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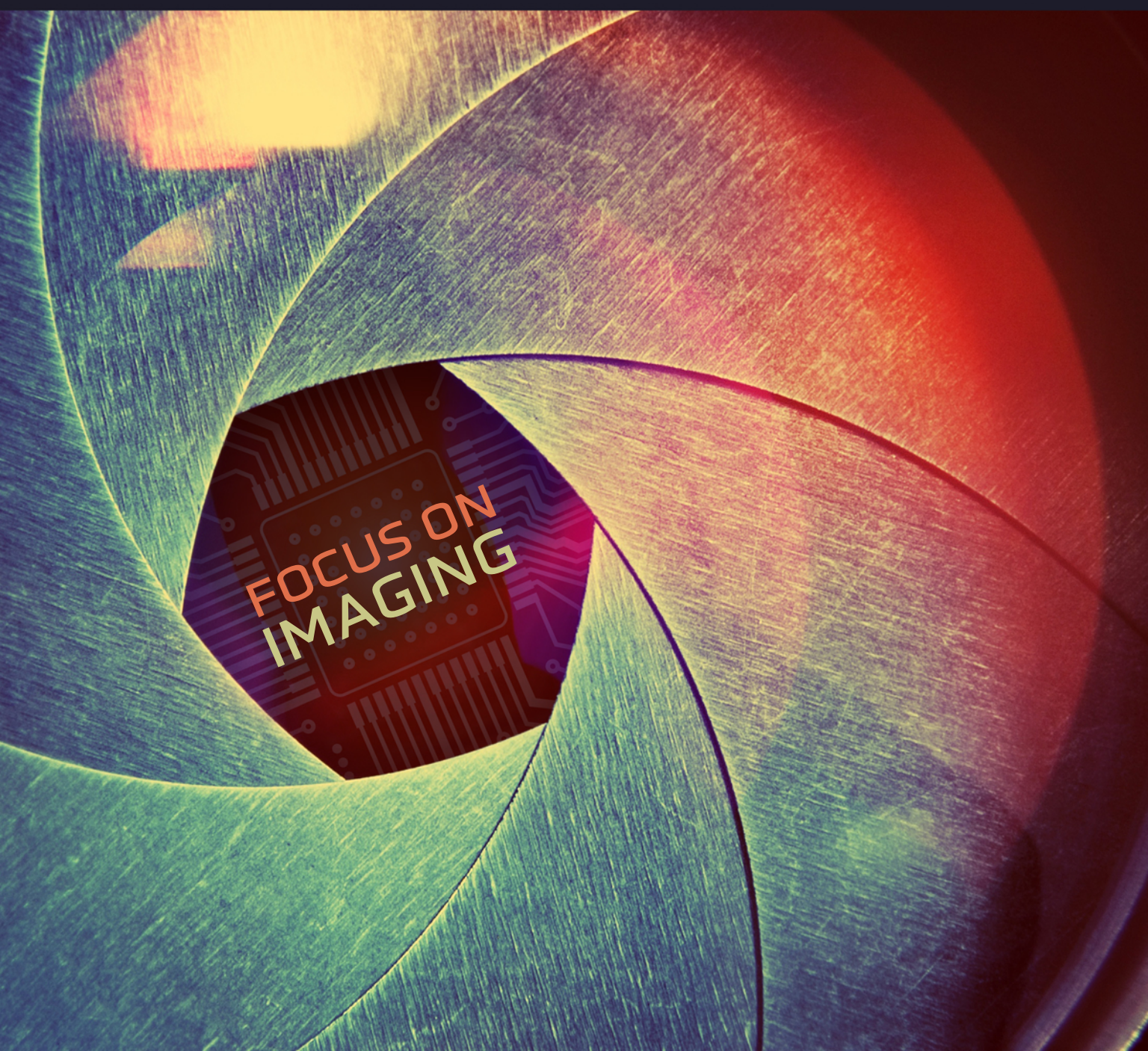

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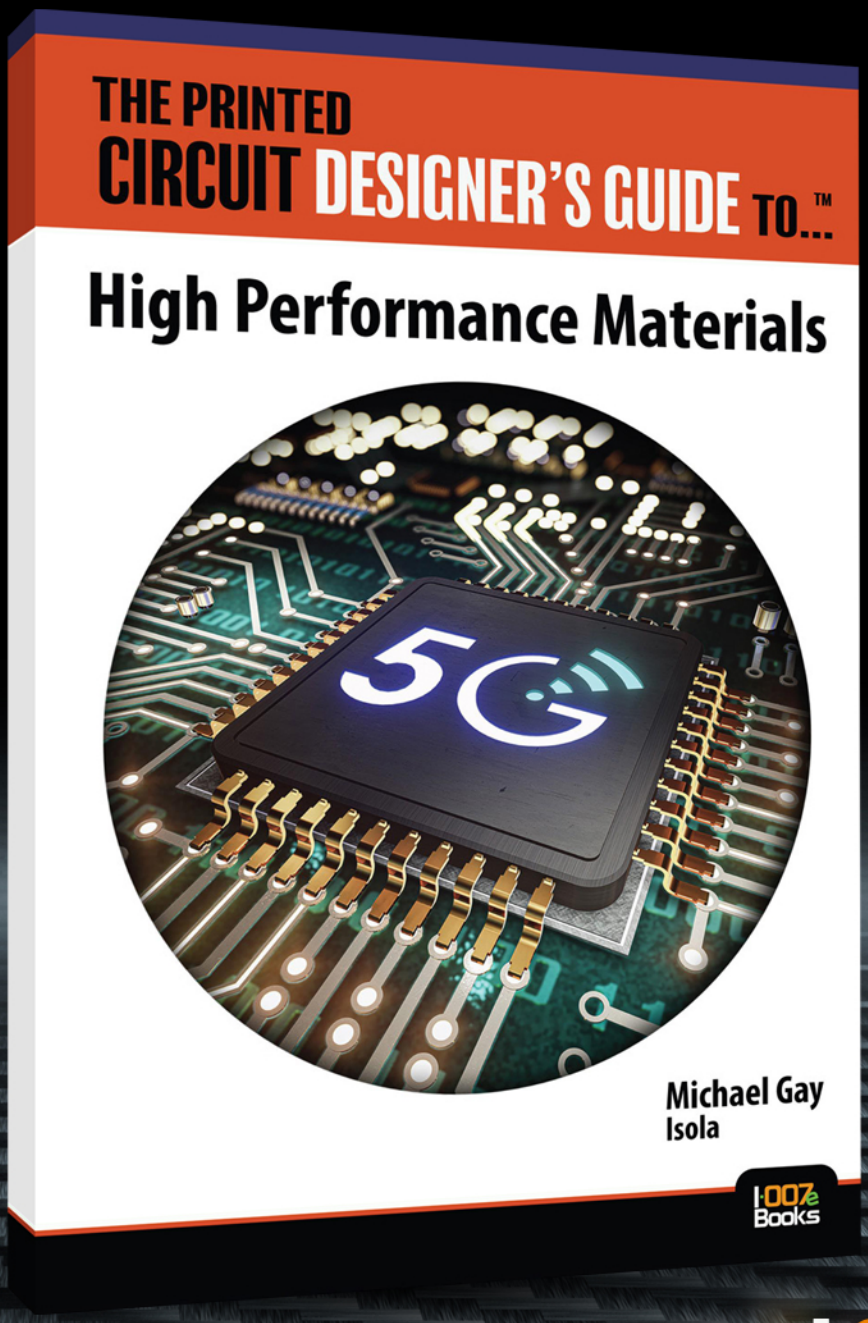

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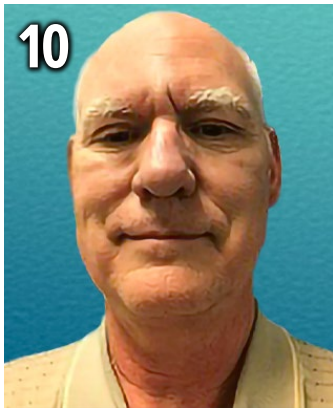
Focus on Imaging

There are many variables to deal with in imaging, making best practices of solid data collection and analysis a must. Cost, yield, and quality all depend on a fabricator's ability to collect and interpret data. Our experts discuss ways for the readers to fine-tune their imaging process by understanding how etching, plating, and imaging all work together.



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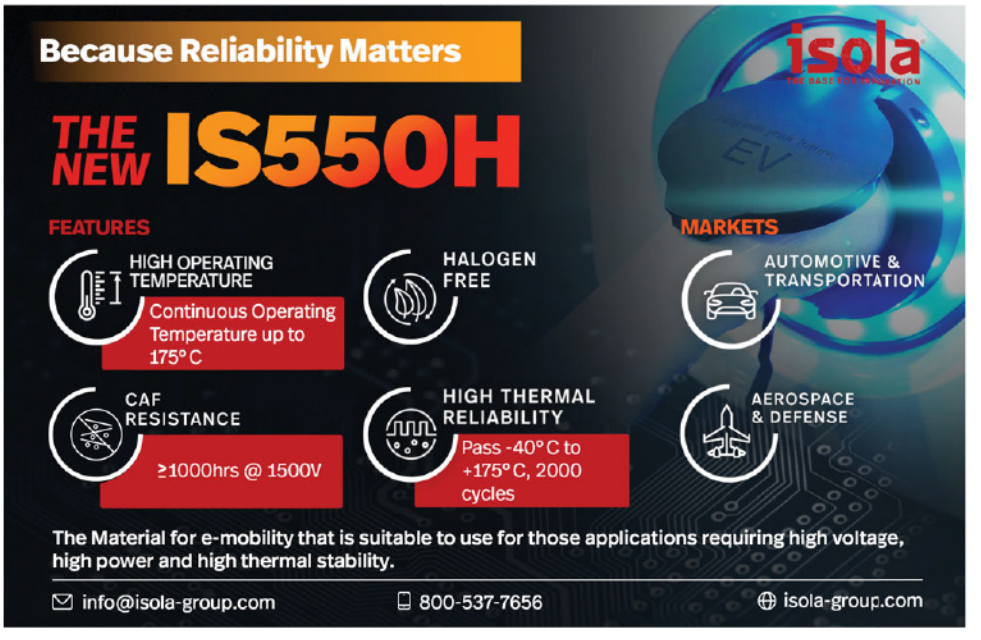

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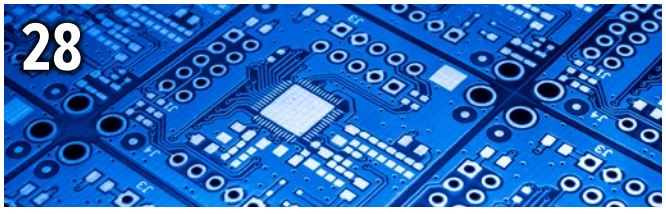

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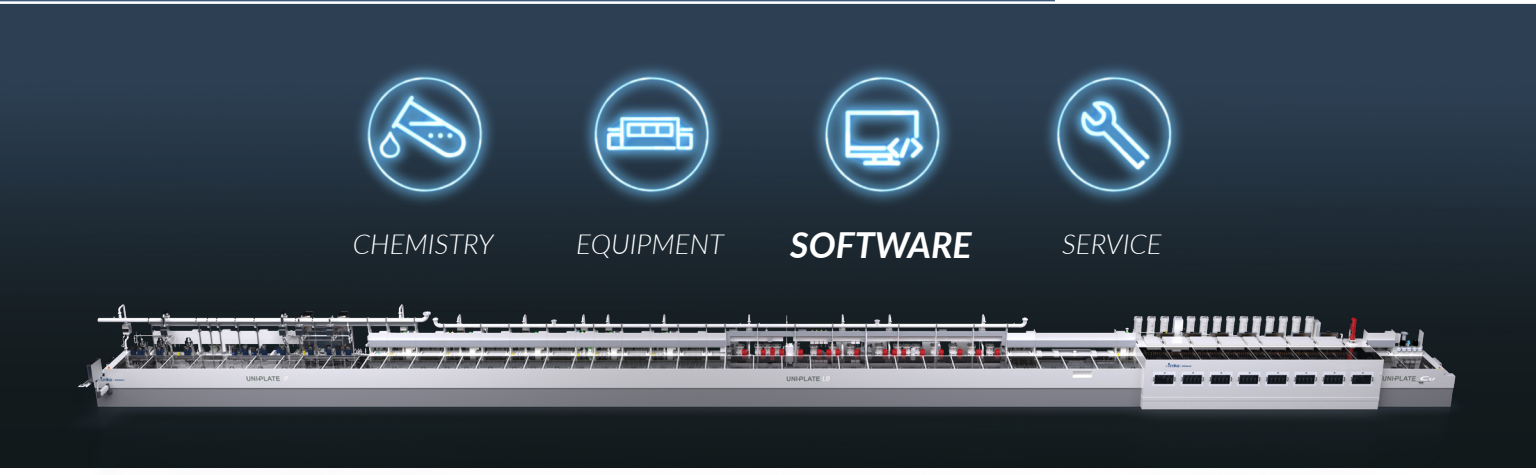

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A Clearer Image

The Shaughnessy Report

by Andy Shaughnessy, I-CONNECT007

Out of all the process steps in a fabrication cycle, imaging may be the most critical. This is where the design begins to take a physical shape, where the theoretical world meets the physical world.

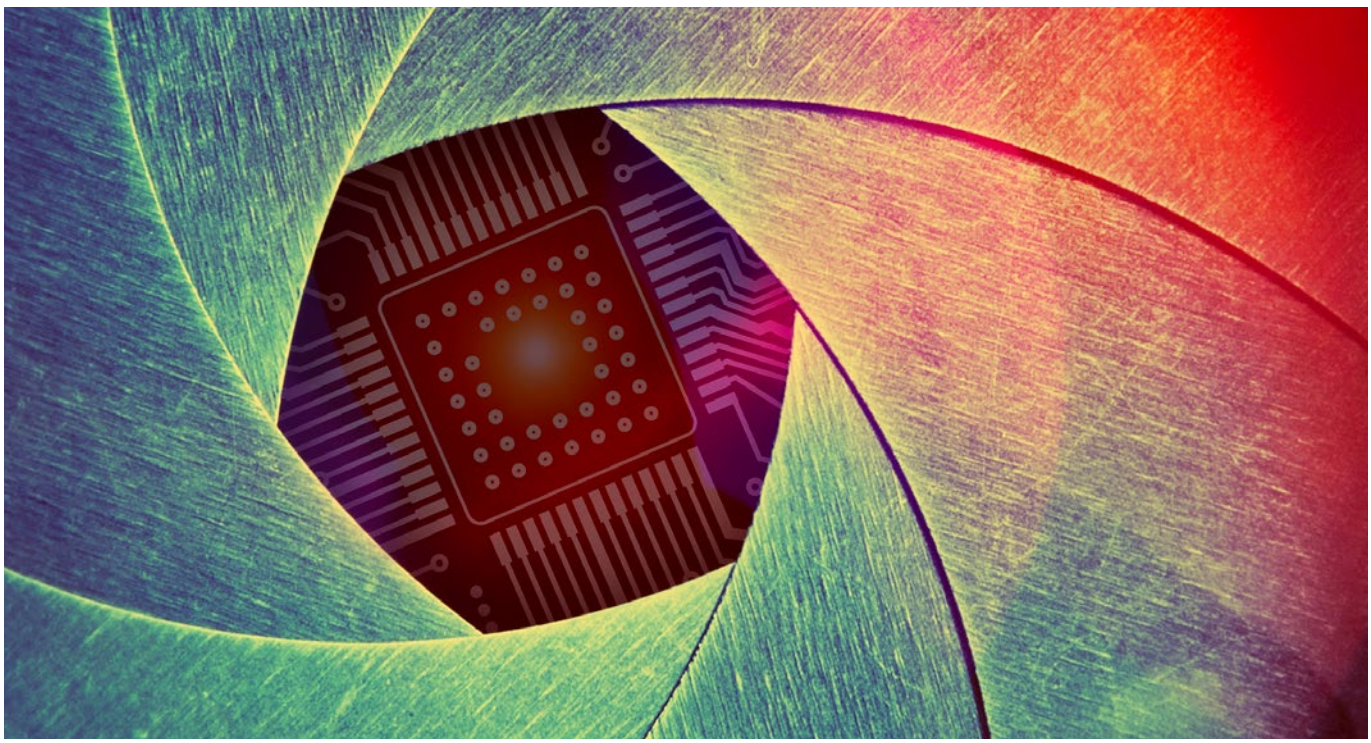
Much like photography, PCB imaging is a nearly magical process. I'll bet the first technologists to use a Gerber Science photoplotter to create a PCB felt a lot like Nicéphore Niépce and Louis Daguerre, trying to coax a Daguerreotype photograph into life in the 1830s.

The primary method of imaging has evolved quite a bit over the last six or seven decades, from screening to liquid photoresist to dry film and then to aqueous dry film. Now laser direct imaging has created a world of possibilities that were unthinkable with film.

Despite all the advantages of direct imaging, the equipment is expensive—nearly seven figures—and there's no automated DI system for lower-volume fabricators. Nor is there a "turnkey" DI system available yet. You may wind up buying a DI machine from one company and the supporting software from another.

Yes, the "old-school" film imaging systems have a big advantage over DI: They're completely automated. Will DI ever replace film imaging completely? Probably not in my lifetime.

Some smaller shops may send this job through a 20-year-old etcher. Your system



is only as strong as its weakest link; the best imaging process in the world is still dependent on your shop's printing, etching, plating, and drilling.

Customers are becoming more educated about the capabilities and hurdles related to imaging. They often want to see straight sidewalls, not trapezoidal, that mSAP has made a reality. Straight sidewalls on traces offer a variety of benefits, including interference reduction, and they just look better, don't they? (Admit it: The beauty contest among your coworkers is real.)

The old axiom says, "It's all relative." We're primarily speaking of the North American fabrication market, which is made up of low- and medium-volume fabricators. These companies are barely an afterthought for the big imaging equipment makers serving the Asian high-volume market. To the big imaging equipment makers, North American fabs are "the little guys." Keep that in mind.

As we see in this issue, there are still plenty of variables to deal with in imaging, making solid data collection and analysis practices a must. Several of this month's contributors point out the many ways to get burned by trusting your gut instinct instead of your imaging data. Cost, yield, and quality all depend on a fabricator's ability to collect and interpret data.

So, in this issue, our experts will discuss ways for the readers to fine-tune their imaging process by understanding how printing, etching, plating, and imaging all work together. We start out with a great interview with Loren Davidson of TTM Chippewa Falls, who explains his medium-volume facility's imaging processes, and why it's so important to let the data drive all your decisions. Happy Holden's column focuses on laser direct imaging—its advantages and its disadvantages. Chris Bonsell of Chemcut discusses how to optimize your etcher for better imaging results. Alexandre Camus, Damien Boureau, and Alexis Guilbert of Altix bring us an article that compares the pros and cons of web and digital imaging systems. And Mivatek's Brendan Hogan provides the five top priorities for implementing a DI system.

We also have columns from our contributors Travis Kelly, George Milad, Hannah Nelson, Mike Carano, Steve Williams, Christopher Bonsell, and Todd Kolmodin. And don't miss the interview with Atotech's Stefan Stefanescu, who discusses the company's latest suite of control software for wet processes.

We have a busy trade show season coming up. I hope to meet with some of you on the road. See you next month. **PCB007**

Andy Shaughnessy is managing editor of *Design007 Magazine* and co-managing editor for *PCB007 Magazine.* He has been covering PCB design for 20 years. He can be reached by clicking here.

