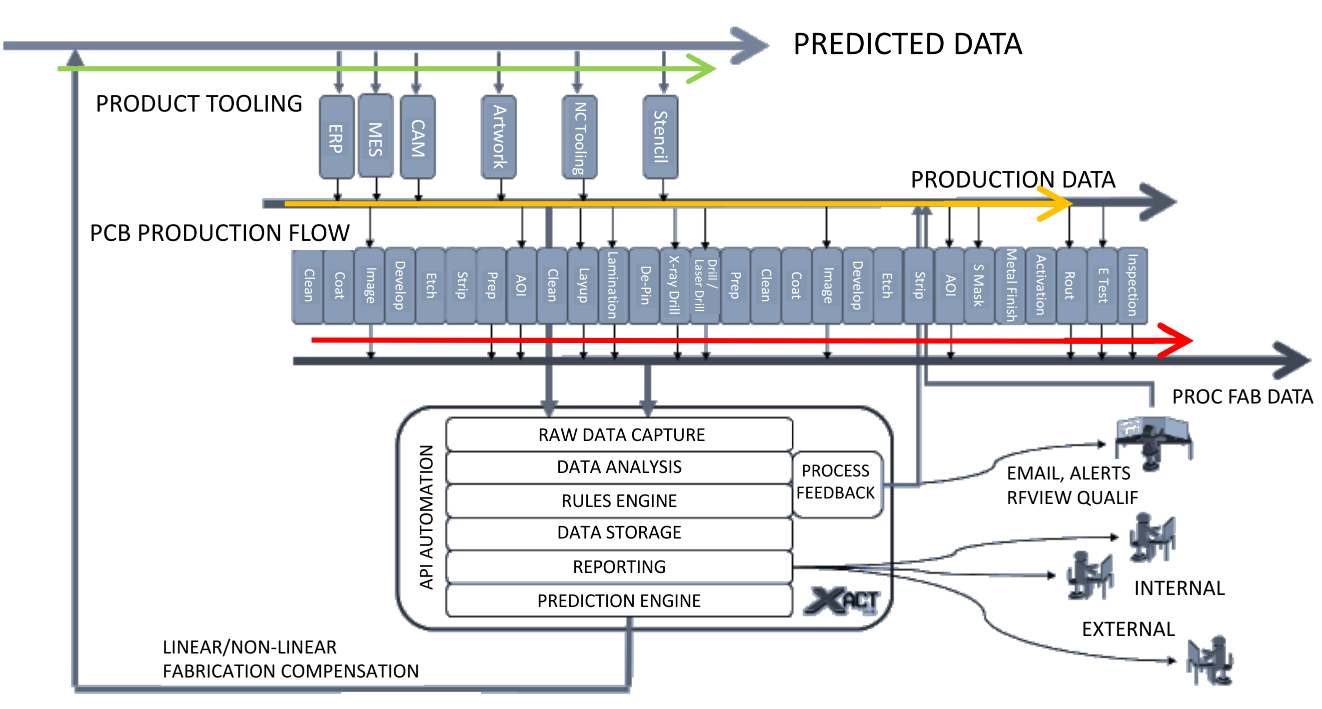


Figure 16: Coordinated analysis of all data leads to better actions and data to predict the future.

Full Automation PCB Fab." Whelen Engineering is an automotive electronics OEM headquartered in Connecticut. After many years, they decided to build their own PCB fabrication facility on their New Hampshire campus. Built in 2015, this represented the newest PCB fab in the world and it is remarkable because of the green zero-effluent strategy and the fact that it was fully automated, thus requiring no production workers. The chemical/water recycling scheme, in addition to not requiring a water or wastewater permit, allowed a 30% reduction in purchased chemical costs and a total cost of one-third to one-half of the former prices of boards from China. Their product turn-around went from many weeks to less than one week.

The heart of the Whelen PCB process is the continuous, conveyorized system seen in Figure 17. It has 60% fewer fabrication steps because of its speed and no human handling. The continuous process starts after drilling and

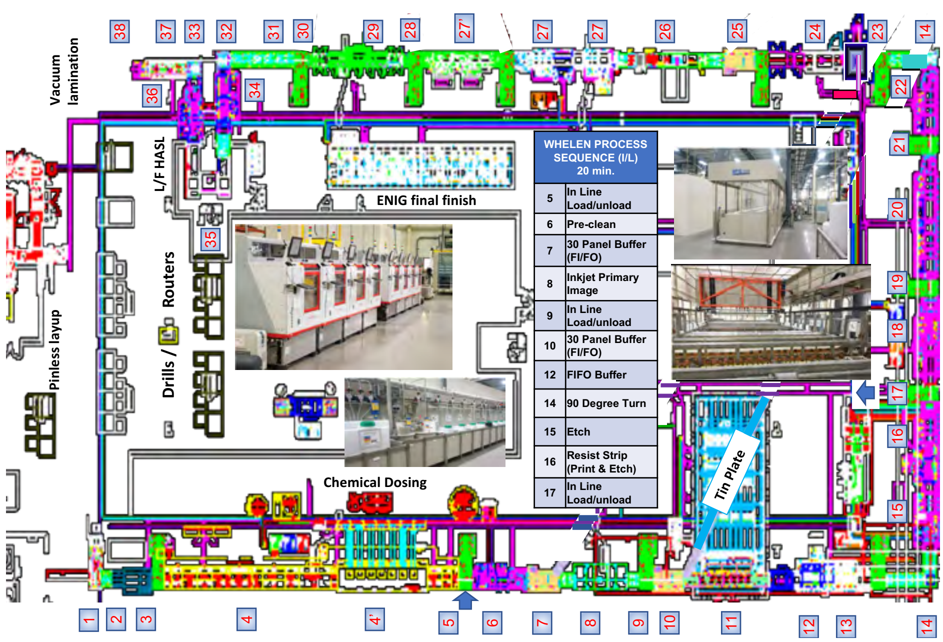


Figure 17: The Whelen continuous process line including final finishes is only 38 stations from load (after drill) to unload (to soldermask and final fab). This has 60% fewer steps than the normal outer layer process and takes only 205 minutes.

takes just 205 minutes to finish the boards to final fabrication and solder mask. Even though three final finishes can be randomly selected (OSP, LF-HAL, or ENIG) and laminates with different copper weights are used, the process runs continuously unless interrupted to image and etch innerlayers, and it can be accomplished for a wide variety of products because of the unique, horizontal pulse-plating panel plate with inkjet image printing of resist and pattern plating of tin as the etch resist.

As innovative and ground-breaking as all the automation is at Whelen, what is truly remarkable is the green/no effluents status of their manufacturing. The central water recycling system is shown in Figure 18. There are six main concepts that make up the zero-effluent strategy at Whelen.

1. Hermetically seal all process equipment to recover the water and chemicals from fumes.
2. Increase the temperature of all processes to evaporate as much water as the process will tolerate (collected by the hermetic seal system).
3. Make the first water rinse after the heated process a contamination capture and replenishment make-up for the preceding process (under continuous automatic chemical monitoring).
4. Make the successive water rinses a 'high-flow-rate" for effective rinsing.
5. 100% recycle this water utilizing ion-exchange and dual reverse-osmosis.
6. Isolate certain process streams and recover valuable chemicals or metals.

These chemical/water recovery units (Figure 19) are:

- Unit 1: Regenerate etchant/recover Cu+ and recycle etchant
- Unit 2: Plating electrolytes destroyed
- Unit 3: Tin stripper—recover tin and recycle
- Unit 4: Oxide alternative—organic destruction
- Unit 5: Acid etchants
- Unit 6: Microetches
- Unit 7: Resist strippers

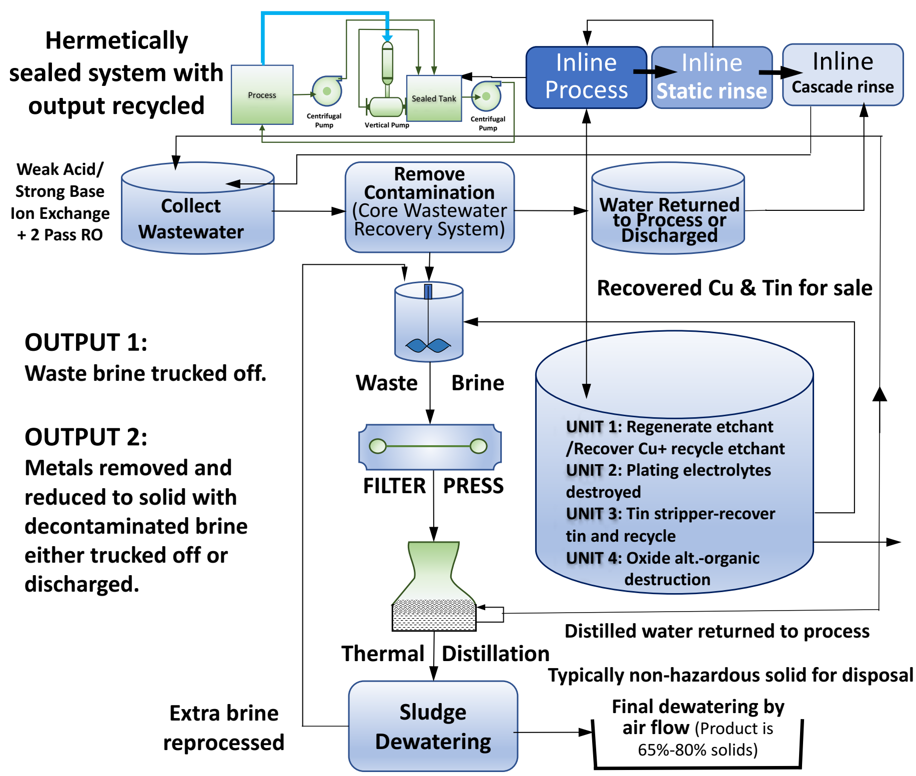


Figure 18: Schematic of water recycling system.