A Sharper Image

Feature Interview by the I-Connect007 Editorial Team

We recently spoke with Loren Davidson, a senior manufacturing engineer at TTM Technologies in Chippewa Falls, Wisconsin. In this wide-ranging discussion, Loren details the medium-volume facility's imaging processes and equipment, a variety of imaging tricks of the trade, and why it's so important to make decisions based on solid statistical data.

Andy Shaughnessy: Loren, would you start by telling us how you got into imaging?

Loren Davidson: I've been in the industry for 38 years. I started in the drill area, then three years later moved to imaging for inner layers. I spent the majority of my time there and have had some interaction with external or outer layer imaging over the years. About five years ago I moved to cover both inner and outer layer imaging. They're pretty complementary other than accounting for the differences in things like plating vs. print and etch.

At TTM Chippewa Falls, we specialize in higher-end product with some volume, but not the high-end volume. We're pushing the envelope on technology to bring it to market quicker, and we're not building necessarily a prototype product, but product that's more mainstream. If it gets to the point where it's a commodity type product or something anyone else can build, then it gets moved to other facilities or even sent to China. That's the niche market we're trying to maintain.

Shaughnessy: Great. Tell us about the process and the equipment.

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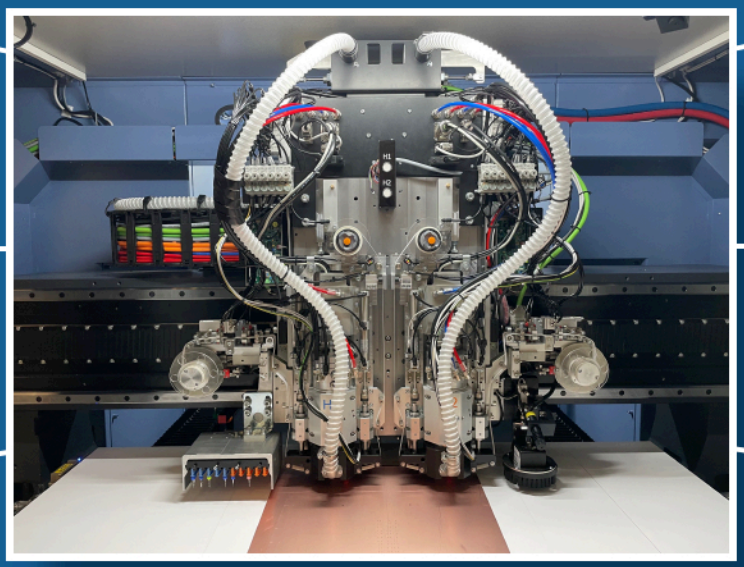

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Davidson: For our inner layer department, we have two Nuvogo laser direct imagers from Orbotech. Those are for our print-and-etch product. I have an Acura from Altix, which is a mechanical printer for a simpler product. It runs faster than an LDI, so we keep it to fit the higher ramp-up quantity area. For outer layer, I have two Nuvogos for the print-and-plate product and specialty prints, so we can do all the selective gold. We do dot plating. We do have ENEPIG and ENIG for all the specialty images needed to meet the customer requirements. For wet processing after print, for inner layer, we use the SCHMID DES (develop, etch, strip) lines, and for outer layer, we use the SCHMID developers. Then it goes over to the plating area. For coating, we use Hakuto CSLs (cut sheet laminators).


Loren Davidson

Shaughnessy: You do laser and film?

Davidson: Yes, for inner layers I have the Acura that runs silver film. It's a clamshell type printer, but it's automated. It autoloads the layer, brings it into the print frame area, prealigns the top and bottom film, pulls vacuum, prints both sides of the layer at the same time, then brings it out. For the laser direct imaging, of course, you can only image one side at a time. But with the Nuvogos, they're double-drawer printers, so they're faster, but still not as fast as a mechanical printer.

Shaughnessy: What's the cutoff? How do you know when to use film vs. laser?

Davidson: It's driven by the spacing. With 3 mil or larger spacing for inner layers, we go to the Acura. Anything less than 3 mil and we will not allow it. Then, we have some product that we're allowed to repair and do welds, but with some products, you can't. With the mechanical printer, you're at a higher risk for repetitive debris defects, so that type of product will get moved over to an LDI where you have much less risk for that. The repairability and spacing are the main drivers on whether we allow it to go to the mechanical or not.

Shaughnessy: When should somebody consider investing in LDI?

Davidson: As soon as possible, actually. There are so many advantages to the LDI for quality that you do not get repeat defects, whereas with a film printer, that repeat can be a killer. Now, the trade-off is that a mechanical printer is fully automated and runs half a million dollars compared to an LDI that is almost a million dollars. The price trade-off is that you need it. If you don't go to full automation, you can go down to right around $300,000 for a good mechanical printer.

Nolan Johnson: With regard to the laser direct imager, can you do everything with that?

Davidson: Yes, I haven't found anything we can't print on it so far. We do know with different LDIs, they have different laser systems to get the UV energy. There are some limitations on some resists that don't expose well on Nuvogo. The Nuvogos have limited wavelengths of energy. One advantage of the Acura printer is the spectrum for the UV energy is much wider, whereas the Nuvogos are basically laser diode, and the wavelengths are very narrow. If you're looking for a "one machine prints all" type machine, be aware of the resists you're using, all the way through solder mask.

Johnson: The takeaway is that with the data inbound, whatever data you have, you can print any of that. That part is 100% slotover.

But you have to pay attention to what you're printing along too.

Shaughnessy: Do you still use a yellow room?

Davidson: Yes, for inner layer and outer layer all the print areas are yellow room because the resist reactivity—the millijoules to polymerize that resist—does not allow white light. We tried to do filtered white light a few years back, but as we went to a faster and faster resist, we had to convert to yellow.

Shaughnessy: Imaging went from screening to liquid photoresist to dry film, and then to aqueous dry film over 50 years or so. How would you describe imaging over the last five to 10 years?

Davidson: When I started 35 years ago, it was all liquid printing for inner layer imaging. Until 10 years ago, we still had a liquid line here at TTM for inner layers. Liquid resist has been around a long time. The problem is the handling mechanisms for liquid coated are very difficult, so dry film has an advantage with the Mylar cover sheet and over the last few years I've seen the increases in speed and resolution. I actually just took a call earlier today from a manufacturer with a faster, better-resolution resist.

There's a certain point where it doesn't buy TTM Chippewa Falls anything; we don't need that speed, because of the cost difference between that speed vs. what we need for our resolution here. Is it worthwhile? We have our advanced technology center about a mile down the road, and they're printing in the much finer category. They're down into the 1 mil trace and space realm. Now their resists are vastly different than ours because of that requirement. Right now, most of our customers are really hanging around 3/3 lines and spaces technology. We see a few of them pushing a little bit under, maybe a 3-mil trace with a 2.5-mil space. You're reducing spacing, which makes wet processing much more difficult. But the traces are generally staying right around 3 mil or larger depending on the product. Most of that is for signal integrity. Most of what we build are high-speed traces. If your trace is too small, your signal gets too rough.

Shaughnessy: Is LDI as automated as the old-school printers?

Davidson: Right. That's one of the drawbacks of LDI. There is some automation available, but it's not cohesive yet; there isn't just one manufacturer making the printer and the supporting equipment, so you have to combine different manufacturers together, and get them to work with each other. But it is doable. It's just trying to get everyone to work together and play nice, so to speak.

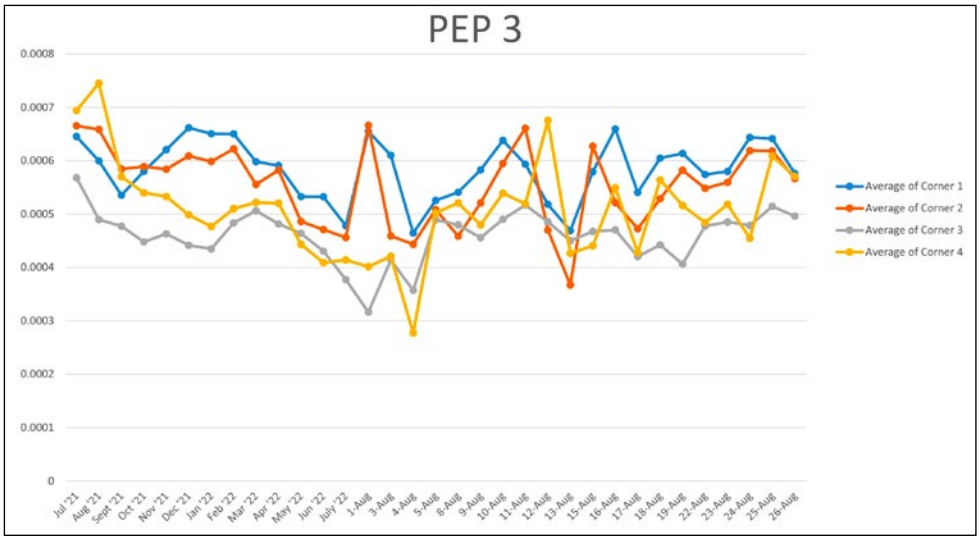
Shaughnessy: There's not a turnkey situation where you can get the software and printer and supporting equipment from one company.

Davidson: For the most part, they work with each other relatively well, but it would be nice to have one system. Right now, there are several automation suppliers that will work with Orbotech, and Orbotech will work with them. But so far I haven't seen anyone say, "Hey, this is the best match." We're a little cautious sometimes. Generally, TTM won't be the first to jump into something like that. They'll be second or third.

Shaughnessy: Are customers worried about geometries of the side walls? What are your thoughts on that?

Davidson: Yes. We have quite a few customers asking if we can improve how the traces look. Throughout my years in the industry, the traces actually have a trapezoid shape, where they're a little smaller at top and a little larger on the bottom from the wet processing. For signal speed, if you can get those square, you'll get a smoother signal, less interference.

On the thinner coppers, it doesn't buy you as much, and most of our customers are only



Regular tracking.

going up to 2-ounce copper on the layers. There is some wet process equipment, and unfortunately, our SCHMID lines are five years or older, so we don't even have the latest, greatest technologies that way. Some of the really interesting stuff is in China; there's not a U.S. representative for it.

Johnson: With the interesting stuff in China, is there any sense that U.S. equipment manufacturers are looking at similar technologies? Do you get a feel for that?

Davidson: I hope they are. I haven't seen anything from Chemcut. Obviously, we have a lot of SCHMID equipment. I saw a presentation about two years ago regarding a nano-etch technology in China. To give you that straighter sidewall, it's a finer droplet of cupric that helps clear out the traces without creating as much of the trapezoid shape. I have not seen anyone pick that up here and create an alternative. Obviously, there's a patent and intellectual property to be careful of, but TTM has facilities in China, so we use some leverage to see whether there are opportunities to bring it over. It's just difficult to do that.

Johnson: Is the best play for the North American market to jump into additive and semi-additive?

Davidson: There are some advantages to it, and we have some product here where we are doing that. It's not our main area, but as you push things tighter together, registration becomes a problem, especially with material shrinkage, growth, and some of the new exotic materials that are not linear in their movement.

We've been so used to a glass cloth inside with a grain and a cross-grain, and it's pretty predictable. The film materials are anything but predictable. If you do an additive, you can look at the features, whether it's a drilled hole, see where it moved in relation to where you think it should be, and adjust accordingly. That's an advantage so you can build up that way. But the majority of our product is still just build-up. We go up to 67 layers right now, and it's about getting them all to line up. We do things to help registration, such as stiffer borders, more copper, some different lamination techniques that we're trying out, and they seem to show some promise.

But you are still at the mercy of what the material wants to do. You have the high stack up to 67, and the flip side is we have some that are four layers on essentially film material and the spacing is super tight. When they move, and they're not linear, we're chasing registration back and forth. The ones I hate to see come through my areas are the super thin and the super thick. They're never fun.

Shaughnessy: What would you say is your sweet spot?

Davidson: I almost never get calls for product that's between 100- and 200-mils thick. It's very rare anything is creating a problem there. I get calls for the 20-mil thick panel, and then the

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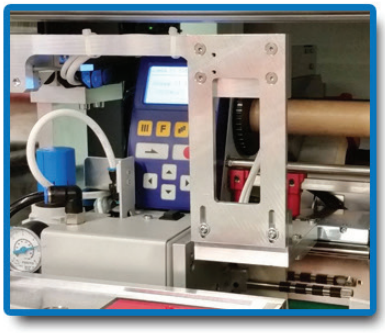

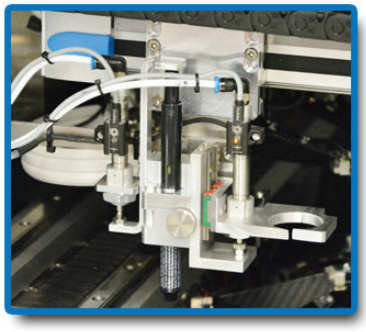

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350-mil panel. My ultimate goal as an engineer is not to ever get called, because that means my process is working perfectly. But in 38 years, that hasn't happened.

Shaughnessy: Do you have any experience with dual-wave dry film?

Davidson: Yes. Many of the new dry films are being created because Orbotech went with two wavelengths: 375 nanometers and 405 nanometers. The film companies are responding and building specifically to those wavelengths so we tested a few. Why did Orbotech pick 375 and 405? Well, 405 made sense to me; 375 I'm not quite so sure about. But more resists are coming out with the direct image designator, and they react well to the 375 or 405. That's been the big help.

Shaughnessy: Interesting. What are your biggest challenges, whether it's technological, the market, or something else?

Davidson: For us, it's reacting and meeting the customer expectations, especially when they're requesting an exotic material because it has a great dielectric property, but it might not be the greatest for manufacturability. They don't necessarily need to see or know that when they first look at a design because they're looking at the numbers.

They need to ask, "Will I get better signal integrity? Will it do this or that for me? Is it thin?" Matching what the customer wants and doing it quickly are probably the biggest challenges. I see rebuilds come through and I try to fix those. It's really about getting it pushed through the first time the right way, and then I'll see what I need to change in my process so I don't have to physically stand there.

Shaughnessy: It sounds like you guys do a certain amount of educating the customer.

Davidson: Yes, our inside sales and field engineers will say to customers, "We know you want this because of the dielectric, but it's really difficult to process." Ultimately the customer might just say, "I need to have that material and then we must figure out how to do it." We'll invest the time and energy to do that, because you must make a product they can use.

Our customers listen. They won't necessarily follow our advice, but they'll listen to it. Sometimes, they'll look at it and say, "Oh, OK, I can go with this material instead." There are new materials constantly coming out, so the same design that might be hard to manufacture with product X flows well and etches well for product Y, and the customer is more than happy. We do have good feedback loops. But when you're trying to do the high-tech products, often you're getting fresh off the drawing board, so to speak.

Shaughnessy: As far as technology, where would you like to see more innovation in imaging?

Davidson: Automation for LDI would be awesome. Get it to where it's a very consistently known commodity.

Shaughnessy: How do you work with the other TTM facilities? I imagine you share information to keep on top of technology.

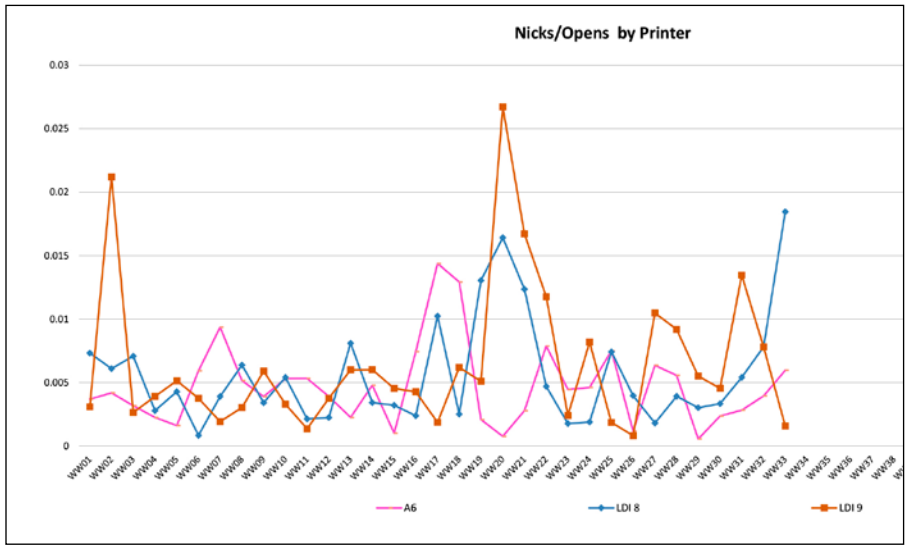
Davidson: We share information on things that work, and if we hit a technology snag, we can talk about it. We have our other facilities with their specialities, and we organize "engineering summits" to discuss a topic, what works and what doesn't, and look for best practices. We recently had one on solder mask processing, for example. We don't want to be a "little silo TTM."

Often, we coordinate it so that I'll get resist X, our Logan (Utah) facility will get Y, and Forest Grove (Oregon) will get the Z. We'll each run an independent test, compare, then say, "Do we want to swap out or follow up with one of these guys to see if there's a benefit?" The advantage is that if you can leverage corpo-

rate purchasing, instead of me buying 100 pounds a year as a corporate, we're buying 1,000 pounds a year, and your cost goes way down.

Shaughnessy: That's great.

Davidson: By the way, I would really love to know if anyone in the U.S. is working on those nano-etch type technologies, because right now it seems limited to the Asian market, and that's obviously difficult for us to get here. Many Asian manufacturers don't want to create a U.S.-based service fleet. They won't even entertain selling it over here.



Defect tracking.

Johnson: It's the right play to leapfrog into the next technology?

Davidson: Sometimes it is. You just jump headfirst, and it's difficult if you're expected to do volume. We're a medium volume shop. It's hard to be an R&D center and do volume, because if you're looking at brand-new equipment that no one else has ever used, that's a lot of trial and error in getting it all dialed in and set right.

Johnson: That becomes a part of the whole dynamic here. North America, in general, is optimized for high mix and low volume, with the high volume in Asia.

Davidson: That's right. I know I won't be the only one to complain, but the automation part is also driven by the fact that we can't get enough people here. The human resource aspect is a huge driver on automation.

Shaughnessy: Speaking of hiring, we see more young people joining the industry. What advice would you give a young process engineer regarding imaging?

Davidson: Study as much as you can about it. Study the stats. I've been around long enough to do DOEs and Six Sigma. If you're not a statistician yourself, most companies have someone who can do the stats for you, so you can look at the information and make wise decisions based on data.

Throughout the years, I've seen decisions made based on feelings, and that's never good. Really look at the data, collect it, and set up systems to collect. Let that drive you, and then learn and read. I don't know how many technical journals I get in a month, but it's quite a few. Some aren't related to inner layers, imaging, or this industry.

Being a manufacturing engineer is great. I get to play around with chemistry, and equipment. I play around with electronics. I've learned PLC programming. To me, it's fun to do that. I've been to China, Korea, and Germany several times. Study the stats and processes, and have fun doing that too.

Shaughnessy: Nice to hear from someone who really loves their job. Thanks for speaking with us, Loren.

Davidson: Thank you. **PCB007**

Direct Imaging Revisited

Happy's Tech Talk #13

Feature Column by Happy Holden, I-CONNECT007

Introduction

It is hard to believe we have had direct imaging for 40 years, starting with Excellon's introduction of its DIS-2000 argon laser imager. Since then, companies in 11 countries[1] have developed various digital direct imagers. Karl Dietz wrote about this technology several times in his columns[2], noting early on the skepticism that laser direct imaging would hit a Golden Age. So, where are we now?

Digital Imaging Updates

I-Connect007 has repeatedly reported on and updated digital imaging[2]. There are several reasons for this extended coverage:

- The technology had a slow, long incubation time that eventually led to accelerated improvement and acceptance for mass production.
- It might also be argued that next to the development of the microvia technologies, digital imaging is probably the most innovative technology to achieve high density interconnects with acceptable yields.
- It is worth mentioning that "direct imaging" is a more appropriate term to refer to this technology than "laser direct imaging" (LDI) because LDI is just one example of digital imaging, albeit its pioneering vision.

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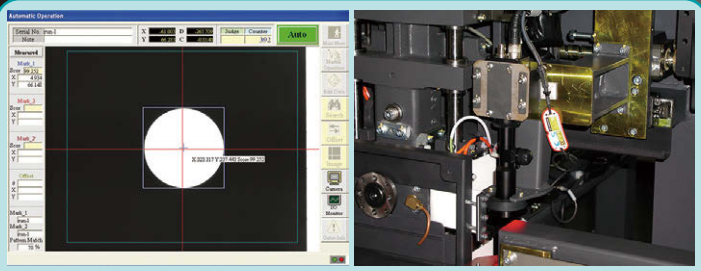

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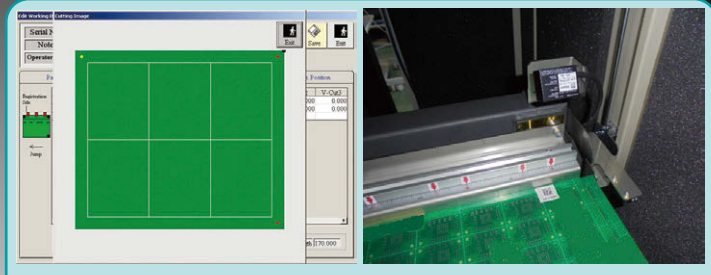

2D Code Auto Reading:
Built-in scanner to load recipe for seamless operation. (Option)

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The advantages of digital circuitization techniques have been described in detail by suppliers of equipment and photoresist. Since phototool generation and conditioning are omitted, there is the advantage of shorter lead time. Small lots can be customized at no extra cost, as an example, with added date and lot number information. There may be an advantage in fine line imaging of surfaces with poor co-planarity because of the depth of focus of the laser beam. Maybe the biggest advantage is the ability to scale, i.e., to change the dimension of each individual exposure for best fit to reference points on an underlying pattern of a multilayer structure. However, early digital imaging systems had substantial drawbacks, such as Orbotech's DP100 which used an argon ion laser with limited radiation power, high power usage, and high cooling requirements.

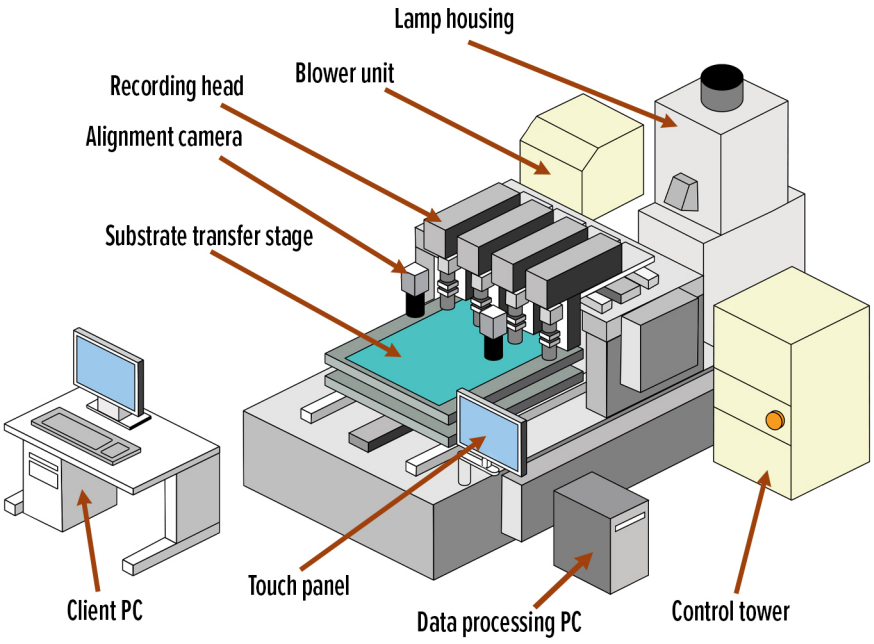

Figure 1: Next generation digital direct imaging (DDI) uses various light sources and the ubiquitous TI DMD micro-electrical-mechanical system (MEMS) micromirror to direct the rich UV light[3].

For years, LDI was synonymous with digital imaging. While most early commercially successful digital processes involved the use of lasers, other more recent processes use non-laser light sources such as LEDs (light emitting diodes) that consume less power, last longer, and have a higher light intensity output (Figure 1).

Alternatively, various types of mercury lamps are making use of more than one wavelength. Others use inkjet technology to build image patterns such as legend print, solder mask, or etch resist. They all have in common the building of a pattern, pixel by pixel, and they employ digital "on/off switches" to form the pattern. The switch might be an optical modulator (as in laser direct imaging) or an array of liquid crystal polymer cells (LCPs) that can be rendered translucent or opaque by addressing it with an electrical pulse. The switch might be micro-mirrors on a chip, such as Texas Instruments' Digital Micromirror Device™ (DMD), whereby tiny mirrors are addressed with an electric pulse so that the mirror is either tilted to direct the light toward the substrate or away from it (Figure 2).

The following is an overview of development and commercial digital imaging systems recently introduced.

Altix-Automata-Tech, the French supplier of imaging systems, first introduced its ADIX-System at productronica 2013. It is based on an advanced high-power LED radiation source (ALDS), a dual multi-wavelength UV-LED, and DMDs. The system is suitable for rigid and flex substrates and has automatic handling options. Earlier systems using DMDs include:

- ORC's DI-Impact (formerly by Pentax)
- Hitachi's DE imagers DE-H, DE-S, and DE-F series
- MIVA Technologies GmbH, Germany, Miva 2600X Direct Imager

- Maskless Lithography's DMD-based system (USA), using a mercury arc light source or LEDs
- Aiscent Technologies (Canada)

The Korean company Ajuhitek, Inc., entered the market with its EP digital imager series using a laser diode radiation source with the wavelength of 405 nm.

To the best of my knowledge, HAN's Laser Technology Group is the only Chinese supplier of direct imagers.

Japanese direct imager suppliers ADTEC, DNS, ORC, and Via Mechanics continue to introduce improved systems.

The Swiss supplier PrintProcess introduced its Apollon DI-F10 (manual single frontload) and the Apollon-DI-A11 (auto double-side reverse inline). Line width resolution is 30 to 20 microns depending on photoresist type. There are one to seven imaging heads (eight is optional). The light source is UV-LED, with multiple wavelengths in the range of 360 to 420 nm. These units offer automated loading and unloading. It offers automatic image scaling and reliably resolves 1-mil features.

KLEO Halbleitertechnik GmbH, Germany, supplies direct imagers since 2009, with systems in production in Germany and Switzerland. The KLEO-LDI-System CB20HV-Twinstage uses a 405 nm wavelength laser diode. The 405 nm radiation source is dominant in Asia. Photoresists (dry film and liquid) suitable of exposure at 405 nm are available from Hitachi, DuPont, Atotech, Eternal, Kolon, and Elga Europe. KLEO was acquired by Manz in 2015.

The UV-P100 UV-LED direct imager by Limata GmbH (Germany) was developed for prototype and short run production. It can use conventional dry film and solder mask. Light source life exceeds 10,000 hours. Maximum panel size is 650 x 540 mm. Resolution of 50-micron features is obtained. Automated load/unload is available, and side-to-side registration is achieved with cameras and registration target holes.

Orbotech has installed over 1,000 direct imagers. Its Nuvogo DI System is designed for mass production of advanced HDI/flex and rigid flex applications, according to Orbotech. The Nuvogo 800 is compatible with nearly all resist types. Its resolution is capable of 18-micron lines and spaces. Nuvogo makes use of Orbotech's well established large-scan-optics-technology (LSO). The MultiWave Laser Technology uses a multi-wavelength laser beam of high intensity so that lower cost resist with standard photosensitivity can be used for high throughput (up to 7,000 panels/day/line) with optimal line structure.

Manz, a supplier of wet processing chemistry modules, has diversified into digital imaging with its

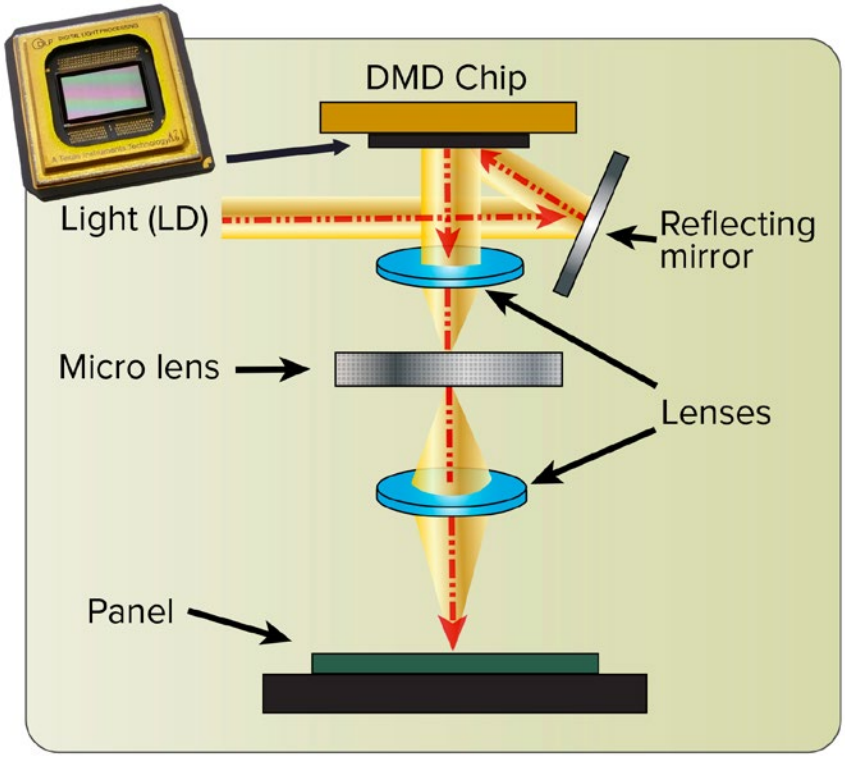

Figure 2: The UV light is directed through the DLP/DMDs down onto the panel surface[4].

SpeedLight 2D system. It features a twin stage, allowing imaging of the first panel while a second panel is being registered. The imager consists of 288 laser diode beams that are modulated by nine polygon mirror modules.

Limata GmbH, the German supplier of laser direct imaging systems used in small lot PCB production and photochemical machining, has developed its established UV-P model into the advanced UV-R Series. It can make use of the latest UV diode lasers with multiple wavelengths and a long operating life. Both models are equipped with one to eight laser heads. Resolution down to 25-micron lines and spaces is being achieved. A pre-registration module can address up to 64 registration targets to achieve near perfect registration. Solder mask can be imaged using up to three wavelengths for maximum intensity, to accommodate less sensitive photoresists. A robotic load and unload station can be added for enhanced throughput and optimal interface with other processing equipment.

A pre-registration module can address up to 64 registration targets to achieve near perfect registration.

Canadian supplier Aiscent Technology has done R&D in digital imaging for more than 15 years. Its system uses DMDR-based photolithography and a proprietary high-power laser. Double-sided models currently offered are suitable for production of PCBs, high-resolution photomasks, digital screen imaging, and other customized industrial use.

Schmoll Maschinen, the well-known supplier of mechanical and laser drilling machines, offers a digital direct imaging (DDI) system ideal for prototyping inner layer, outer layer, and solder mask images. It is based on semiconductor laser diodes and large (wide) optics. The imager is equipped with two to eight diode lasers. Schmoll also offers micromirror digital imaging (MDI) systems. The unique "light engine" head is mounted to a granite platform providing a precision positioning system. This new technology transfers UV light images to the circuit board substrate utilizing over 2 million high-resolution micromirror chips. These systems are available as a single-table unit, a tandem table unit, or the XXL model that can handle a maximum single panel size of 1371 x 914 mm. The units use high-power LEDs and DMDR with multiple wavelengths from 365 to 405 nm.

The Swiss company First EIE SA supplies photoplotters, inkjet printers, and direct imagers suitable for quick-turn, small lot size shops. Its direct imager is named EDI500. The light source technology is based on TI's DMDR devices with advanced UV lens and very high-pressure mercury arc lamps. Panel registration is done with a building CCD camera or by manual pin registration. Maximum panel size is 620 x 690 mm, but the newer EDI700 can handle an even larger panel size.

Visitech is a Norwegian company that supplies optical modules (optical subsystems) for direct imagers. The Luxbeam Rapid System (LRS) is based on TI's DLPR (micromirrors) and multiwavelength LED light sources, emitting in the range of 350 to 440 nm. Five modules are available with different resolution capabilities: LLS2500 (2.5-micron t/s); LLS04 (4-micron t/s); and LLS06 (6-micron t/s) with two more up to 30-micron t/s. Optical multiplexing allows the units to achieve their very fine resolution.

Front to Back Registration

It is desirable to achieve good front-to-back registration. There are several ways to achieve this, some without the need to drill target holes on the panel before exposure ("hole-less registration"). Figure 3 shows four methods utiliz-

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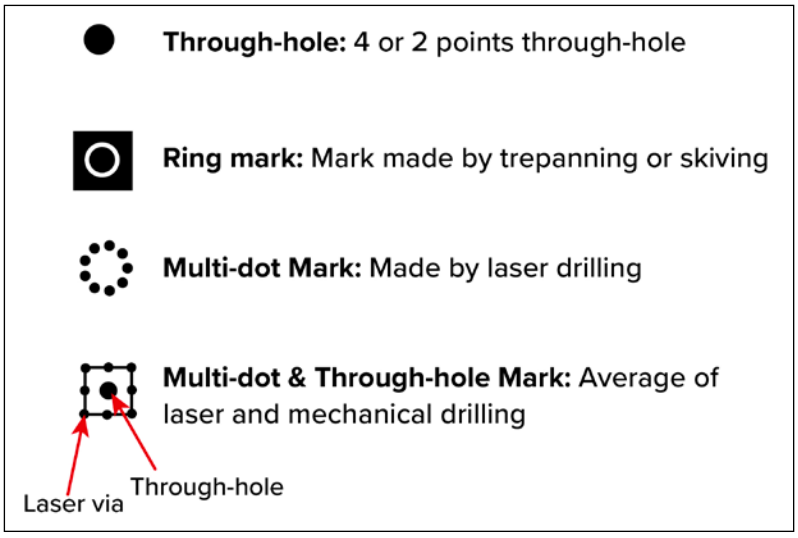

Figure 3: Many different registration techniques can be accommodated. Here are four different ways:[3]

ing mechanical and laser drills. The "hole-less registration" is achieved through the "print-out image" characteristic of the photoresist, a color change of the resist during exposure that makes the latent polymerized features visible. For both types of registration, the panel is placed on the machine's table for topside exposure. As vacuum is applied, the markers placed inside the table start to image the targets or holes on the bottom side of the panel. CCD cameras then align the panel to the table as the panel moves in, and the topside is imaged during the reverse movement. After flipping the panel, CCD cameras locate the target or hole marks on the bottom side; registration and imaging follow.

Another method is shown in Figure 4. First, the recording heads of the DLP Towers are calibrated (step a) and detect any position corrections using the alignment cameras and the registration type (step b), then on fast computers compensation for scaling, rotation, positioning, and enlargement to conduct highly reliable and accurate imaging. Auto-focus follows the board and compensates for warping and board thickness.

Summary

In the application of DI for next generation ultra-HDI, Figure 5 shows the results of the 3 µm line/space resolution evaluation on larger 510 mm x 515 mm panels. A CCL/ABF substrate with a 10 µm-thick dry film resist was selected for this demonstration, resulting in lines with just over a 1:3 aspect ratio. Best dose and best focus were determined using a focus exposure matrix (FEM). Best dose was used for the resolution demonstration. The figure indicates that CDs showed less than 10% deviation from -10 µm to -70 µm, at a DOF of 60 µm. The data from the FEM were used to generate a Bossung plot (Figure 5a) in which the X-axis is focus (µm) and the Y-axis is CD (µm). The plot shows the 60 µm DOF. Figure 5b also includes a lower magnification image of 3 µm,

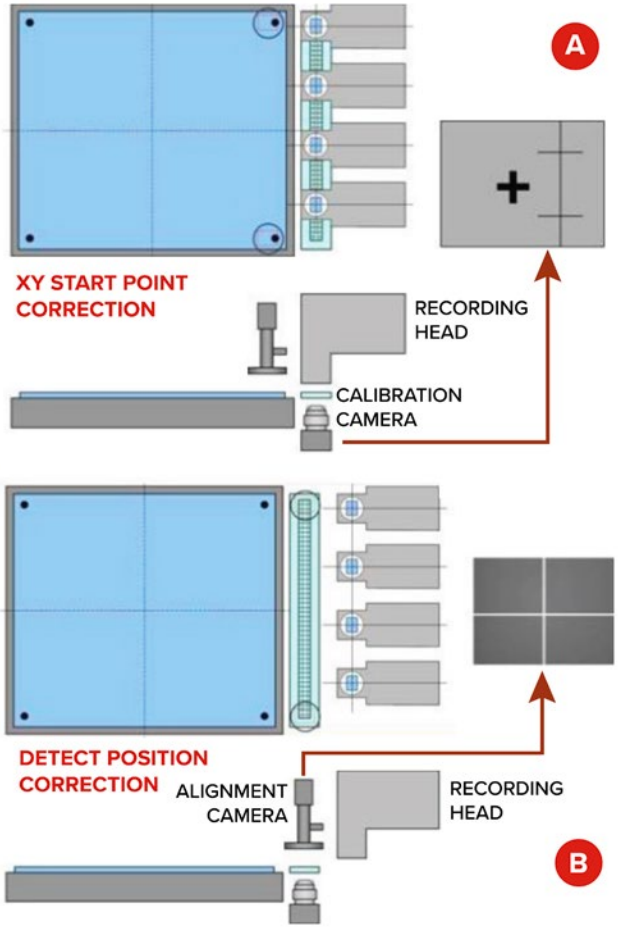

Figure 4: Setting up registration target to boards can differ quite a lot. Here is one scheme. (Source: Dainippon Screen Mfg. Co. Ltd.)