In their efforts to recover all their water and conserve their important chemicals/metals, the green theme of Whelen has led to a rapid payback and ROI recovery. Table 2 shows the annual savings from these systems. Over $614,050 is saved annually. The wastewater system was automated to the point of requiring only 10 hours/week of total labor. Total capital expenditure for all chemical recovery systems associated with this project was $1.4 million.

The many innovations at Whelen are best understood by reading the two articles published in I-Connect007's *The PCB Magazine* on October 2015[3] and August 2017[4]. **PCB007**

Process Bath	Recovery Method	Recovered Product	Capital ROI
Alkaline Etchants	Oxidation/Galvanic Cu	Fresh Etchant and Cu Metal	6-14 months
Acid Etchants	Oxidation/Galvanic Cu	Fresh Etchant and Cu Metal	6-14 months
Plating Electrolytes	Organic Destruction	Electrolyte minus Organic	2-3 months
Tin Strippers	Galvanic Cell	Etch Resist and Fresh stripper	4-6 months
Microetches	Galvanic Cell	Fresh Microetch and Cu Metal	4-6 months
Oxide Alternatives	Organic Destruction	Fresh Chemical minus Organic	2-3 months
Resist Strippers	Membrane	Fresh Stripper & Contaminated Brine	2-3 months

NOTE:
Resist strip recovery enabled by use of primary image inkjet process with hot

Figure 19: The seven chemical/metals/water recovery systems and their ROIs.

CATEGORY	SAVINGS
Annual Savings from Elimination of Chemical & Waste Treatment:	$243,050
Annual Savings from Reclaim of Copper for Resale:	$371,000
ANNUAL TOTAL:	$614,050

Process Step	Liters/day of waste	Annual Cost of Chemicals & Waste Treatment Savings
Pre-clean	120	$14,300
Pre-clean Rinse	3,600	$4,100
Developer	310	$12,100
Developer Rinse	3,600	$3,500
Etcher	1,440	$182,400
Etcher Rinse	3,600	$4,900
Stripper	240	$17,700
Stripper Rinse	3,600	$4,050
TOTAL	**16,510**	**$243,050**

Table 2: Annual savings from the elimination of chemical and water treatment and recovery of valuable metals (copper and tin).

References

1. Whelen Engineering and AWP Explain their Unique Collaboration.
2. Process Control for HDI Fabrication.
3. Whelen Engineering Reduces Cycle Time by Building a New Automated PCB Factory.
4. Whelen Engineering, Two Years Later.

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

IMPACT 2018: We Need Your Voice in Washington, D.C.!

One World, One Industry

by John Mitchell, IPC-ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

It's that time of year again: IPC's IMPACT Washington, D.C. 2018 is on the horizon.

As a global, industry-driven organization, IPC exists to help its member companies innovate, compete, and succeed in the electronics industry. Effective government relations are crucial to our members' success because many of the policy debates taking place in world capitals have wide-reaching impacts on our industry.

If we want to protect and advance our industry's interests, it is time for our collective voices to be heard. IMPACT Washington, D.C. 2018 is the best opportunity for industry leaders to present a unified voice to U.S. policy makers.

During this two-and-a-half-day event on May 21-23, IPC member company executives will:

- Connect with like-minded executives who share a commitment to the success of our industry
- Gain a deeper understanding of the policy issues our industry faces
- Speak to leaders in Congress and the Administration in support of our policy goals
- Share company concerns and unique experiences with key policymakers

This year, our priority issues will include:

- Regulatory reform
- Strengthening the electronics supply chain
- Workforce and education

During IMPACT, IPC also will announce this year's recipients of the IPC Government

Source: IPCAssociation @ YouTube

Ucamco
Former Barco ETS

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

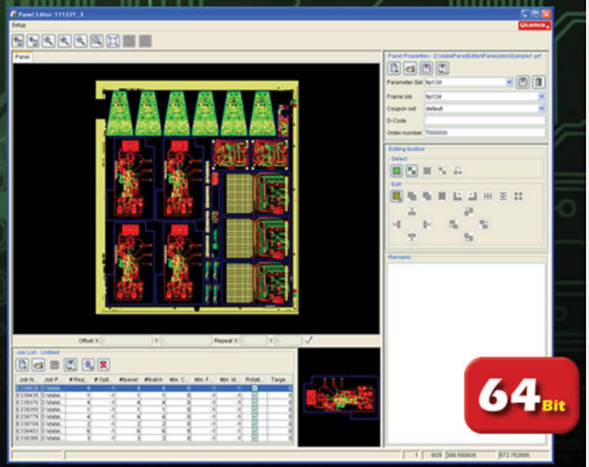
Software

Multi Job Panelizer

High-yield multi-job panel generation made easy ...