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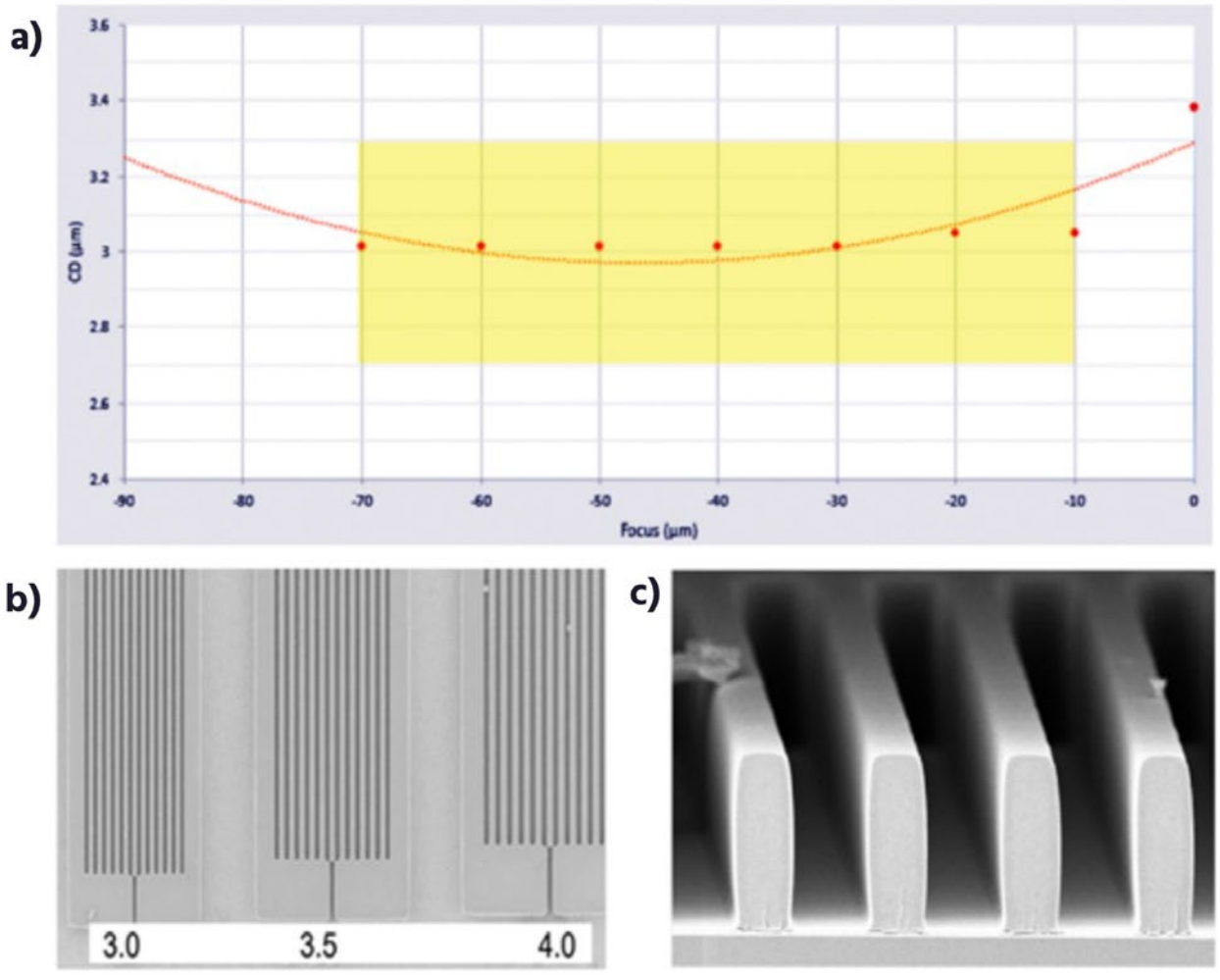

Figure 5: a) Bossung plot generated from FEM data showing less than 10% deviation over 60 µm DOF; b) lower resolution image of 3 µm, 3.5 µm, and 4 µm isolated and dense area line/space arrays; c) cross-section image of 3 µm lines in 10 µm thick dry film resist on copper substrate; the line critical dimension is 3.181 µm, and the resist height is 9.873 µm in the cross-sectional image. (Source: IMAPS SiP Conference—2022 Proceedings[5])

3.5 µm, and 4 µm isolated and dense line/space arrays. A higher resolution cross-sectional image of 3 µm lines (Figure 5c) shows dimensions for the middle line: 3.181 µm line width and 9.873 µm line height (resist thickness).[5] **PCB007**

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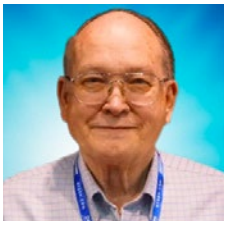

Happy Holden has worked in printed circuit technology since 1970 with Hewlett-Packard, NanYa Westwood, Merix, Foxconn, and Gentex. He is currently a contributing technical editor with I-Connect007, and the author of Automation and Advanced Procedures in PCB Fabrication, and 24 Essential Skills for Engineers. To contact Holden or read past columns, click here.

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The CHIPS Act is Just the Beginning

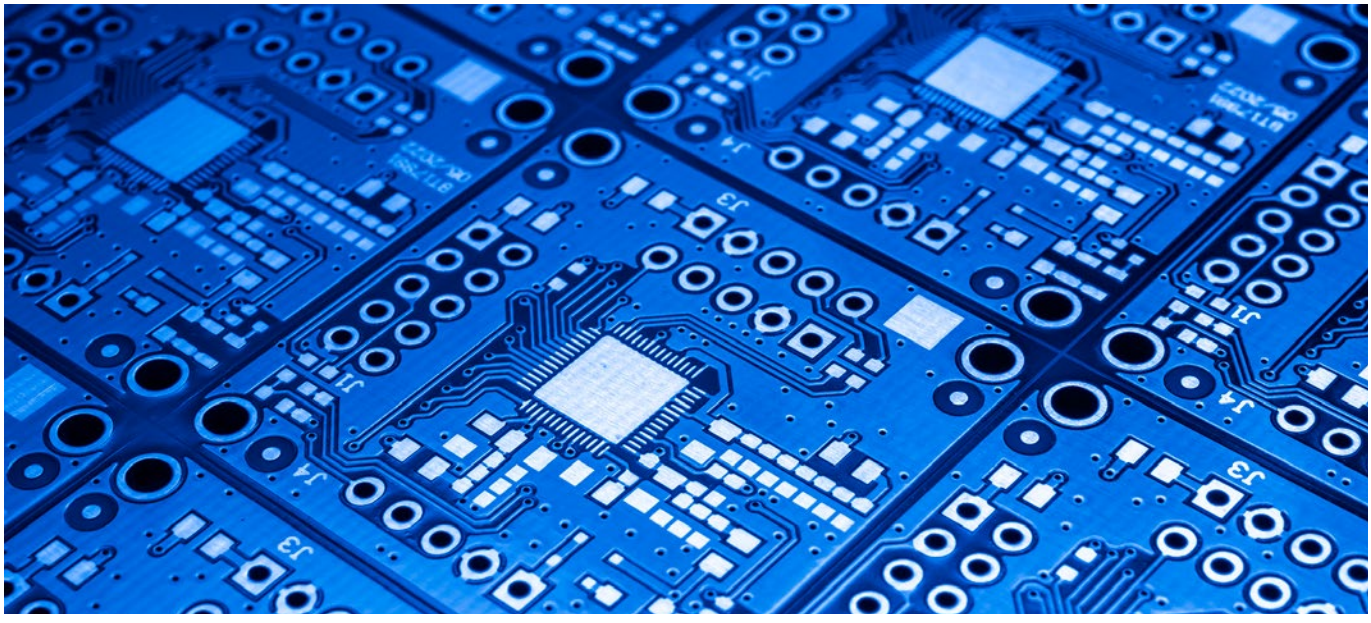
American Made Advocacy

by Travis Kelly, PCBAA

Now that the much-heralded CHIPS and Science Act has been signed into law, the work to secure the entire microelectronics ecosystem must begin. We have a long way to go in restoring balance and resilience to our critical supply chains. Over the past 20 years we have let the manufacturing and the know-how that goes with it migrate overseas. U.S. dependence on foreign suppliers won't be reversed overnight, even by building semiconductor fabrication plants here.

The offshore migration of microelectronics manufacturing was driven by lower labor and production costs in other countries—primarily in Asia—that chose long-term national investment strategies. These countries subsidized their industries to provide cheap labor and an unfair economic advantage to capture the market while the United States took a short-term, quarter-to-quarter financial focus to let the markets decide. U.S. companies moved work—and the brainpower—to the countries that made competitiveness a priority. U.S. companies simply couldn't compete with other countries. Many U.S. companies went out of business, others consolidated to survive, and more moved work overseas.

Nowhere is this more evident than with the printed circuit board industry. Every chip, regardless of where it is made, needs a printed circuit board, or PCB, to mate to an end use device. Today PCBs themselves are complex microelectronic components that require a skilled workforce and complex and expensive equipment to keep up with technology advances.



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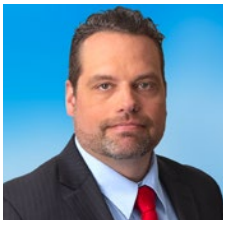
Several decades ago, the U.S. produced almost 30% of the world's PCBs; now we make only 4%. This means that despite the chip fabrication plants being built in the United States, we will still be vulnerable to supply chain disruptions for the PCBs and other microelectronics those plants produce. As we have seen with COVID and real time political and military rumblings in Asia, it is not hard to imagine we could see a disruption to critical sources of PCBs and other microelectronics. On our current course, the U.S. is not prepared to weather such a supply chain storm.

There are three things that need to happen to reverse this trend for PCBs, to protect the economic and national security of this country:

1. Encourage existing PCB manufacturers to increase production. The demand signal from customers must be clear, strong, and sustainable.
2. For those companies to move ahead, they need to invest in R&D and capital improvements to keep pace with global industry. There must be a good case for the investment community to join in this effort. They need to see the future value of such an investment and how their input figures a mutually beneficial public/private partnership.
3. Reclaiming a fair share of the world's supply of microelectronics requires consistent investment by the federal government. The DoD has led the way in this area. While only constituting about 10% of the demand for PCBs, DoD is, through policy and budgeting, pushing for a secure, trusted, reliable, and resilient supply of PCBs. The Pentagon already knows what many in Washington are just now learning: Microelectronics are key to both the economic and national security interests of the country.

The decline of American innovation and manufacturing is not inevitable. Policymakers can act now to revitalize the nation's microelectronics industry through a comprehensive strategy of public and private investment. **PCB007**



Travis Kelly is CEO is IsolaGroup and current chairman of the Printed Circuit Board Association of America. To read past columns, click here.

New Nanowire Assembly Process Could Enable More Powerful ICs

In a newly published study, a team of researchers in Oxford University's Department of Materials led by Harish Bhaskaran, Professor of Applied Nanomaterials, describe a breakthrough approach to pick up single nanowires from the growth substrate and place them on virtually any platform with sub-micron accuracy.

The innovative method uses novel tools, including ultra-thin filaments of polyethylene terephthalate (PET) with tapered nanoscale tips that are used to pick up individual nanowires. The nanowires are then transferred to a transparent dome-shaped elastic stamp mounted on a glass slide. Nanowires, materials with diameters 1,000 times smaller than a human hair and fascinating physical properties, could enable major advancements in many different fields, from energy harvesters and sensors, to information and quantum technologies.

DPhil student Utku Emre Ali (Department of Materials), who developed the technique, said, "This new pick-and-place assembly process has enabled us to create first-of-its-kind devices in the nanowire realm. We believe that it will inexpensively advance nanowire research by allowing users to incorporate nanowires with existing on-chip platforms, be it electronic or photonic, unlocking physical properties that have not been attainable so far. Furthermore, this technique could be fully automated, making full-scale fabrication of high-quality nanowire-integrated chips a real possibility."

(Source: University of Oxford)

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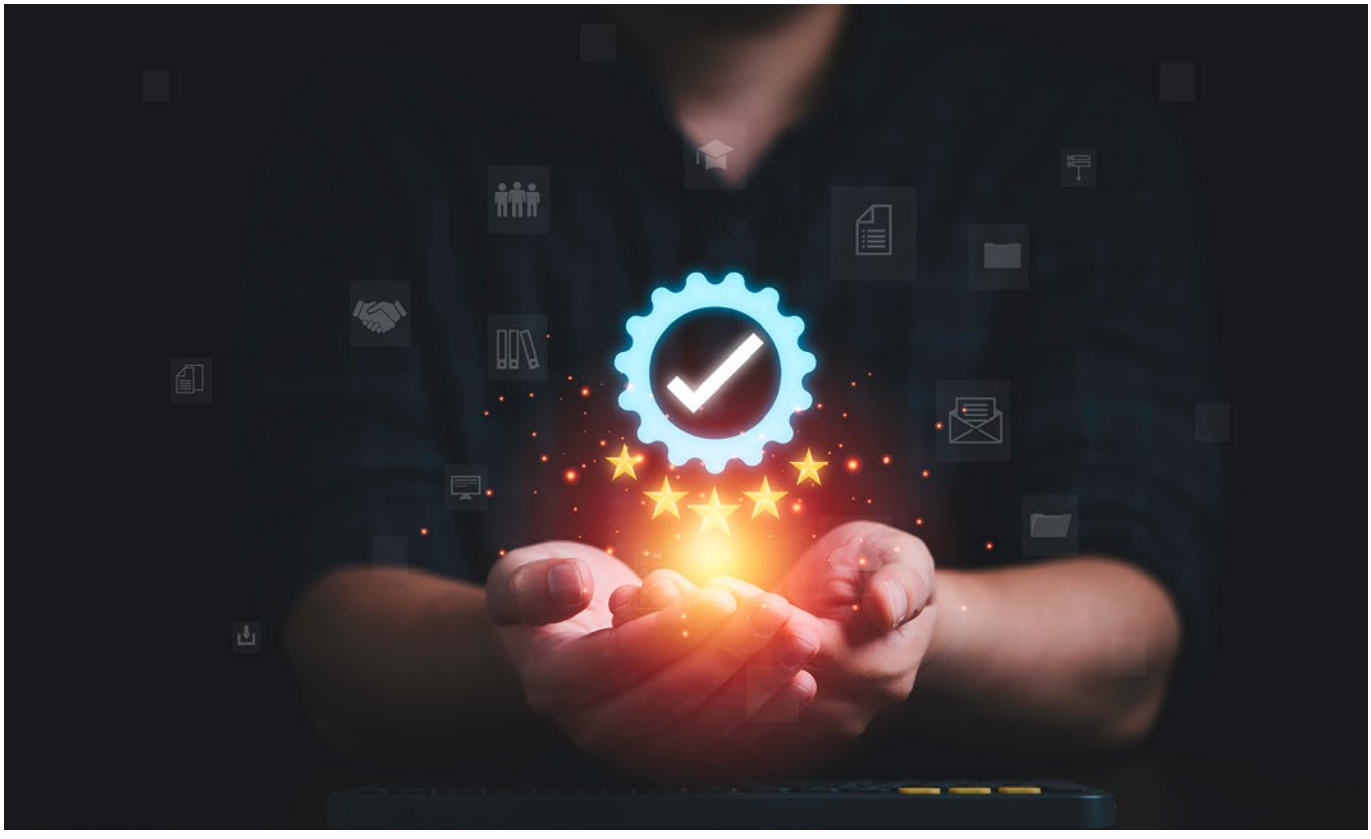

Optimize Your Etcher for Best Image Quality

Feature Article by Christopher Bonsell
CHEMCUT

When it comes to obtaining high-quality images, many different factors come into play. Typically, most of these factors come down to your imaging equipment and cleanroom; however, there are factors involved in the etching process that can affect the quality of your image. Here are five steps to ensure your etching process is optimized for the best image quality.

1. Be wary of undercut.

When you are etching to obtain your circuitry patterns on a PCB, beware of undercut. Due to your solution's etch factor—the ratio of sideways etch to downward etch—your image will need to compensate any change and variation that can arise. Naturally, when you create a line with a photoresist to make a feature, the outcome of that feature will be smaller because of the sideways etching. PCB designs typically account for this, but if you are working with thicker copper layers for your PCBs, you will have to be cautious and ensure that the sideways etch does not impact the features you desire.

2. Monitor your etchant quality.

Maintaining consistency of your etch chemistry is the key to ensuring your etcher gives a quality image. As you etch panels, your etchant will decline in quality because it loses reaction potential (from the depletion of reactants), and with that, you will pick up contaminants. To prevent this from affecting your etching process, you will need to implement process controls to maintain the properties of

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your etchant. Depending on the etching solution you utilize, the factors you need to control will vary. If you are unsure how to monitor or maintain your etch process, it is best to seek experienced help and consult your etch equipment manufacturer.

3. Clean your nozzles regularly.

As I mentioned, etching panels will introduce contaminants into your etching bath. With this, your nozzles can become clogged with debris. Frequently cleaning your nozzles is an easy measure you can take to prevent debris from affecting etch quality. Doing this will ensure that your panels receive a consistent spray pattern throughout the etch chamber.

4. Choose the correct resist.

Different photoresists are compatible with different etching chemistries. To maintain your etch quality, it is necessary to ensure your resist and etchant are compatible. If they are not compatible, the resist can lift off the surface of the panel during etching and fail to produce the circuitry pattern you desired. Avoiding this problem can be done by researching your resist film and running a few test boards through your etcher to see if there are any signs of lifting.

5. Start with a micro-etch.

Although resist lifting can be related to etchant compatibility, it can also be caused by contaminants on the surface before applying the resist film. To make sure these contaminants don't get in the way of adhesion, it is a good practice to have your panels go through a micro-etch cleaning process to remove these contaminants and restructure the surface to promote adhesion of your photoresist. It should be noted, however, that different photoresists will work better with different micro-etch solutions.

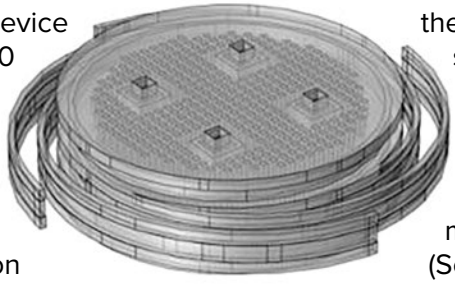
If you take these measures, your etching process will be working at its fullest capacity to provide you with the high-quality features on your PCBs. **PCB007**

Christopher Bonsell is a chemical process engineer at Chemcut and an I-Connect007 columnist. To read past columns, click here.

Nanusens Granted First Patent with More in the Pipeline

The multi-award-winning pioneer of nanosensors, Nanusens, has had its first patent granted in the US, with filings in other countries underway, and has more patents in the process of being applied for. These all protect its innovative technology of building nanoscale structures within a standard CMOS metal layers to create novel NEMS (Nano Electro Mechanical Systems) sensors.

This first patent is for a round device with a diameter of less than 150 microns with three evenly distributed springs that are spiral so that they can be long to give high sensitivity. This design can be used by Nanusens in a number of its sensor designs such as a bone conduction sensor, motion detector and accelerometer, among others.



"You can't simply shrink a MEMS sensor design and build it with the CMOS metal layers," explained Dr Josep Montanyà, founder and CEO of Nanusens. "We have had to invent completely new sensor structures that will work reliably when made in a standard CMOS fab line, which means that they need to work with large residual stress and large process tolerances. These have taken years to perfect but now we have working NEMS in silicon so we are filing ten patent families that between them protect more than 100 inventions."