- Combines different PCBs into a production panel
- Optimizes material utilization
- Reduces material costs
- Interactive or 24/7 automated operation
- Hotlinkable to ERP or Planning systems

Read more



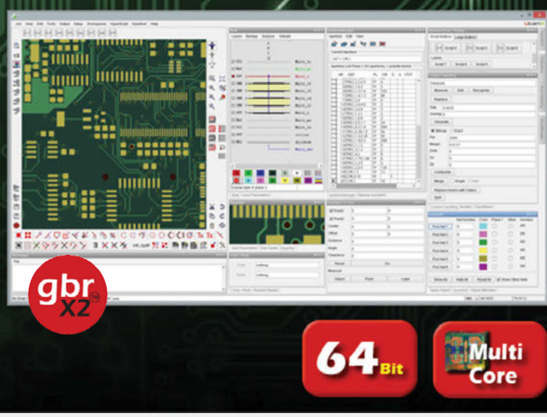
Software

UcamX

New ground-breaking CAM Software

- For Rigid, Flex and HDI PCBs
- New Graphical User Interface with Workspaces
- Optimal performance using Parallel Processing
- Multi Job Processing via load balanced Sessions
- Support for Gerber version 2 (X2) format

Read more



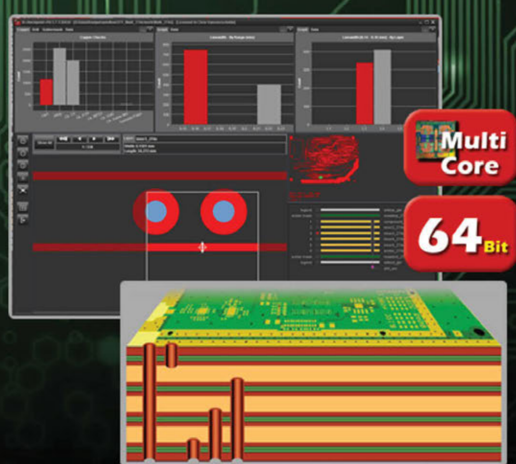
Software

Integr8tor

Automated data entry and design analysis

- Ucamco's 9th Generation Sales & Engineering Tool
- Field proven with more than 250 installations in daily production
- Seamless integration into any environment

Read more



For more information please contact info@ucamco.us,
call (415) 508-5826 or check out our website at www.ucamco.com

IMPACT Award. This award is presented to one or more policymakers for their leadership roles on issues of importance to the electronics industry. Be sure to follow us on Twitter and check our website[1] for the announcement.

If you are a senior-level executive at an IPC-member company, we invite you to join us and urge you not to miss this event. The more executives who sign up early, the stronger position we'll be in to make powerful presentations. For a glimpse of what you can expect, look at our recap from IMPACT Washington, D.C. 2017 [2]. This magazine also published a special insert last July that you may find interesting [3].

IMPACT Washington, D.C. 2018 presents the chance to build lasting relationships with members of Congress, collaborate with fellow industry executives, and present a unified voice for the electronics industry. Register today[4] using the referenced link.

We look forward to seeing you in D.C.! **PCB007**

References

1. Current IPC News.
2. IMPACT 2017 Washington, D.C.
3. Special Coverage: IPC's IMPACT Washington, D.C. 2017.
4. Registration for IMPACT 2018 Washington, D.C.

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

AI Helps Soldiers Learn Many Times Faster in Combat

New technology allows U.S. soldiers to learn 13 times faster than conventional methods and Army researchers said this may help save lives.

At the U.S. Army Research Laboratory, scientists are improving the rate of learning even with limited resources. It's possible to help soldiers decipher hints of information faster and more quickly deploy solutions, such as recognizing threats like a vehicle-borne improvised explosive device, or potential danger zones from aerial war-zone images.

The researchers used low-cost, lightweight hardware and implemented collaborative filtering, a well-known technique on a state-of-the-art, low-power Field Programmable Gate Array platform to achieve a 13.3-times speedup of training compared to a state-of-the-art optimized multi-core system and 12.7-times speedup for optimized GPU systems.

The new technique consumed far less power too—13.8 watts, compared to 130 watts for the multi-core and 235 watts for GPU platforms, making this a potentially useful component of adaptive, lightweight tactical computing systems.

2018 Programs

May 2 — San Diego, CA, USA

IPC Technical Education — PCB Layout — Place and Route

In conjunction with Del Mar Electronics and Manufacturing Show

May 8 — Milwaukee, WI, USA

IPC Technical Education

Morning: Real World Challenges and how IPC-HDBK-630: (Guidelines for Design, Manufacture, Inspection and Testing of Electronic Enclosures) has Helped

Afternoon: IPC/WHMA-A-620 CABLE & HARNESS DOCUMENTS: The Evolution of IPC's Cable and Harness Documents – A Brief History

In conjunction with Electrical Wire Processing Technology Expo

May 15–17 — Linthicum (Baltimore), MD, USA

IPC High Reliability Forum

May 21–23 — Washington, DC, USA

IMPACT Washington, D.C.