(Source: Nanusens)

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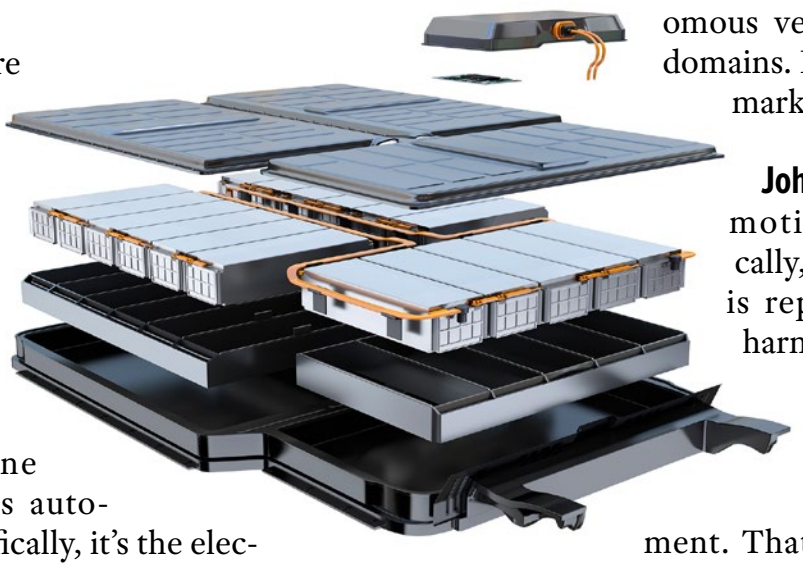
Web vs. Direct Imaging

Feature Interview by the I-Connect007 Editorial Team

As flexible printed circuits (FPC) continue making waves in PCB manufacturing, the Altix team of Alexis Guilbert, Damien Boureau, and Alexandre Camus look at today's use cases for FPCs, and detail the finer points of roll-to-roll technology vs. direct imaging. For example, how long can a flexible circuit be? Which technology works best with extremely long circuits, and how does a customer know which one to use? The I-Connect007 Editorial Team explores these trending topics and what it means for PCB manufacturers.



Nolan Johnson: We're here to learn more about Altix's continued work on roll-to-roll technologies. What do you see as the market drivers for roll-to-roll?

Alexis Guilbert: One booming market is automotive. More specifically, it's the electric vehicle battery manufacturing market, which is enjoying tremendous growth. One report I read mentioned a $7 billion growth in market size by this year. I believe the flexible printed circuit segment is growing in the industry because it replaces wires, for example, which used to always be wire harnesses. Now it's FPC, which saves assembly time and space as well as space and weight in the vehicle. You divide those by approximately two compared to normal wires. Of course, it's an FPC, so you will have data like temperature, voltage, and everything else.

Alexandre Camus: The main drivers will be, for example, battery packs, interconnects, some sensors, and wire harness replacements. I want to stress that for battery pack interconnects, it will mostly be for electric vehicles but there will always be more FPC in traditional ICE vehicles. The EV and autonomous vehicles are growing domains. It's a really dynamic market.

Johnson: For the automotive sector specifically, it sounds like this is replacing some wire harnesses.

Guilbert: Yes, it's basically a wire harness replacement. That's one of the main drivers for both our roll-to-roll contact printers and direct imager (DI).

Johnson: What's the value-add for moving to flex over the wire harness? Why is flex better than a traditional wire harness?

Guilbert: It saves space and reduces weight. For a vehicle, that's tremendously important as

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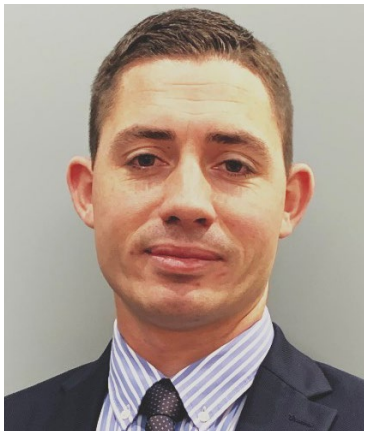
those are critical features. It saves part count and assembly time. In electric vehicles, it gives data to the battery management system (BMS), such as the temperatures or voltage. If I go a bit deeper, you have a thermal management system for the batteries, and you need to send this data as well to the BMS. A lot of data needs to be transmitted—and not only to the BMS as you have the communication between the BMS and the dashboard. This is incorporated for the driver to look at.



Alexis Guilbert

Johnson: By using flex circuits, in this case, you can get more data channels into a smaller space?

Camus: It's a win-win because you save space, and you get more out of the product. It's a clear upgrade. No downsides.

Barry Matties: Is there an advantage for eliminating crosstalk or noise compared to the wire harness?

Guilbert: Yes. There is less noise concern when you have an FPC compared to a wire harness. That is also true.

Matties: That's probably one of the big advantages in design as well. We're talking automotive, but are you seeing any trends into perhaps the commercial or military aircraft spaces as well?

Camus: Yes. I've definitely seen cases for unmanned aerial vehicles (UAVs) in both military and civilian applications. We haven't seen the end of the market yet. It's still growing.

Matties: With the roll-to-roll technology, there's no limit to the length, correct?

Guilbert: That's correct.

Damien Boureau: In fact, this is part of what we are bringing together with our contact printer or direct machine units in roll-to-roll. We can bring options to help our customer produce something like an unlimited flexible circuit. We added some functions, like stitching images all together over the web, or clipping a very long image so that we can recompose it at the end.

Johnson: Are there other sectors or parts of the market that seem to be moving toward roll-to-roll?

Guilbert: Yes. We see more equipment working in the medical sector. For example, we see some FPC manufacturers making a medical catheter. It seems that the FPC makers can develop a new and effective method for this type of product. They can save the cost and improve the performance of such a product by using FPC boards. We're also seeing what they call minimally invasive surgery (MIS). The product is a long FPC of two meters, and they are running with very small tracks and spaces between 35 to 50 microns. We see an increasing demand to build such a product.

Johnson: I hadn't thought about having to go for a long-distance on a medical catheter. Seems to me like that's a similar design demand: more data in a very small and flexible space, traveling what would be considered a significant distance. In this case, multiple meters in length.

Guilbert: Yes. This is the most difficult aspect as an exposure manufacturer. We must build equipment that can do very thin lines and spaces over a very long length, about two meters and sometimes more. Therefore, we developed Adix Roll to Roll (RtR), which has been running for four to five years.

Thanks to the new clipping function that we have developed, as Damien mentioned, we are now able to answer such requirements on the market.


Damien Boureau

Matties: What does it take for a fabricator to incorporate this technology into their current manufacturing process? Is this something where they must make a significant change in their manufacturing to bring this product to their customers, or is it a simple process they can add on?

Boureau: They should improve their roll handling inside the whole factory. We then bring the clipping function as an add-on—it's basically plug and play. We can load the very long Gerber file as it is from the customer to clip it into several parts and expose the pieces so that they are stitched together without any input from the customer.

Matties: What is the interest? Are more fabricators looking to add this to their portfolio?

Boureau: The demand is for applications in the medical sector, as well as for battery applications.

Guilbert: There are fewer customers asking for original equipment without asking for stitching or clipping functions. Considering the line and space expected of 50 microns, it's not possible to realize such a product with a startup conventional printer with large glass and, let's say, solder with a stencil—which is impossible. In this case, and for such a long product with different images, the Adix RtR is mandatory.

Johnson: Flex circuits are used quite a bit in antennas, RFIDs, and those types of signaling applications. You mentioned that roll-to-roll seems to be quite helpful.

Guilbert: We are working with several FPC makers, developing all kinds of high-frequency antennas in the U.S., Europe, and Asia. All those products are delivered in the whole format. As a part of the antenna and RFID, they are working on the long flex separate as well. We see different web widths from 250 to 550 millimeters.

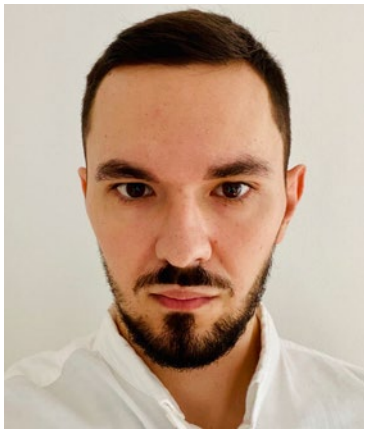
The direct image roll-to-roll can run with the stitching function. We can expose one image that will be repeated, and all the images will be connected. However, for this type of process the conventional contact printer makes more sense for endless exposure.

Johnson: A common theme for automotive, medical, antennas, and RFID has to do with putting your stitching and clipping capability to good use. For each of those market segments, you're using the same manufacturing capability, but achieving different goals. How does the stitching and clipping part of the manufacturing work?

Boureau: In fact, we are talking about stitching when we consider a photo exposure conventional unit. In this type of process, we have a mask to transfer through a photolithographic process onto a web. We can repeat this image several times. All the images along the web are repeated perfectly so that the downstream process can be done without any further alignment.

When we talk about clipping, we use the Adix reel-to-reel machine, which is also a direct imaging process. This is for doing very long images on the web, from 0.6 up to 100 meters or more. In a case like this—and as the equipment can't do it all at once—we have to clip the Gerber file at the beginning and put each part we have clipped on the web as a step, then use the second part of the image, then the third,

and the fourth, etc. At the end, the whole image is recomposed on the web. So, these are two very different kinds of processes using the equipment we have.



Alexandre Camus

Johnson: These applications, such as vehicle and technologies, short-throw radio signals for RFID, etc., sound like they're well-suited for a roll-to-roll approach. But when choosing between contact printer and direct imaging, how do designers and manufacturers decide?

Guilbert: It depends on the throughput required and the expected resolution. First, if the customer is looking for very high throughput equipment and simultaneous double-sided exposure, then for sure, the roll-to-roll conventional unit would make sense. We now have LED light sources for which the consumption would be very low. This type of unit would be perfect. If the customer is looking to expose a very long image, the roll-to-roll DI would be mandatory. This is only one advantage of the Adix RtR. We've also developed a panel function with our equipment, where the user can expose just some small panels as a prototype or small volume production.

Boureau: The roll-to-roll direct imaging machine has more versatility compared to the conventional exposure unit. If you want to have a machine able to do very long surfaces as well as very small batches, or batches that are requiring a very precise alignment or distortion in the images, you can have them through the direct imaging with your machine. This is the limitation with the photo exposure units. They are more dedicated to a repeatable and very high productivity process.

Camus: To get the most out of the clipping and stitching functions, we developed fully customizable unwinder and winder systems which are designed and manufactured here. Our customers say they appreciate our ability to adapt to their current production line. We've had some really good feedback. To be honest, it helped us win some deals, so we're happy about that.

Johnson: What are some of the things that require customization? Are we talking about materials, applications, or the length of the surface that you're manufacturing? How do you set up a customized winder and unwinder?

Guilbert: We offer three types of winders and unwinders that play on different technical aspects. First is the internal shaft diameter. Sometimes, we see 3 to 6 inches, so Altix can adapt the size of the shaft diameter. Another point is the cool weight. Some customers are using FPC, so we're working with the photochemical market as well. We see different coil weights, and we can adapt the shaft. Then there's the bonding on the quality of products on the coil; it's going to play on the maximum coil diameter. In this case, we have to rearrange the size of the winder/unwinder systems. To not damage the product at the end, we play with the size of the global rolls we have on the system to limit the distortion of the product. These are different aspects we can customize our winder/unwinder for.

Boureau: The main parameters are the type of products the customer wants to use with our system, considering the type of material, the widths, thickness, and quantity of the material we will have on this coil. Through these main characteristics we can design the right unwinder systems dedicated to its application.

Johnson: Looking ahead, what are the emerging

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trends or demands from flex manufacturers that still need to be addressed?

Boureau: We see more demands for specific web widths. With our current equipment, we can have under 550 millimeters web width. But we are challenged by new demands to go above 600 for very large flexible circuits. Some applications are in automotive, but we get inquiries for antennas, especially for 5G applications. One of the trends is the enlargement of the exposure surface and enlargement of the images.

Camus: We have seen a lot of announcements, especially in Europe, about the EV market, particularly regarding supply chain and value chain, localizing battery production, instead of depending on other countries. I believe the United States is doing something similar. So, we see that as a trend.

Johnson: Yes, there is the whole trend toward supply chain resilience.

> It's a boon for us because that means that new factories will open, and that's more opportunities for us to sell machines.

Camus: It's a boon for us because that means that new factories will open, and that's more opportunities for us to sell machines. We're looking forward to the years ahead, especially in the roll-to-roll market.

Johnson: From the perspective of an OEM or a design team putting together a product and wanting to use some of these flex applications that require the roll-to-roll, what technical advice or recommendations can you offer for how they approach their design? How do they best take advantage of this capability in manufacturing their product?

Boureau: One of the main issues they face producing FPC is regarding either mechanical or thermal distortion during the process. Flexible circuits are very sensitive, flexible materials. This FPC—a single-sided, simple circuit or a multilayer circuit—will go through many kinds of equipment from the beginning of the process to the end. Considering the right type of material, such as copper and substrate thicknesses, is very important to reach the goal of our product. Even if our equipment is designed to avoid any stress on the web, if the customer is trying to reach, for example, a very low resolution in the images, but with a very sensitive material continuing distortion, they will have difficulties handling the process and having a good product at the end.

When our customers have a specific type of material or application, we propose testing prior to the investment here at Altix on our equipment so that we can demonstrate that we are going to handle this material. If we are not, we discuss with the customer how we can improve our equipment or the process on that side.

Johnson: So, there is the opportunity for a design team to test their concept through demo equipment before they commit to it. That should be very useful for somebody who is new to this.

Boureau: Of course.

Johnson: Thanks for taking the time to talk with us.

Camus: You're welcome. PCB007

Alexis Guilbert is sales and product manager, **Damien Boureau** is R&D director, and **Alexandre Camus** is marketing manager at Altix.

Surface Finish Evolution from Conventional to Advanced

The Plating Forum

by George Milad, UYEMURA

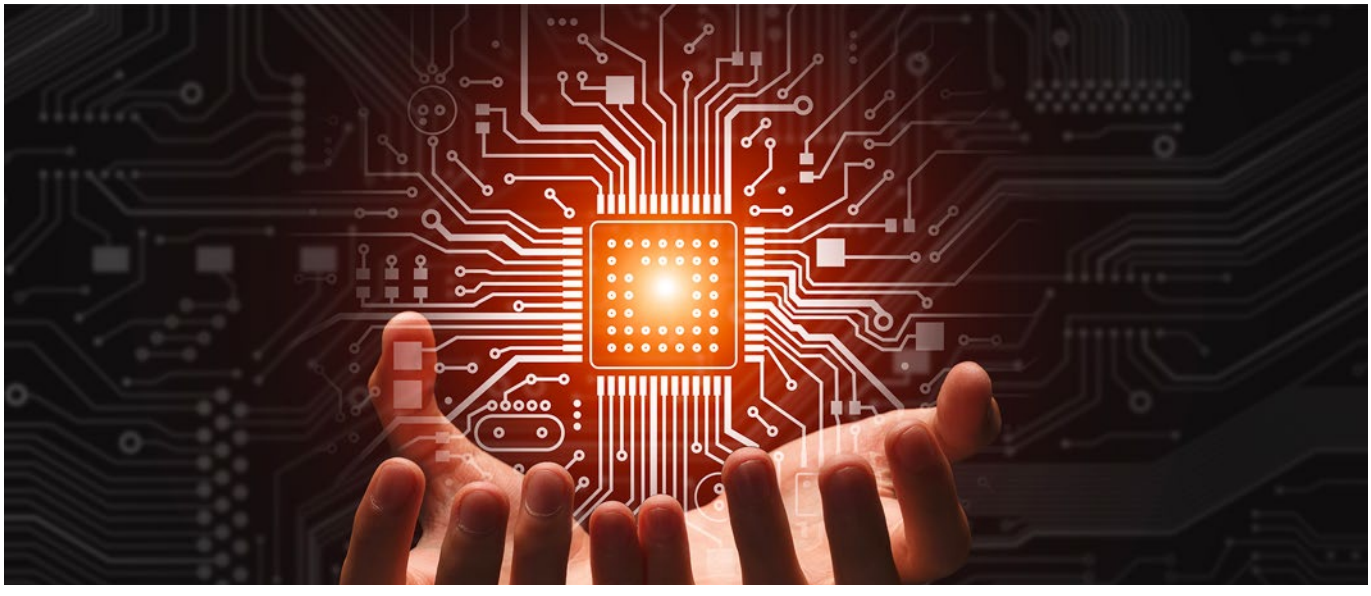
Surface finish is a critical component in PCB design and functionality. Surface finishes form the interface between the component and the circuitry. As its most essential function, the final finish process is intended to provide exposed copper circuitry with a protective coating to preserve solderability. Select surface finishes are also used for wire bonding or as an electrical contacting surface. Perhaps no other step in the PCB manufacturing process has undergone more change in the era of surface mount manufacturing than the final finish chemical process.

Electrical signals are transmitted through copper circuitry connecting the different components throughout the finished board. Copper is a highly conductive metal but one of its shortcomings is that it oxidizes when exposed to ambient air. An oxidized copper surface will not solder and is a poor conductor with no possibility of wire-bonding. Surface finish is applied to ensure no exposed copper is in the final product. Soldering, wire bonding, and contacting are all made with the finished surface.

Today there is a wide variety of finishes that board designers can specify to meet the desired functionality and intended use of their circuit boards:

- A reliable solder joint with leaded and lead-free solder interface
- Bonding surface Al, Au, Cu, Cu/Pd
- Contacting surface insertion
- A finish that will not impede RF signal transmission

When soldering of through-holes was the only desired attribute, three SFs dominated



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in manufacturing facilities. These were hot air solder leveling (HASL) and reflowed tin/lead for surface contacting (insertion) and electrolytic tab plating of nickel/gold as needed. As solder mask over bare copper (SMOBC) made its debut, reflowed tin/lead fell out of favor.

In the next generation (lighter, smaller, and faster), two major manufacturing developments dominated PCB designs, namely surface mount technology (SMT) and ball grid array (BGA) to meet the requirements of newer designs.

SMT and BGA created challenges at assembly. Coplanarity was an absolute must. HASL formed a meniscus that interfered with the application of solder paste on surface mount pads.

This requirement made organic solderability preservative (OSP) and electroless nickel/immersion gold (ENIG) come to the forefront for these applications.

The next major evolution in PWB manufacturing was the elimination of lead from solder.

The next major evolution in PWB manufacturing was the elimination of lead from solder. A new generation of lead-free (LF) solder—tin/silver/copper (SAC) alloys—were the prevailing replacement for tin/lead. The SAC family of alloys have a melting point of 217–219°C, with a peak liquidus temperature of 240°C for complete wetting and for forming a consistent intermetallic compound (IMC), as compared to tin/lead which averaged 187°C for a melting point and a peak soldering temperature of 215°C.

To accommodate the elimination of lead from solder, equipment makers made design changes to accommodate the higher reflow temperature of LF alloys. Although HASL only provides a soldering surface, it remains a viable surface finish today for products that have adequate spacing between pads and do not require contacting or bonding. In the same way, OSP suppliers were able to produce the next generation, namely OSP-HT (high temperature). OSP and OSP-HT are widely used worldwide.

For designs that require high temperature soldering and coplanarity, immersion silver and immersion tin filled that need. However, neither could meet all the demands of solder joint reliability and long shelf life. Silver is susceptible to tarnishing and creep corrosion, and tin requires a thick immersion coating to retain its solderability. Over time, copper will diffuse into the immersion tin, forming a non-solderable Cu/Sn IMC. Both immersion silver and immersion tin remain viable surface finishes with allowances made to overcome their shortcomings.

ENIG, although it is a more complex and more costly process compared to immersion silver and immersion tin, was successful in filling the need for a surface finish that is solderable with LF solder, aluminum wire bondable, and a good contacting surface with an extended shelf life. ENIG had a challenging start when it was first introduced; there were incidents of nickel corrosion under the immersion gold. The corrosion, if excessive, would interfere with IMC formation and the affected part would fail to form a reliable solder joint.

IPC ENIG Specification 4552 Rev B, issued in 2021, spelled out a method to evaluate and measure the extent of ENIG nickel corrosion. Now that there is a method to measure and quantify nickel corrosion, the defect is on its way to being eliminated. "You can't fix what you can't measure."

ENIG remained a popular finish for parts that required its attributes. The next challenge was the need for an additional attribute and that was gold (Au) wire bonding. ENIG is not Au wire bondable because of the possible

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diffusion of nickel into the thin immersion gold layer. A diffusion barrier was needed to prevent the nickel from reaching the surface. Electroless palladium was the answer and ENEPIG (electroless nickel/electroless palladium/immersion gold) was the right finish when the desired attributes included Au wire bonding.

As military and aerospace boards continued to advance into RF signal propagation, there was a need for a new class of finishes that did not include electroless nickel. RF signals travel along the surface of the trace and the presence of electroless nickel would interfere with high frequency (RF) signal propagation.

One way to achieve this was to dramatically reduce the thickness of the nickel layer in ENEPIG to below 0.1 micron. Other finishes, including EPIG or EPAG (electroless palladium/immersion gold or electroless palladium/autocatalytic gold), eliminated the nickel completely. These finishes relied on catalyzing the copper surface with immersion palladium; a more advanced system to achieve the same goal is using immersion gold to catalyze the copper surface. IGEPIG (immersion gold/electroless palladium/immersion gold) was shown to provide a more reliable solder joint.

Still another option was to also eliminate the palladium and immerse gold directly on copper, immersion gold (DIG). A new development in DIG is reduction-assisted immersion gold. RAIG deposits a thicker gold layer (6-8 µins) that prevents the diffusion of copper into the gold wire bonding surface.

Newer and advanced surface finishes are constantly being researched, tested, and implemented. It is important to keep in mind that all the SFs mentioned above are presently used in board fabrication. More advanced finishes are beginning to make headway as the higher technology boards continue to use high RF signals in their designs. Stay tuned. **PCB007**

George Milad is the national accounts manager for technology at Uyemura. To read past columns, click here.

Researchers Develop Novel Spectrum Sensing Technique for 6G IoT Comms

With the explosive growth of the spectrum demand of the Internet of Things (IoT), Non-orthogonal Multiple Access (NOMA) and spectrum sensing are considered as key candidate technologies to improve spectrum utilization in next generation wireless communications technology. However, this brings new challenges on how to ensure the performance of spectrum utilization and system throughput in large-scale IoT scenarios when using both technologies at the same time.

A joint research team from the Shanghai Advanced Research Institute (SARI) of the Chinese Academy of Sciences, VTT Technical Research Centre of Finland and University of Windsor of Canada, proposed a novel spectrum sensing technique for 6G-oriented intelligent IoT communications, seeking a feasible way to provide underlying support for perceptual interference and intelligent identification between large-scale coexistence and aliasing IoT users in future 6G scenarios. Results were published in the latest issue of IEEE Internet of Things Journal.

Focused on inter-system orthogonal/non-orthogonal aliasing coexistence scenarios, the researchers designed a multilayer spectrum sensing technology based on feature detection in NOMA scenarios with multi-users. The corresponding rational workflows and transceiver structures according to different scenarios were presented, and the threshold expressions were deduced accordingly.

This work will promote the theory of signal perception and recognition for 6G-oriented intelligent IoT communications, and provide technical support and development potentials for the promotion of global 6G strategy.

(Source: Chinese Academy of Sciences)

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Retaining Engineers in the Workplace

The New Chapter

by **Hannah Nelson,** VALPARAISO UNIVERSITY/IPC STUDENT DIRECTOR

The burgeoning job market means our communities will need to recruit talent for years to come. Many companies view this as a challenge and have expressed concern that not enough students are graduating with engineering degrees. However, colleges and universities are seeing breakthroughs in their pervasive low retention rates as they create diverse environments where students can flourish. Installing similar programs within the engineering industry itself will prove vital to industry growth.

Engineering is one of the most difficult undergraduate degrees to pursue, but the difficulty heightens as workplace culture sometimes becomes a barrier for students. According to the American Society for Engineering Education, undergraduates pursuing education in engineering disciplines are at high risk for dropout, with an average rate of 40 to 50%[1]. Causes for this dropout have been linked to poor social environments, the inability to keep up with workload, and students who doubt their engineering skill set. For minority groups and women, the *Harvard Business Review*[2] states that there seems to be "greater isolation from supportive networks," due to a "hegemonic masculine culture." This had led to roughly 40% of women leaving their degree behind.

In addition, many students, especially when they are just starting their undergraduate degrees, begin to doubt their intelligence, and feel they will be unable to perform the work of an engineer despite their rigorous coursework. They feel like they don't belong in a career where they aren't comfortable. If students can feel a sense of belonging, they will thrive, so if

Left: Hannah Nelson (holding antenna) works with her senior design team in a "doing" project.
Right: The team continues to explore technical subjects in engineering.

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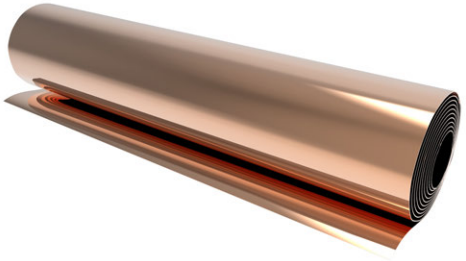

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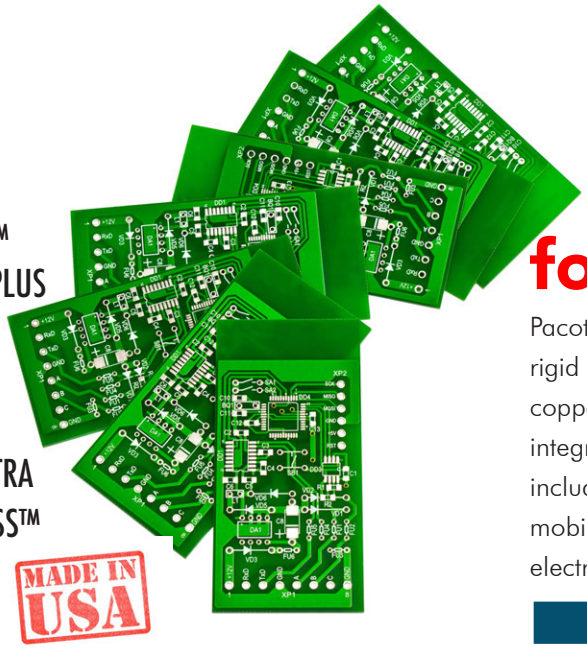

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IPC President and CEO John Mitchell visited Valparaiso University's IPC student chapter. For Hannah, this was an exercise in "sensemaking."

this isn't established during college, many students will leave school feeling unsatisfied or unfulfilled by their career choice.

As students enter college, they leave behind their known and comfortable environment and enter quite a challenging environment. Negative surroundings can leave many students feeling like outcasts or that their degree program leaders don't want them, so they end up changing majors or dropping out of school. One experimental study[3] has shown that students do not have to feel uncomfortable within their environment; they can start identifying themselves within engineering. This is done by "doing," "interacting," and "sensemaking."

- "Doing" asks a student to start developing the skills and technical knowledge needed to excel within their career. They are asked to work intentionally and become present in activities that engage with the engineering design process. Students start to feel more comfortable with discovery and building problem-solving capabilities.
- When "interacting" is present, students are asked to network with individuals within the engineering profession and engage with their work. When students interact with professionals in their field, they quickly get a sense of what a future role will entail. This also helps students understand the value of their work. A professional can be an engineer in the field, or it can be one of the students' professors—individuals they see daily and who will guide them toward feeling passionate about their future careers. Most professors see the talents their students possess and mentor them into successful careers.
- "Sensemaking" is a way for students to combine their personal identity with their professional engineering identity. Most students enter engineering and quickly become overwhelmed by the depth of technical knowledge they lack, which leads to feelings that their personal and professional identities can never be conjoined. But when students become part of something other than education within their campus communities, they quickly learn that engineering isn't just technical expertise but a way to work with and lead others. Joining a student organization provides opportunities to realize the importance of a diverse working environment and it creates more inclusivity within colleges. Students develop their soft skills often not learned in an engineering course.

Education that incorporates the "doing," "interacting," and "sensemaking" are vital to building the next generation of engineering leaders.

The field of engineering needs greater diversity, but with employee morale and retention rates dropping each day, it feels like this diverse culture is on the decline. Innovative R&D has led to exponential growth in the electronics industry, but as companies implement new roles, they aren't able to keep up with employee demand. This is where integrating "sensemaking" into work cultures may lead to tremendous growth in retention rates. When incorporating "sensemaking," it is important

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to create an inclusive environment for employees. Promoting inclusivity in a work environment helps employees feel valued, and encourages them to start identifying with their role and their company.

How do you implement it? Here are three ideas:

1. It can be as simple as setting up new employees with a mentor in the company, similar to a student interacting with a professor. This allows co-workers to build professional and trusting relationships by setting up an environment where new hires feel comfortable and see their potential to grow personally and professionally.
2. Employee resource groups help establish "sensemaking" within the workplace. Resource groups create an environment where individuals of different backgrounds come together for one common goal. It promotes an inclusive environment where employees can flourish, and it helps identify and encourage future leaders in the company.
3. Mentors and supervisors should encourage employees to employ lifelong learning. Many new employees may feel inexperienced and nervous about taking on challenging work. Leaders can encourage employees to see challenges as learning opportunities, encouraging them to network and begin to identify their roles in teams. This inevitably leads individuals to feel they have a greater purpose for their career within the company.

To keep up with demand for employees in the ever-changing environment of the electronics industry, educators and employers must work to create inclusivity in their respective environments. The field of engineering needs professionalism, interaction, and determination. To encourage this, schools must instill and develop passion as early as possible. Schools and businesses must welcome diversity and belonging. Without passion, many students will lack the drive they need to fully engage in engineering careers, leaving all of us scratching our heads about what to do next. **PCB007**

Hannah Nelson (second from left) interacted with other attendees during a networking event at IPC APEX EXPO 2022.

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Hannah Nelson is a student at Valparaiso University, part of the IPC Emerging Engineer Program, and an IPC student director. To read past columns, click here.

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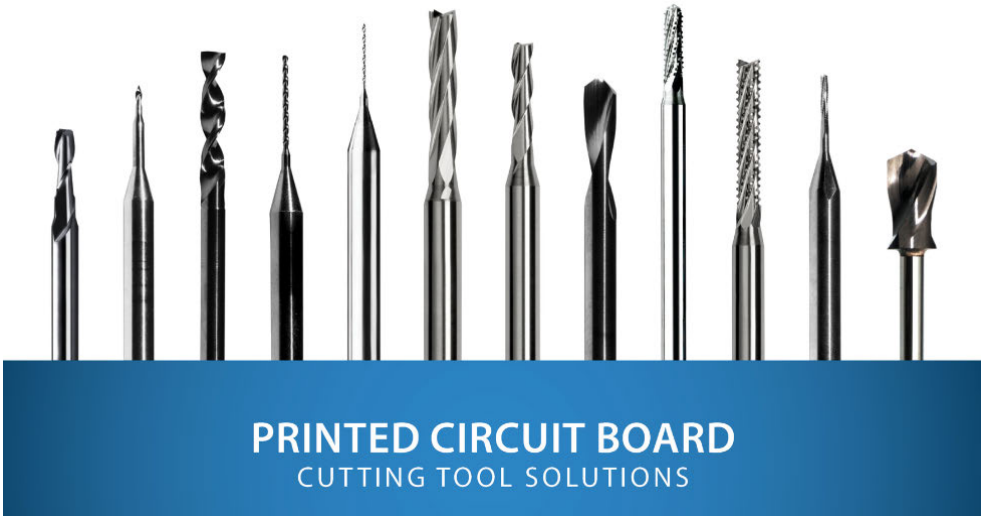

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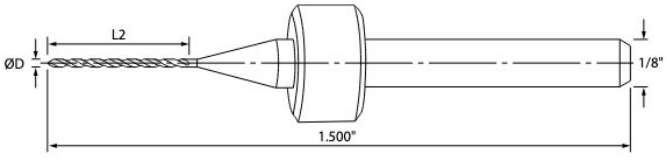

4 Facet Point Geometry

REPOINTING will be a new service offered by Insulectro through Kyocera. The company has recently invested in automated, state-of-the-art equipment and all repointing will be done in Southern California.

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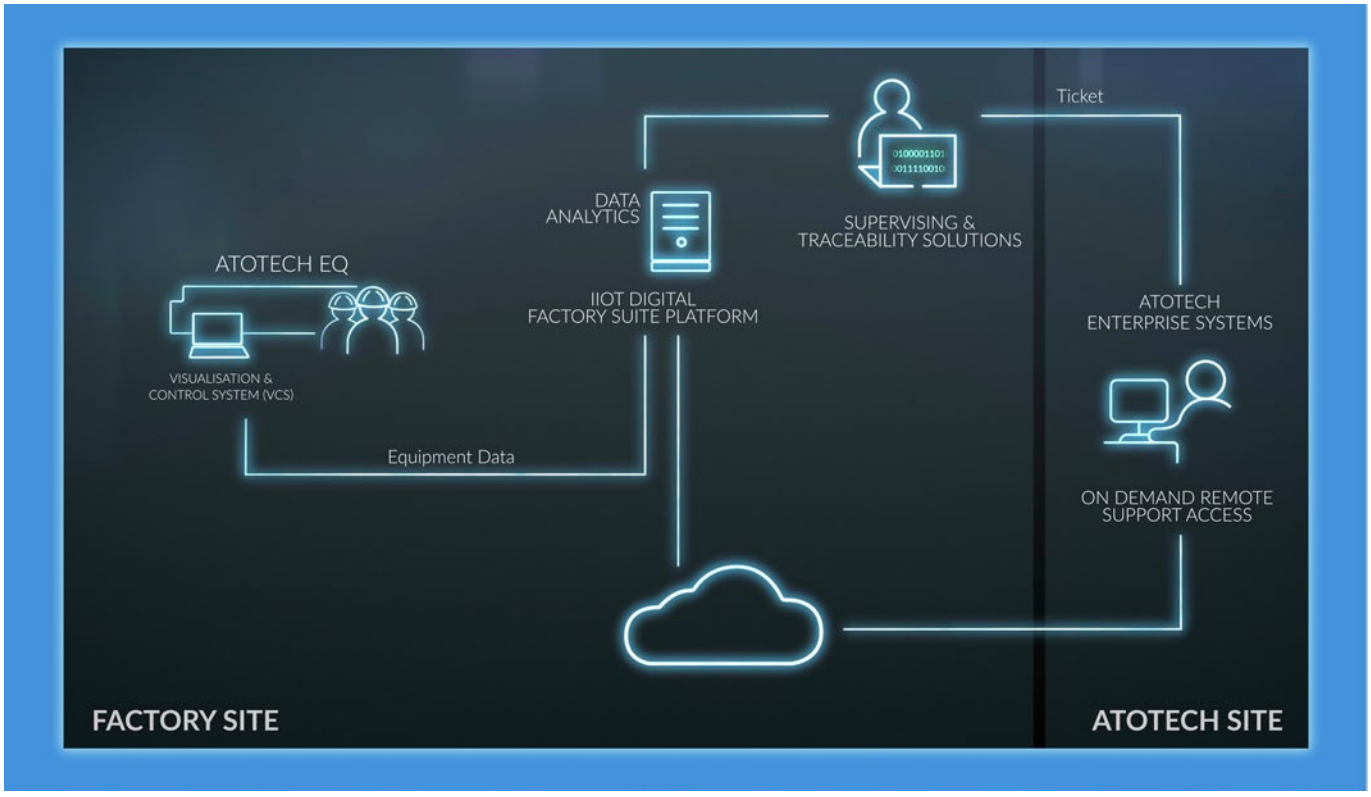

Digital Factory Suite: Custom Made

Interview by Nolan Johnson
I-CONNECT007

Stefan Stefanescu is head of business development for Atotech's industrial digital transformation solutions. Here, he discusses how the Digital Factory Suite (DFS) fits into a PCB fabricator's workflow. The new software connects to the onsite production equipment and continuously collects process and equipment data. But it's more than that, Stefan says. It's a way to help customers increase productivity and take steps toward developing a smart factory.

Nolan Johnson: Stefan, would you introduce your role regarding Atotech products?

Stefan Stefanescu: We understand that digitalization plays a key role in the development and evolution of every company. When I was hired in 2019, my initial role was to help identify digitalization opportunities within the company, in both our internal processes and our products. I have focused very intensely on a strategy for industrial digitalization around our equipment, especially printed circuit board manufacturing equipment. Obviously, digitalization is a core enabler, but transformation is not just about a platform or solutions. It's about processes and people. It's very complex. Atotech has been responsive and open and that's why I enjoy working with a company that understands that transformation needs to happen.

Johnson: Atotech, which is now part of MKS, recently announced it is expanding its product offering with a Digital Factory Suite, particularly wet processes. What can you tell me about that?

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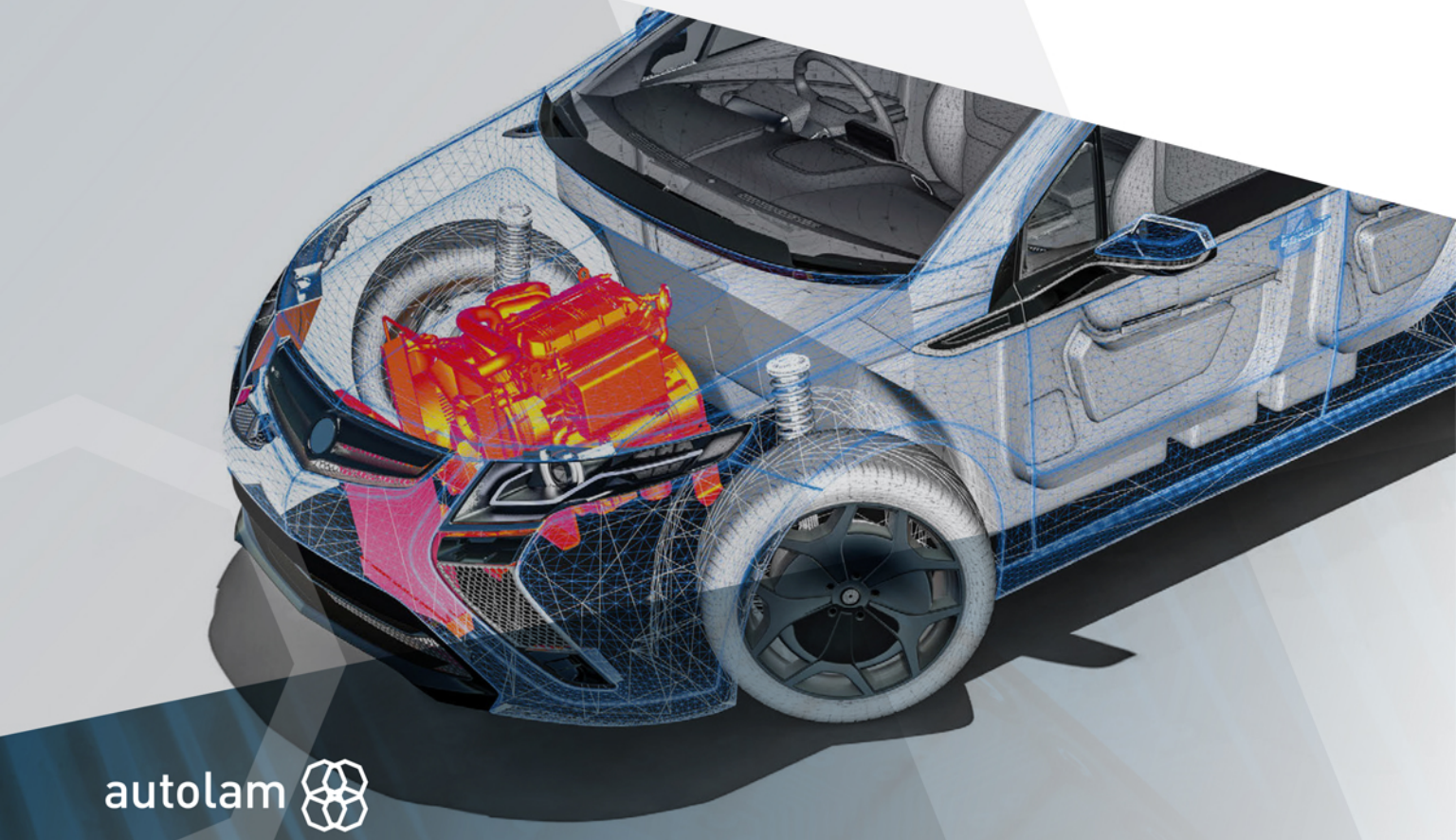

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Stefanescu: For almost 20 years, we have delivered equipment for PCB manufacturing with our control software that allows our customers to operate and run our equipment in production. This enables our customers to run their production as best as possible. Our visualization and control system (VCS) is embedded and delivered when a customer receives our equipment, and the Digital Factory Suite is an add-on, which works with our VCS to bring a suite of values around the equipment.