An executive-level, members-only event

June 4 — Boston, MA, USA

ITI and IPC Conference on Emerging & Critical Environmental Product Requirements

June 4–5 — Nuremberg, Germany

Automotive Electronics Reliability Forum

June 5–6 — Glasgow, UK

IPC PERM International Meeting No. 36

June 6 — Chicago Area, IL, USA

ITI and IPC Conference on Emerging & Critical Environmental Product Requirements

June 7 — Frankfurt, Germany

Automotive Executives Roundtable

June 8 — Silicon Valley, CA, USA

ITI and IPC Conference on Emerging & Critical Environmental Product Requirements

September 13 — Des Plaines, IL, USA

IPC E-Textiles 2018

October 13–19 — Rosemont, IL, USA

IPC Fall Standards Development Committee Meetings

co-located with SMTA International

November 13–15 — Schaumburg (Chicago), IL, USA

IPC/SMTA High-Reliability Cleaning and Conformal Coating Conference

December 5-7 — Shenzhen, China

HKPCA International Printed Circuit & IPC APEX South China Fair

January 26-31, 2019 — San Diego, CA, USA

IPC APEX EXPO

WISDOM WEDNESDAY WEBINARS — Exclusive for Members

May 9	July 11	August 8	September 26	December 12
May 23	July 25	August 22	October 10	November 14
June 13	June 27	September 12	October 24	November 28

For more information, **visit www.IPC.org/events**

1 All About Flex: ISO 9001 Basics

ISO 9001 is an internationally recognized standard that specifies requirements for a business's or organization's quality management system. Companies achieving ISO 9001 certification are audited to review compliance for systems to assure products or services are delivered with a consistent quality level and meet agreed upon specifications.

2 It's Only Common Sense: Taming the Extraordinary Salesperson

We spend a great deal of time talking about how to handle poor-performing salespeople—those who are not making their numbers, or those who just can't seem to get out there and visit customers, get an appointment, or close a sale.

3 IPC 6012-DA Revisions: The Approach to Cleanliness, Thickness, Inspection, and Wicking

IPC's Automotive Addendum task group was started in November 2014 and the first edition of IPC 6012-DA was released in April 2016. We are now working on the revised version and expect a release in Q2 2018. As standards need to evolve, develop and follow the needs of the industry, this work is continuous.

4 Flex to Divest Multek's China Operations to MFLEX

Flex Ltd. has entered into an agreement with Multi-Fineline Electronix Inc. (MFLEX), a wholly-owned subsidiary of Suzhou Dongshan Precision Manufacturing Co., Ltd (DSBJ), to divest the China-based operations of the Flex subsidiary, Multek.

5 Weiner's World–March 2018 ▶

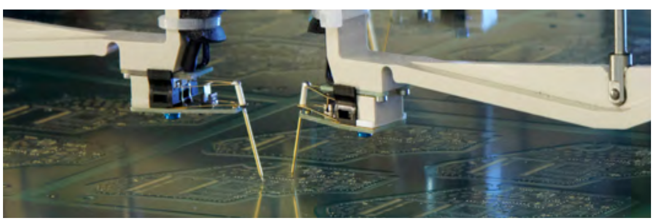
SEMICON China 2018 was amazing in its size and attendance. More than 1,000 exhibitors filled an event venue of more than 74,000 square meters of exhibition space—the size of nearly 10 professional soccer fields. This year's theme was "collect, collaborate, innovate."

6 PCB Manufacturing (R)evolution in the Making ▶

At the recent HKPCA and IPC Show 2017 in Shenzhen, China, I was able to interview Les Sainsbury, CEO, and Andrew Kelley, CTO, of XACT PCB, as well as Alex Stepinski, vice president of Whelen Engineering's PCB Fab Business Unit, to discuss process evolution and technology developments in the PCB manufacturing industry.

7 Aspocomp Acquires Technopolis Facility in Finland ▶

Aspocomp Group Plc has acquired the production facility from Technopolis Plc, located in the Linnanmaa district in Oulu, Finland.



8 IPC APEX EXPO 2018... the Show Goes On! ▶

Access I-Connect007's first edition of *Show & Tell Magazine* as a flip book! Inside you will find exclusive interviews, photos, videos, contest results, and commentary that will show and tell you all about this year's event.

9 It's Only Common Sense: The Cost of Keeping a Customer ▶

Experts estimate that we spend hundreds, if not thousands of dollars acquiring new customers each year. When you think of all the money we spend on marketing, advertising, trade shows, websites, salespeople, and their travel and other expenses, you know these experts are right.

10 IPC Releases PCB Industry Results for February 2018; Industry Rebound Continues ▶

Total North American PCB shipments in February 2018 were up 8.8% compared to the same month last year. This year to date, shipments are 9.3% above the same period last year. Compared to the preceding month, February shipments decreased 0.9%.

Career Opportunities

TAIYO KOGYO CO., LTD.

New Business Development Representative for USA market

Taiyo Kogyo is a Japanese PCB manufacturer. We started manufacturing PCBs in 1962, and have unique and differentiated boards used in various industry segments. Our products are appreciated for application in power electronics. High current PCB and thermal solution PCBs are our strength.