Stefan Stefanescu

It helps to see it in steps. I like to start with understanding our motivation, and there are four key areas of focus. First, our products are developed with a customer focus. We see digitalization as a tool to bring this focus to higher levels, reduce friction and response time, and help the customer solve problems faster. Second, we see digitalization and industrial digital solution as a tool to increase productivity and especially help our customers operate their production more smoothly. It also touches on sustainability, an important topic for our customers and the whole ecosystem.

Third, digitalization helps us with our R&D processes to bring products to the market faster. Thus, we have adjusted our procedures and planning. Finally, we look at how our customers are doing production today. Some are already looking at what a smart factory means and how to do it. They have started with basic solutions such as a manufacturing execution system (MES), but much more can be done. We see our solutions as enabling our customers to begin this smart factory journey. It's something that needs to be done together with the suppliers of equipment and other solutions and with the customer, because a smart factory is an ecosystem, not just one system.

Johnson: Stefan, when transition and significant change finally happens in an organization, it's usually because there was some compelling event. Overall pressures will push you toward change, but finally something seems to force your hand. Is there a theme for what's triggering PCB fabricators to move to a digital environment?

Stefanescu: Yes, we see that quite a bit. The things that happened due to the pandemic accelerated digitalization. That's a fact. But to summarize the need for digitalization and the drive from our customer's side, there are three important factors. First is compliance in the form of traceability and sustainability. There are requirements for reporting, warranties, and having the proper tools to understand how "green" the production is.

Second is the demand of production, reduced downtime, improved yield, and so on. Customers understand that digitalization is no longer the buzzword it was five years ago, where maintenance now can be done better. There are solutions to decrease the downtime.

Third, they understand that digitalization is not even a choice anymore because you're working with companies upstream and downstream that already have digital tools and solutions. You are being pushed to connect your processes in a digital world. For instance, in the basic solutions of doing end-to-end procurement, which is basically system based, the process is optimized to operate more efficiently and with less friction.

If you don't have your own systems to do that, you cannot be part of that ecosystem. There is a lot of pressure coming from your ecosystems of customers, partners, and suppliers who have digital solutions to achieve the

level of digitalization and process automation everyone is looking for. It has become very clear that we need to be digital to make our workplaces attractive to all generations. It's a big challenge for our customers in industrial manufacturing to get new generations interested in an environment with no digital tools. Having this understanding helps our customers decide to bring their manufacturing to a different level.

Remember, digitalization is not about taking people out, but rather making them more effective. There are processes where digitalization can be more efficient than people. That's a big win for everybody.

Johnson: Stefan, what about data security? When you're in a digital environment, you're more exposed to remote access.

Stefanescu: Our customers have been very protective about the data and general access to information, and that's why we designed the Digital Factory Suite to be on-premises. We don't put it in the cloud because we know some customers have their own internal cloud to protect their ecosystem. This system inserts into that ecosystem so we are not creating an open door to data security issues.

> "digitalization is not about taking people out, but rather making them more effective"

We are looking to help our customers with digital solutions running in their factory, so what is the best way? As we talked with big suppliers of industrial digitalization, we understood that being in the full cloud is not an option for two big reasons: data security and faster response time. We see that customers must do a lot of internal IT transformations, and for a lot of applications, you need edge computing. You need that faster response time, and that's why on-premises is still a good solution.

While there might be hybrid solutions, we want to allow our customers to apply the same security standards they have today to the Atotech solutions. Some of our customers are already running big programs to leverage digitalization solutions in their factory. I'm happy to work with them and drive digitalization forward in our industry. It's a very productive collaboration. It's a good starting concept that will allow us to evolve if other platforms or solutions can enable them to do more.

Johnson: Great, thank you. We know that globally it is difficult to fully staff our facilities. Is there an opportunity within the Digital Factory Suite to increase automation?

Stefanescu: Oh yes, absolutely. The software does three things: maximize the use of data, embed hardware and digital solutions to help solve critical yield and scrap problems, and the whole remote service. I will explain these in more detail.

I mentioned VCS. Today, every engineer uses the computer with our equipment. Maintenance, quality, and process engineers all need to work with the computer on each piece of equipment. The maintenance engineer, for example, uses it to know what to do next, or when the maintenance is coming. If there is a problem, the quality engineer goes to the same computer. Basically, the first thing we do is get the data out of the visualization and control system so that all engineers can have access and work with it directly at their own desks.

We also install sensors to generate more data. We can create a digital twin or a digital map, if you will, of the functionality of the equipment and the process. We then apply advanced analytics, so the applications focus exactly on what the engineers do every day. One simple example is the maintenance engineer, who monitors the equipment from a dashboard at their desk so they can look at the data and plan mainte-

nance tasks based on what condition the monitoring tool is showing. This reduces a lot of friction.

It also helps with preventive maintenance, learning from the signals to set up a maintenance plan. This reduces downtime, which can cost the production plant millions of dollars every year. We're not just bringing the information; we're bringing them insights. We are transforming raw data into insights so customers can make well-informed decisions that benefit operation efficiency and product quality.

You asked about automation. So, for instance, if the maintenance engineer finds that a part needs to be replaced, we can integrate that with the logistics and the procurement so that with one click the maintenance engineer sends an order to check the stock. We can monitor chemistry consumption, and the customer can immediately know and make a prediction, depending on the production, when the chemistry might need to be ordered, which is about optimizing stock and logistics as well.

> "a smart dosing solution will help reduce scrap and increase the yield"

Second, we are focusing on hardware embedded into our equipment to improve production and yield. This is about quality inspections. Performance quality inspections today are highly manual, but by having embedded hardware and digital solutions, the quality inspection is done as the production happens and that helps our customers reduce scrap. Additionally, this reduces unnecessary manual work. But this embedded hardware and software is like smart dosing, for instance. Bringing a smart dosing solution is another area of focus that will help reduce scrap and increase the yield. Chemistry concentration is always something that our customer needs to monitor and adjust during production. A smart dosing solution brings the opportunity to automate the replenishment process so that the customer doesn't need to do this manually.

The third thing is remote service. We are very well positioned because we understand the equipment and the data. We acquired the partner that developed the visualization controls software with us. This enables us to develop these solutions in-house. We are testing them in our technical centers globally, and then deploying them to our customers.

Additionally, we are using the MindSphere® Remote Service solution from Siemens that allows us to have a secure remote access solution from a well-known company, and to help us do more through remote service. We have experts for our Atotech products around the world. When I started with the company—just before the pandemic—we sent them out to our customers when there was a problem. But this is not always fast enough as travel takes time. That's why I took the initiative with the Microsoft smart glasses, the HoloLens, which we introduced in our service operation early in 2020, to transition to a more remote support model. Obviously, the HoloLens cannot solve everything, but it was a huge help. It proved that it could work from both sides. Yes, the customer is sometimes reluctant, but you can make it work. You can focus only on your task, bring our engineers who are in the region with the HoloLens, and then work with the experts remotely. Therefore, issues are solved faster and more sustainably.

Johnson: Stefan, is the DFS a software platform also embracing a heterogeneous equipment environment? If a customer has pieces of equipment other than Atotech in their line, can that be incorporated to give that fully digital twin view to maintenance, or is the DFS something that works exclusively with Atotech equipment?

Stefanescu: This is a question I get asked a lot. We understand that the smart factory is an eco-

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system, and you don't build one with just one software. You need to connect different software together from the shop floor to where the engineers work. That's why the platform we chose for the Atotech solution works with open standards. Technically, yes, we can integrate third-party equipment and we will work out with our customers the best solution for both sides.

Johnson: Right. You created the system to be open?

Stefanescu: Yes, upstream and downstream. Because of the way it works, the DFS is a platform that gets the data, and then has applications running on top of it. These insights can be published to a different system for process automation or making decisions, which means that if the customer, for instance, already has a control software at the enterprise level—and obviously we don't want it to push any UI of our solutions or our applications—we can integrate that into their control software, so we don't disturb their operations. But suddenly they have much more information that they can consume. Downstream, we have open standards, and the platform can connect other equipment to it. We can get the data and apply the same concept of digital twin and advanced analytics. Of course, our system is optimized to Atotech equipment being connected.

> "we can integrate third-party equipment... finding the best solution for both sides"

Johnson: I'm sure that part of the product will be driven by customer interest and demand.

Stefanescu: Yes, it is. I understand that if I am an IT manager, I don't want so much fragmentation. I don't want a lot of systems running in my factory. On the other hand, you will need to work with more systems. You cannot avoid that, so make it scalable. That's why we went with open standards for both connecting different equipment and publishing. It doesn't bring them to a dead end.

Johnson: Are there situations where, to have a digital twin of your factory, additional sensors may be required at different spots during the process? Is that commonplace?

Stefanescu: For our condition monitoring application, we can make use of the data that exists and offer, for 90% of the cases, a lot of information. However, there are functionalities, for instance, like the monitoring of the drive systems where we don't have a sensor. Therefore, a monitoring drive system is not possible out of the box. We are working on installing vibration sensors, making that possible. We connect this sensor data directly to the DFS, so we don't need to disrupt too much of the design of the equipment and the integration with the equipment control software.

We send this data directly to our DFS platform, so that information can be monitored. This can be different depending on the use cases, and what the customer's pain points are. We can control this as required. Our aim, though, is to reduce the use of sensors, because we've learned that there is information about certain parts or functionalities that you cannot install a sensor for. With a filter, for example, how do you know when it's fully loaded? There is no sensor to tell you that, so we combine data from the pumps with the flow sensors, and we create a model to estimate the load.

That's what I meant about advanced analytics. We're not just monitoring data like the temperature and so on, but instead creating a model which predicts parameter values of equipment and processes which cannot be measured. For instance, how to predict the wear of a certain part, which is very important. We have done a lot of analysis and testing, and

we see that our concept is working.

This is not a big problem. Our DFS is strong in providing measurements through prediction and applying advanced analysis for things that cannot be measured. We built the equipment, we know that data, and we know how to make this transition. At one point, someone asked me why our customers cannot do this with their MES system, for instance. I told them that the MES is responsible for ensuring that the production of the plant works according to the plan, but it cannot check and take care of the health of each piece of equipment. This is what our DFS does. It's a very complementary solution and they don't conflict in any way.

> "the DFS is 100% designed for our customers"

Johnson: As we're talking, I'm realizing that every customer is different. Some will be particularly easy to install and integrate, others have unique issues that create challenges. What's a typical integration process for a customer installing and moving to DFS?

Stefanescu: You're right. Some customers are a bit more advanced in this topic. They have hired people to work on digitalization, and they already know what problems they want to solve. What we are doing is looking at the kind of equipment they have and understanding how we can deploy the DFS into their IT structure. But we always start with the business needs; that's important. If it doesn't help solve some of their problems, then it doesn't bring a lot of value.

For example, the options of condition monitoring are indefinite. You can create different dashboards for each company. Next, we look at the equipment that is needed because we need them to understand that our VCS was built to serve that equipment for control purposes. For some equipment that is quite old, we will probably update the software, make sure there is full compatibility, and we get the right data from the VCS to the DFS. Finally, it's talking to the IT team and understanding how the DFS is integrated.

We understand customers are sometimes reluctant because it's new, so we offer a trial phase. We are very open in helping our customers with some clear use cases that they wanted to have. We can have the deployment done relatively quickly so they can get hands-on practice, test it, and see how it works. We've seen as they do this, they start to get more ideas and to understand how it can help them. This trial approach is beneficial for both the Atotech team and the customer, because it helps us to understand how we can integrate into their ecosystem, and for the customer to understand how to make better use of our platform and solutions. It also further strengthens relationships and trust with customers that we've had for years and that's important to us.

Johnson: Yes, that's important.

Stefanescu: I also wanted to mention that the DFS is 100% designed for our customers. This makes our introduction to the customer a bit easier because we don't have generic platforms or solutions. When we develop an Atotech product, we really speak the language of our customers, and their product needs.

Johnson: Fantastic, thank you. This is a very informative and comprehensive look at the product.

Stefanescu: I hope so. Thank you for giving me the opportunity to speak about it. I hope we can sit here in a year and talk about the next levels of our product.

Johnson: Thank you, Stefan. PCB007

Success in Photolithography Starts With Surface Preparation

Trouble in Your Tank

by Michael Carano, AVERATEK

Introduction

The photolithography process defines the circuitry on the panel. As one may surmise, the imaging process used in the fabrication of high-density and ultra high-density circuitry has made significant advances over the last decade—and just in time, as customers demand finer lines and spaces, as well as more attention to fabricating advanced packaging substrates. However, as is so true of many of the processes in PWB fabrication, upstream and downstream processes can and will influence what happens in a particular process. As an example, one can encounter voids in the via. It would be easy to assign root cause to the electroless copper process. Yet, a void in the via can originate due to debris left in the via, smooth resin surface due to less than optimum desmear, or aggressive micro-etching in the electrolytic copper plating as well. One can see that surface preparation plays a role in the adhesion of the photoresist to the copper surface.

Also, fabricators are asked to use lower-profile copper for signal integrity. These impact adhesion of the resist. To ensure that the image of the circuitry conforms as close to the desired design as possible (i.e., lines and spaces), surface preparation of the copper foil surface is one of the most critical success factors. Employing the optimum mix of surface cleaners, micro-etchants, and surface topography modifiers will provide a clean virgin surface free of soils, conversion coatings, and organics, as well as impart a microroughened surface to further enhance the adhesion of the resist.

The Surface of Copper

As previously discussed, as clean as the incoming copper-clad laminate and copper foil appear, there is more work to be done prior

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to resist lamination. A closer look at the copper surface will find several things that need attention:

- Chromate conversion coating
- Release agents
- Fingerprints
- Oils

It goes without saying that surface preparation is the cornerstone of the imaging process. (This is not to shortchange the importance of the photolithography process.) However, the optimum surface prior to photoresist lamination provides several critical attributes:

- Increases process latitude for the resist
- Provides a stain-free surface
- Removes organic surface contamination as well as the chromate conversion coating

The overarching goal of surface preparation is two-fold:

- Produce a surface free of soils, fingerprints, etc.
- Provide a microroughened surface topography to enhance the adhesion of the resist

In general, surface preparation is done to assure good adhesion of metal, dielectric, photoresist, or solder mask to the prepared surface, although avoiding excessive adhesion could also be the object. Take the example of surface preparation before dry film photoresist lamination and potential failure modes (Figure 1):

- Failure to achieve good adhesion in a print-and-etch process will cause etchant attack under the resist and ultimately an "open" defect
- Failure to achieve good adhesion in a plating process will cause tin/lead or tin underplating, ultimately leading to "shorting" defects ("shorts")
- Failure to achieve good release of unexposed resist during development can cause etch retardation in a print-and-etch process, ultimately leading to shorts
- Failure to achieve good release of unexposed resist during development in a plating process can cause poor adhesion of the plated copper—causing peelers
- Failure to achieve good release of the exposed resist during the print-and-etch process of inner layers can inhibit the uniform formation of the subsequent oxide or oxide alternative bond enhancement coating
- Failure to achieve good release of exposed resist in the plating process can reduce the effectiveness of the final etchant—leading to excess copper

The Importance of Uniform Surface Topography

Why should we be concerned about a nonuniform topography? Quite simply, today's dry film resist technology relies on a clean and adequately roughened surface to promote the

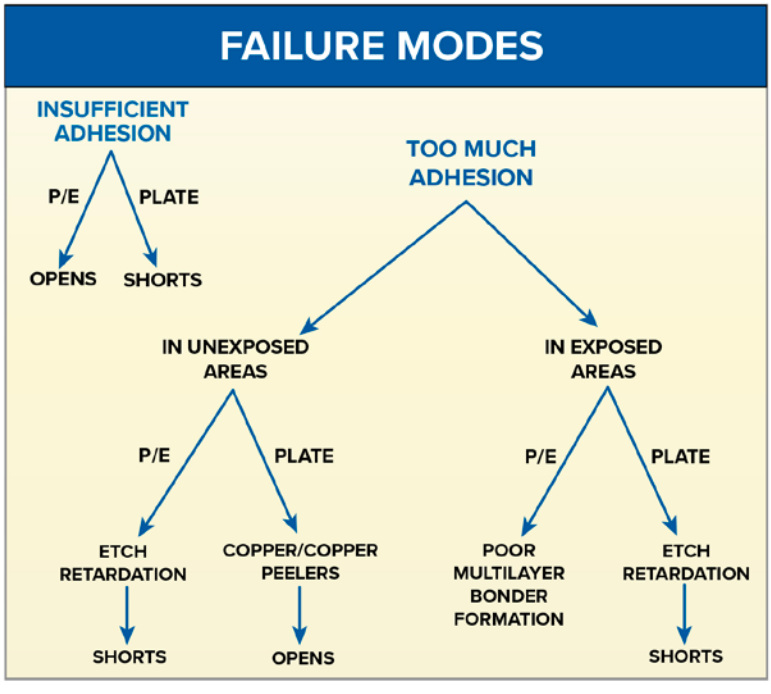

Figure 1: Improper surface preparation leading to excessive or insufficient adhesion of resist.

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adhesion and the conformation of the resist. There is less reliance today on the chemistry of the resist for adhesion. Topography matters. However, a non-uniform roughened surface can present its own set of issues for the adhesion of the film. The actual profile of the copper surface may be due to excessive mechanical brush pressures, defective brushes, lack of pumice effectiveness, and over- or under-aggressive chemical treatments. This invariably leads to areas on the copper surface where there may be deep gouges and depressions as well as areas where the roughening is inadequate (Figure 2).