Position Summary:

Responsible for creating new business and expanding business with existing customers in the U.S. Work at your home office. Part-time (half-day/ 5 days a week) okay. (Option: After first 6 months, job can be upgraded for full-time work based on performance.)

Responsibilities:

- Develop new customers: Work closely with local sales representatives and independently in territories without sales reps.
- Educate and support local sales representatives.
- Operate as company's U.S. Sales office and communicate daily with Japanese headquarters for smooth and speedy communications with local sales reps and customers.
- Travel and visit prospective customers with local sales reps or alone to develop new customers (about 6 to 10 times a year).
- Attend company booth at business expo (APEC) during the show.
- Search for and appoint competent local sales reps in non-covered regions.

apply now

ventec
INTERNATIONAL GROUP
騰輝電子

Technical Support Engineer, UK

As a UK-based Technical Support Engineer, you will help customers choose and optimize the use of Ventec materials in their Printed Circuit Board manufacturing processes. You will provide a two-way channel of technical communication between Ventec's production facilities and UK/European customers. You will be required to undertake some laboratory testing (including the use of TMA, DSC, Melt Viscometer, Gel Plate Timer, and laboratory scale multilayer presses) and provide appropriate technical support to Ventec UK and European sales personnel to maximize results.

Skills and abilities required for the role:

- Hold a HNC, HND, degree or equivalent in a technical/scientific discipline.
- Excellent communications skills and ability to write full technical reports for group or customer distribution.
- Ability to work in an organized, proactive, and enthusiastic way.
- Ability to work well, both in a team as well as an individual.
- Good user knowledge of common Microsoft Office programs.
- Full driving license essential.

Appropriate training will be given if required.

This is a fantastic opportunity to become part of a successful brand and leading team with excellent benefits. For more information, please click here.

Please forward your resume to HR@ventec-europe.com.

apply now

Career Opportunities

Mentor®
A Siemens Business

PCB Manufacturing Marketing Engineer

Use your knowledge of PCB assembly and process engineering to promote Mentor's Valor digital manufacturing solutions via industry articles, industry events, blogs, and relevant social networking sites. The Valor division is seeking a seasoned professional who has operated within the PCB manufacturing industry to be a leading voice in advocating our solutions through a variety of marketing platforms including digital, media, tradeshow, conferences, and forums.

The successful candidate is expected to have solid experience within the PCB assembly industry and the ability to represent the Valor solutions with authority and credibility. A solid background in PCB Process Engineering or Quality management to leverage in day-to-day activities is preferred. The candidate should be a good "storyteller" who can develop relatable content in an interesting and compelling manner, and who is comfortable in presenting in public as well as engaging in on-line forums; should have solid experience with professional social platforms such as LinkedIn.

Success will be measured quantitatively in terms of number of interactions, increase in digital engagements, measurement of sentiment, article placements, presentations delivered. Qualitatively, success will be measured by feedback from colleagues and relevant industry players.

This is an excellent opportunity for an industry professional who has a passion for marketing and public presentation.

Location flexible: Israel, UK or US

apply now

American Standard Circuits
Creative Innovations In Flex, Digital & Microwave Circuits

Front-End CAM Operators

Chicago-based PCB fabricator American Standard Circuits is currently seeking front-end CAM operators to join their team. Desired applicant will have three years of CAM experience.

The candidate should also possess:

- Expertise in Valor/Genesis CAD/CAM software and PCB process
- Ability to process DRC/DFMs
- Excellent customer/people skills
- Ability to be a self-starter
- Ability to read prints and specifications

American Standard Circuits is one of the most diverse independent printed circuit board fabricators in the country today, building PCBs of all technologies, including epoxy MLBs, flex and rigid-flex, RF and metal backed.

To learn more about this position, please send your information to American Standard Circuits.

apply now

Career Opportunities

MacDermid Enthone ELECTRONICS SOLUTIONS

Technical Service Rep, Northeast

Do you have what it takes? MacDermid Enthone Electronics Solutions is a leading supplier of specialty chemicals, providing application-specific solutions and unsurpassed technical support.

The position of the Technical Service Rep will be responsible for day-to-day support for fabricators using MacDermid Enthone's chemical products. The position requires a proactive self-starter who can work closely and independently with customers, sales group members and management to ensure that customer expectations and company interests are served.

- Thoroughly understand the overall PCB business, and specifics in wet processing areas
- Prepare action plans for identification of root cause of customer process issues
- Provide feedback to management regarding performance
- Create and conduct customer technical presentations
- Develop technical strategy for customers
- Possess the ability to calm difficult situations with customers, initiate a step by step plan, and involve other technical help quickly to find resolution

Hiring Profile

- Bachelor's Degree or 5-7 years' job-related experience
- Strong understanding of chemistry and chemical interaction within PCB manufacturing
- Excellent written and oral communication skills
- Strong track record of navigating technically through complex organizations
- Extensive experience in all aspects of customer relationship management
- Willingness to travel

apply now

KYZEN Where Science and Care Converge.

KYZEN Regional Manager – Midwest Region

General Summary: KYZEN is seeking a Regional Manager to join our sales team in the Midwest. This position is ideally suited for an individual that is self-motivated, hard-working and has a "whatever it takes," positive attitude, especially with customers. Being mechanically inclined is a plus. KYZEN will provide on-going, in-the-field training to help you succeed.

CORE FUNCTIONS:

- Collaborates with the Americas Manager in establishing and recommending the realistic sales goals for territory
- Manages the assigned geographic sales area to maximize sales revenues and meet corporate objectives
- Develops sales strategies to improve market share in all product lines (Electronics and Industrial)
- Ensures consistent, profitable growth in sales revenues through planning, deployment and management of distributors and sales reps as well as continued direct support for customers and prospects processes

REPORTING:

- Reports directly to Americas Manager

QUALIFICATIONS:

- A minimum of seven years related experience or training in the manufacturing sector or the equivalent combination of formal education and experience
- Excellent oral and written communication skills
- Working knowledge of Microsoft Office Suite
- Mechanically inclined a plus
- Valid driver's license
- Travel within the region up to 75% of the time with occasional travel outside the region

apply now

Career Opportunities

ventec
INTERNATIONAL GROUP
騰輝電子

Ventec Seeking U.S. Product Manager for tec-speed

Want to work for a globally successful and growing company and help drive that success? As a U.S.-based member of the product and sales team, your focus will be on Ventec's signal integrity materials, tec-speed, one of the most comprehensive range of products in high-speed/low-loss PCB material technology for high reliability and high-speed computing and storage applications. Combining your strong technical PCB manufacturing and design knowledge with commercial acumen, you will offer North American customers (OEMs, buyers, designers, reliability engineers and the people that liaise directly with the PCB manufacturers) advice and solutions for optimum performance, quality and cost.

Skills and abilities required:

- Technical background in PCB manufacturing/design
- Solid understanding of signal integrity solutions
- Direct sales knowledge and skills
- Excellent oral and written communication skills in English
- Experience in making compelling presentations to small and large audiences
- Proven relationship building skills with partners and virtual teams

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

Please forward your resume to jpattie@ventec-usa.com and mention "U.S. Sales Manager—tec-speed" in the subject line.

apply now

CHEMCUT
BOUNDLESS INNOVATION | UNBEATABLE PRECISION

Field Service Technician

Chemcut, a leading manufacturer of wet-processing equipment for the manufacture of printed circuit boards for more than 60 years, is seeking a high-quality field service technician. This position will require extensive travel, including overseas.

Job responsibilities include:

- Installing and testing Chemcut equipment at the customer's location
- Training customers for proper operation and maintenance
- Providing technical support for problems by diagnosing and repairing mechanical and electrical malfunctions
- Filling out and submitting service call paperwork completely, accurately and in a timely fashion
- Preparing quotes to modify, rebuild, and/or repair Chemcut equipment

Requirements:

- Associates degree or trade school degree, or four years equivalent HVAC/industrial equipment technical experience
- Strong mechanical aptitude and electrical knowledge, along with the ability to troubleshoot PLC control
- Experience with single and three-phase power, low-voltage control circuits and knowledge of AC and DC drives are desirable extra skills

To apply for this position, please apply to Mike Burke, or call 814-272-2800.

apply now

Career Opportunities

BLACKFOX
Premier Training & Certification

IPC Master Instructor

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

For more information, click below.

apply now

MacDermid Enthone
ELECTRONICS SOLUTIONS

Account Manager, Northeast

Do you have what it takes? MacDermid Enthone Electronics Solutions is a leading supplier of specialty chemicals, providing application-specific solutions and unsurpassed technical support.

The position of Account Manager will be responsible for selling MacDermid Enthone's chemical products. The position requires a proactive self-starter who can work closely and independently with customers and sales management to ensure that customer expectations and company interests are served while helping to promote MacDermid Enthone's exclusive line of products.

- Develop a business plan and sales strategy that ensures attainment of company sales and profit goals
- Prepare action plans for sales leads and prospects
- Initiate and coordinate action plans to penetrate new customers and markets
- Create and conduct proposal presentations and RFQ responses
- Possess the ability to calm a situation with customers, initiate a step-by-step plan, and involve other technical help quickly to find resolution

Hiring Profile

- Bachelor's Degree or 5-7 years' job-related experience
- Strong understanding of chemistry and chemical interaction within PCB manufacturing
- Verifiable sales success in large complex sales situations
- Desire to work in a performance driven environment
- Excellent oral and written communication skills
- Decision making skills and the ability to multitask

apply now

Career Opportunities

ARLON

Arlon EMD, located in Rancho Cucamonga, California is currently interviewing candidates for **manufacturing** and **management positions.** All interested candidates should contact Arlon's HR department at 909-987-9533 or fax resumes to 866-812-5847.

Arlon is a major manufacturer of specialty high performance laminate and prepreg materials for use in a wide variety of PCB (printed circuit board) applications. Arlon specializes in thermoset resin technology including polyimide, high Tg multifunctional epoxy, and low loss thermoset laminate and prepreg systems. These resin systems are available on a variety of substrates, including woven glass and non-woven aramid. Typical applications for these materials include advanced commercial and military electronics such as avionics, semiconductor testing, heat sink bonding, high density interconnect (HDI) and microvia PCBs (i.e., in mobile communication products).

Our facility employs state of the art production equipment engineered to provide cost-effective and flexible manufacturing capacity allowing us to respond quickly to customer requirements while meeting the most stringent quality and tolerance demands. Our manufacturing site is ISO 9001: 2008 registered, and through rigorous quality control practices and commitment to continual improvement, we are dedicated to meeting and exceeding our customer's requirements.

more details

IPS INTEGRATED PROCESS SYSTEMS INCORPORATED

PCB Equipment Sales

World-class manufacturer of wet process equipment for the PCB and plating industries, Integrated Process Systems Inc. (IPS) is seeking qualified candidates to fill a position in equipment sales. Potential candidates should have:

- Process engineering knowledge in PCB manufacturing
- Outside sales background
- Residency on the West Coast to manage West Coast sales
- Knowledge of wet process equipment
- Sales experience with capital equipment (preferred)

Compensation will include a base salary plus commission, dependent upon experience.

more details

Events Calendar

Thailand PCB Expo 2018 ▶
May 10–12, 2018
Bangkok, Thailand

IPC High Reliability Forum for Mil-Aero and Automotive Sectors ▶
May 15–17, 2018
Linthicum (Baltimore), Maryland, USA

Medical Electronics Symposium 2018 ▶
May 16–18, 2018
Dallas, Texas, USA

IMPACT Washington, D.C. 2018 ▶
May 21–23, 2018
Washington, D.C., USA

2018 EIPC's 50 Years Anniversary Conference ▶
May 31–June 1, 2018
Bonn, Germany

JPCA show 2018 ▶
June 6–8, 2018
Tokyo, Japan

IPC E-Textiles 2018 Workshop ▶
September 13, 2018
Des Plaines, IL, USA

electronica India productronica India ▶
September 26–28, 2018
Bengaluru, India

electronicAsia 2018 ▶
October 13–16, 2018
Hong Kong

SMTA International ▶
October 16–17, 2018
Rosemont, Illinois, USA

TPCA Show 2018 ▶
October 24–26, 2018
Taipei, Taiwan

electronica 2018 ▶
November 13–16, 2018
Munich, Germany

HKPCA/IPC International Printed Circuit & South China Fair ▶
December 5–7, 2018
Shenzhen, China

Additional Event Calendars

IPC

SMTA Surface Mount Technology Association

iNEMI

pcb 007

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

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

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

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

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

CONTRIBUTING TECHNICAL EDITOR: **DAN FEINBERG**
baer@iconnect007.com

CONTRIBUTING TECHNICAL EDITOR: **HAPPY HOLDEN**
(616) 741-9213; happy@iconnect007.com

MAGAZINE PRODUCTION CREW:
PRODUCTION MANAGER: **SHELLY STEIN**
shelly@iconnect007.com

MAGAZINE LAYOUT: **RON MEOGROSSI**

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

INNOVATIVE TECHNOLOGY: **BRYSON MATTIES**

COVER: **SHELLY STEIN**

COVER IMAGE: **ADOBE STOCK © KATRINA BROWN**

PCB007 MAGAZINE

PCB007 MAGAZINE®
is published by BR Publishing, Inc.,
942 Windemere Dr. NW, Salem, OR 97304

May 2018, Volume 8, Number 5
PCB007 MAGAZINE is published monthly,
by BR Publishing, Inc.

ADVERTISER INDEX

atg Luther & Maelzer GmbH.......... 11
Bowman XRF.......... 31
Burkle North America.......... 61
DB Management.......... 43
Electra Polymers.......... 19
Entelechy Global.......... 65
ESI.......... 17
Excellon.......... 41
Gardien.......... 57
I-Connect007 eBooks.......... 2, 3
I-Connect007 Flex Magazine.......... 88
IPC.......... 63, 85
ITEQ.......... 45
MacDermid Enthone Electronics Solutions.......... 5
Matrix USA.......... 49
Mentor, a Siemens Business.......... 13
Meptec.......... 71
MivaTek Global.......... 47
Mutracx.......... 21
Nordson March.......... 55
Panasonic Electronic Materials.......... 37
Pluritec.......... 7
Prototron Circuits.......... 51
Rogers Corporation.......... 29
Super Dry.......... 25
Taiyo America.......... 39
The Right Approach Consulting.......... 79
Ucamco.......... 83
Uyemura.......... 53
Ventec International Group.......... 9
Viking Test.......... 67

Coming Soon to PCB007 Magazine:

JUNE: Wet Processing
The latest on wet processes for PCBs.

JULY: Solder Mask
The latest in chemistry, equipment and coating methods.