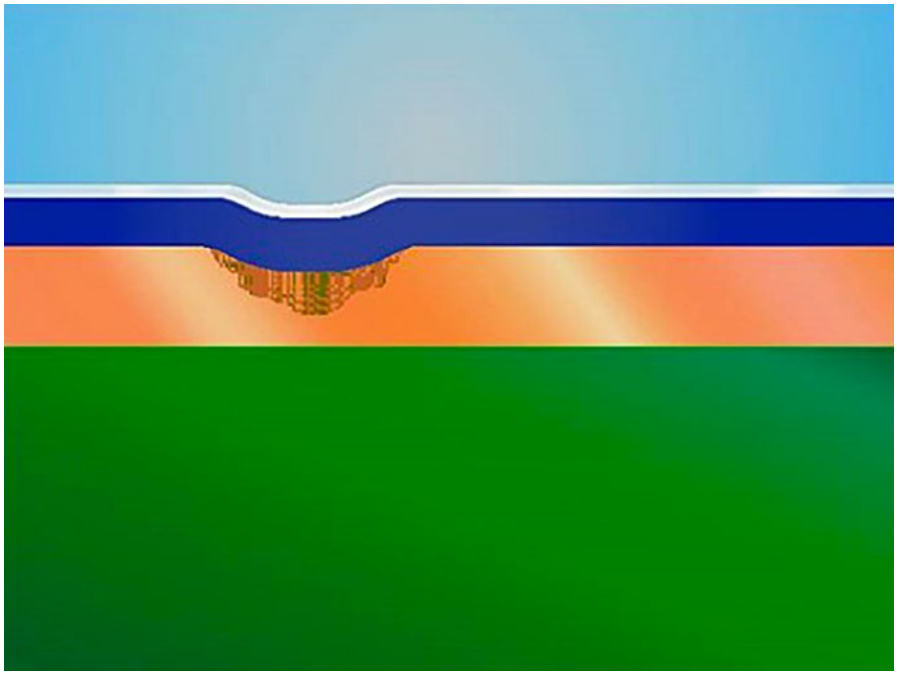

Figure 2: Excessive roughness in copper surface preventing dry film adhesion.

When the copper surface is non-uniform with areas of deep crevices, as well as areas where little topography is seen, dry film resist adhesion is compromised. Depending on the particular unit operation in the fabrication process, this can lead to dish-downs, nicks in the copper circuitry, signal integrity loss, poor impedance matching, and non-unform dielectric thickness within the bondline.

In a future column, I will take a deeper dive into the various surface preparation methods. PCB007

Michael Carano is VP of quality at Averatek. To read past columns, click here.

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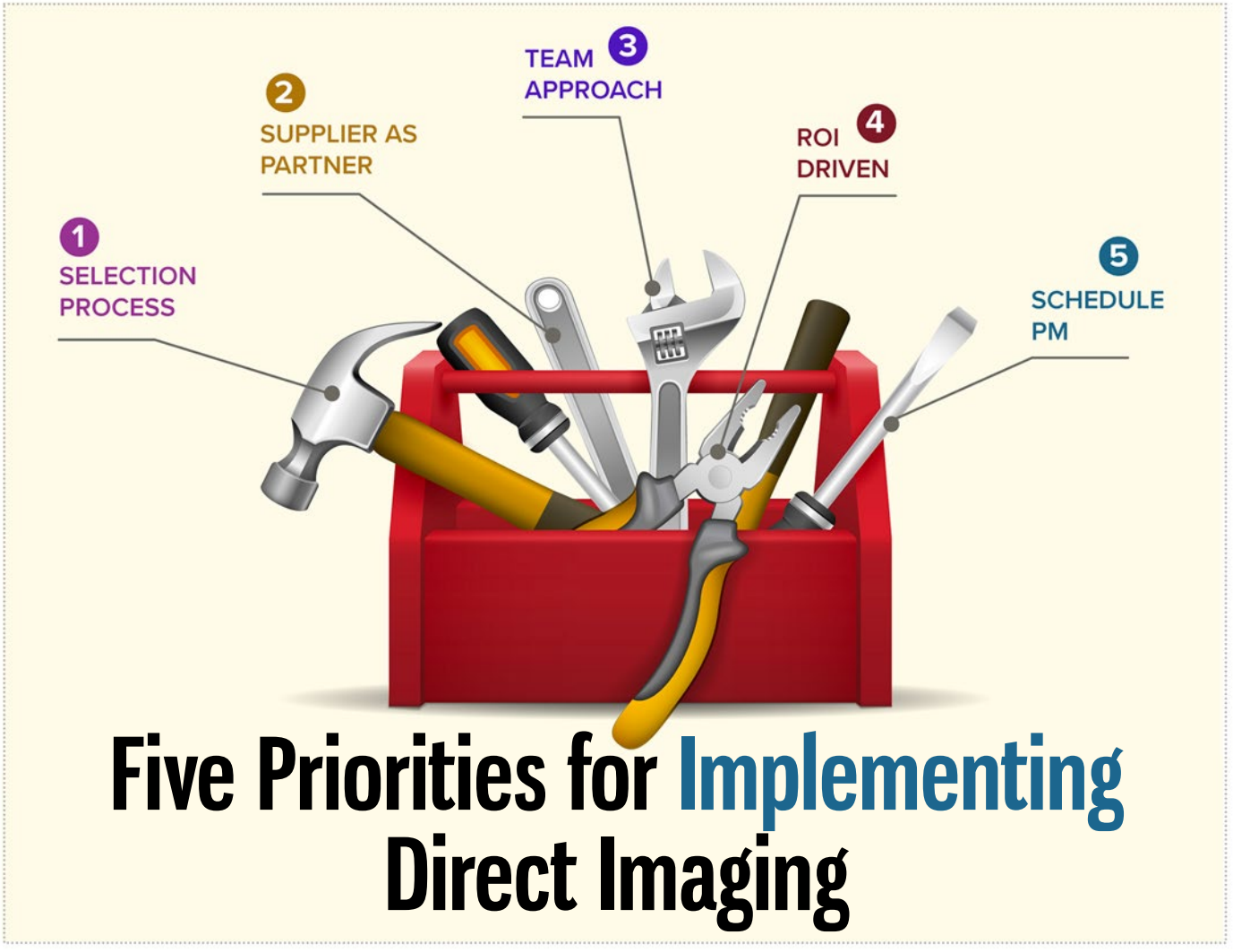

Five Priorities for Implementing Direct Imaging

Feature Article by Brendan Hogan
MIVATEK

The circuit fabrication industry has always been the unsung hero of the electronics era. SPC, TQM, ISO, and 50 other acronyms have ruled the day to govern quality and process approaches. I've been in the industry for 39 years and I feel more like a craftsman than ever before—trying to figure out how to produce the impossible and maintain a profit.

With smaller features, exotic materials, endless plating, and press cycles, the industry feels like it is in transition. Soon enough the lines between microelectronics and PCB will be forever blurred. The result is that digital direct imaging has become an instrumental tool in the circuit craftsman's toolbox, but the selection process is just the first key step in tapping this valuable and expensive technology. Here are five priorities for your own "toolbox."

1. Selection process.

A thorough examination of what a direct imager can do is vital. Often the PCB shop is looking at its most current difficult problem to solve and it prepares a sample that confirms DI can do today's tough applications. The selection process must give a high score to a tool (and a supplier) that is adaptable and a true problem solver, because by next month, year, or decade the direct imaging system will need to do things that haven't been thought of yet. Direct imaging is a major capital purchase; extending the investment time horizon by

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acquiring a tool that has many uses must be a factor in the ROI.

2. Supplier as a partner.

Direct imaging is a tool that relies on and influences many different processes. It's important to look at the role the supplier has within the industry and their approach or "passion level" for solving problems with rational cost and agility. Direct imaging combines so many disciplines; it is much more than selecting a machine. Imaging suppliers must be experts with imaging, of course, but should also contribute to the processes that DI impacts. If you make the right choice the supplier will become your partner and you will become theirs.

3. Team approach.

The selection process usually includes a core group of two to four people at the PCB facility. However, a successful implementation should involve many more people. Our experience is that the most successful deployments of direct imaging are those that initiate communication and training immediately after the purchase agreement. Initiating a successful implementation before the machine even arrives accelerates the timing of all savings and traps issues not considered during the selection process. The supplier is your partner; he wants a successful implementation and should be happy to participate.

4. ROI doesn't happen by itself.

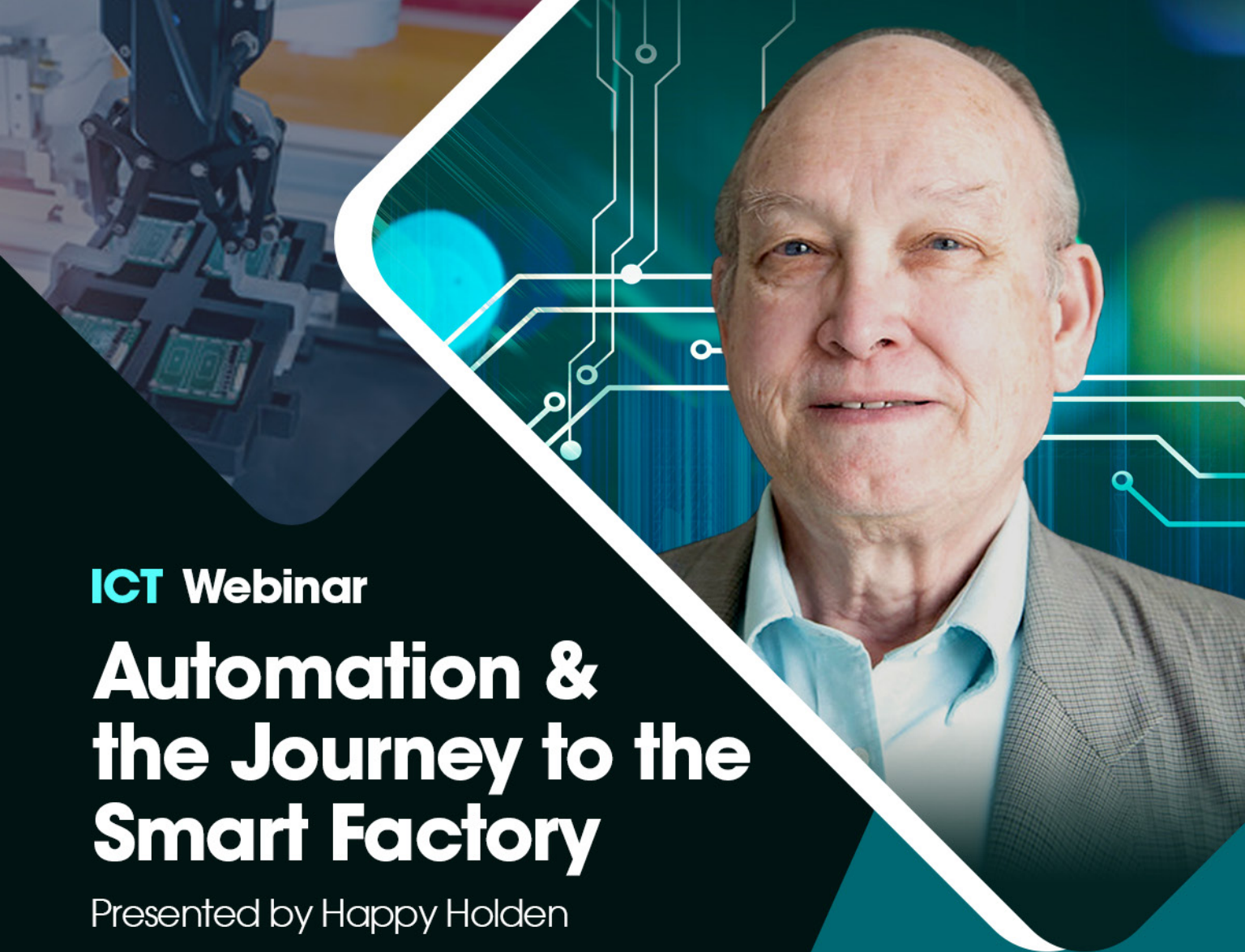
So, your team has done its homework and has evaluated savings and performance benefits that result in a positive ROI. Two things are true: The savings and costs the team assessed were sincere but also likely incomplete, and leaders need to remain vigilant about securing the ROI and expanding potential savings as your team understands more about the technology and its impact on your processes. Direct imagers should be adaptable. Your supplier is your partner. Pick up the phone and pick his brain. He sees 200 PCB shops a year and five times the process issues.

Brendan Hogan

5. Stupid is as stupid does, so don't skip the PM.

Direct imaging systems are precise machines that rely on stable conditions. While the cost of technical support and PM can seem like an expense, it ensures that the ROI the machine should produce materializes. Building a rigid PM schedule for the imaging room and the direct imager is not only a critical element of performance but dramatically lowers the long-term cost of the unit. Our data reflects a direct correlation between routine PM expenditures and long-term performance. To take the step of making a major capital purchase without the relatively minor PM expenditure is shortsighted. Your supplier is your partner, so work out a PM schedule that meets the cost and objectives of the equipment. Most suppliers will train your staff to conduct the PM themselves, but it needs to be a priority. **PCB007**

Brendan F Hogan is managing director of MivaTek Global, a leading producer of direct imaging systems.



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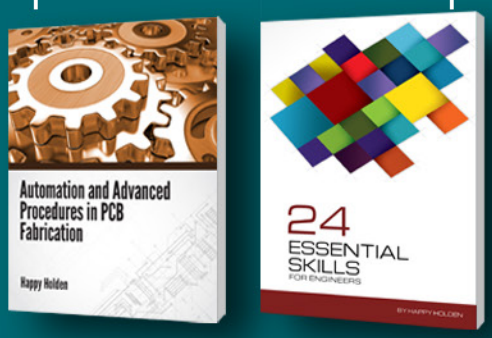

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Leadership 101: The Law of Explosive Growth

The Right Approach

by **Steve Williams,** THE RIGHT APPROACH CONSULTING

Introduction

Good leadership always makes a difference; unfortunately, so does bad leadership. This leadership truth continues as we will be talking about law 20 of the 21 Irrefutable Laws of Leadership.

"To add growth, lead followers; to multiply growth, lead leaders." —John Maxwell

Multiply Your Growth

Referencing my past articles on the prior 19 laws, do you remember the difference between a manager and a leader? A manager does what's right, a leader does the right thing. There is a corollary with the above quote and the manager/leader discussion in that they are both about taking your leadership to the next level. Another recurring theme across the leadership laws is the concept that developing leadership skills in those you lead is the fastest way to improve your leadership skills.

A leader must have followers, of course, but an important exercise is to consider who makes up that group of followers in the context of Figure 1. Followers who are content on being followers will yield a modest return to the company, but only add value to the company one person at a time. They are typically not "impact players," but leaders don't need an entire team of impact players, only a strategic few.

On the other hand, followers who are leaders themselves and willing to follow your lead multiply the value added to the company, creating the opportunity for explosive growth. When looking at your team, consider what your followers bring to the proverbial table. When a follower comes to the table, he or she only brings themself. But when a leader comes to the table, the leader brings his or herself as well their followers.

Explosive growth is driven by leaders, not followers.

A Different Mindset

Leaders who develop other leaders require a different mindset than leaders who only develop followers. So, how then to multiply our growth and not just add to it? Maxwell gives us a hint when he says, "Becoming a leader who develops lead-

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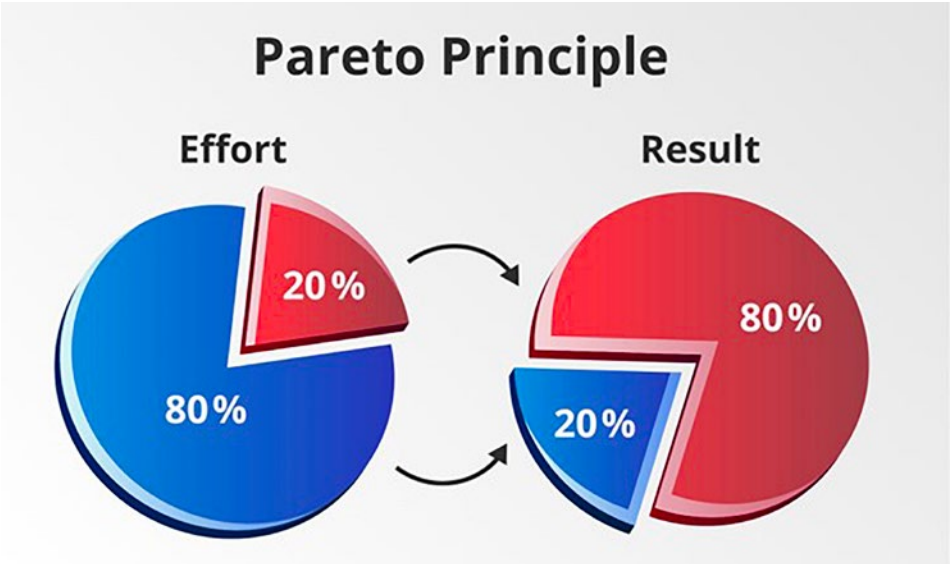
ers requires an entirely different focus and attitude from simply attracting and leading followers. It takes a different mindset."

Leaders who develop leaders desire to be succeeded and embrace the success of their followers. In other words, the greatest compliment this type of leader can receive is to see their work continue on through others. Not everyone is leadership material, and many are perfectly content to remain a follower. Leaders who develop other leaders use the 80/20 rule: They are intentional in their focus on developing the top 20% of their followers to become leaders themselves. The leaders who only develop followers do the exact opposite. What follows is a list of attributes of these two types of leaders.



Leaders Who Develop Followers

- Need to be needed
- Focus on weaknesses
- Develop the bottom 20%
- Treat their people the same for "fairness"
- Hoard power; insecure about transferring knowledge
- Grow by quantity
- Spend time with others
- Grow by addition
- Impact only people they touch personally

Leaders Who Develop Leaders

- Want to be succeeded
- Focus on strengths
- Develop the top 20%
- Treat their leaders as individuals for impact
- Give power away
- Grow by quality
- Invest time in others
- Grow by multiplication
- Impact people far beyond their own reach

Here are some other distinguishing factors about leaders who develop leaders: They intentionally focus on the top 20% (who represent 80% of the team's leadership potential) of their followers by building on these followers' strengths and not dwelling on their weaknesses. These leaders don't believe in treating everyone the same, because they are not. This is reinforced through creation of a results-based method of providing greater opportunities for those who rise to the top. In addition, they recognize the long-term benefits of making a time investment in developing other leaders that will contribute to explosive growth. This law parallels The Law of the Lid in that your leadership level will only rise to the level of your development of other leaders under you.

Follow these guidelines and The Law of Explosive Growth and you will truly be surprised at the results. Focus on enhancing your leadership skills to lead by example and the results will be epic. **PCB007**

Steve Williams is president of The Right Approach Consulting. He is also an independent certified coach, trainer, and speaker with the John Maxwell team. To read past columns, click here.

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How the UV light is directed

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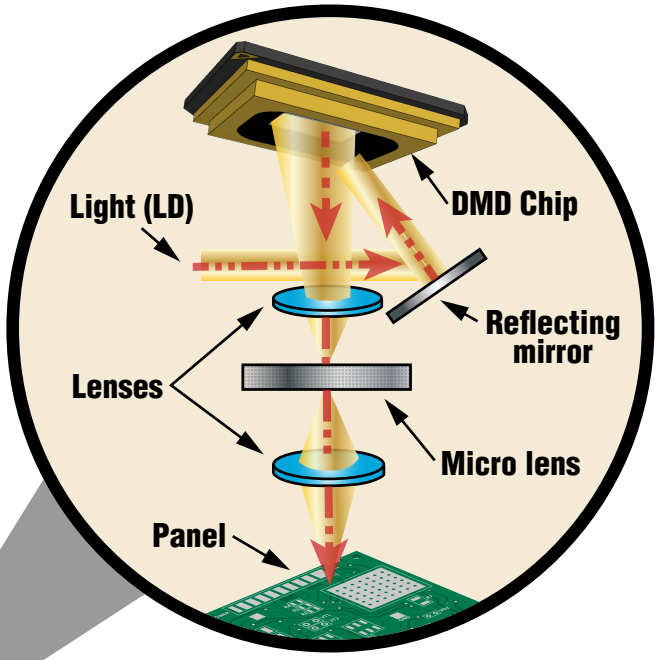

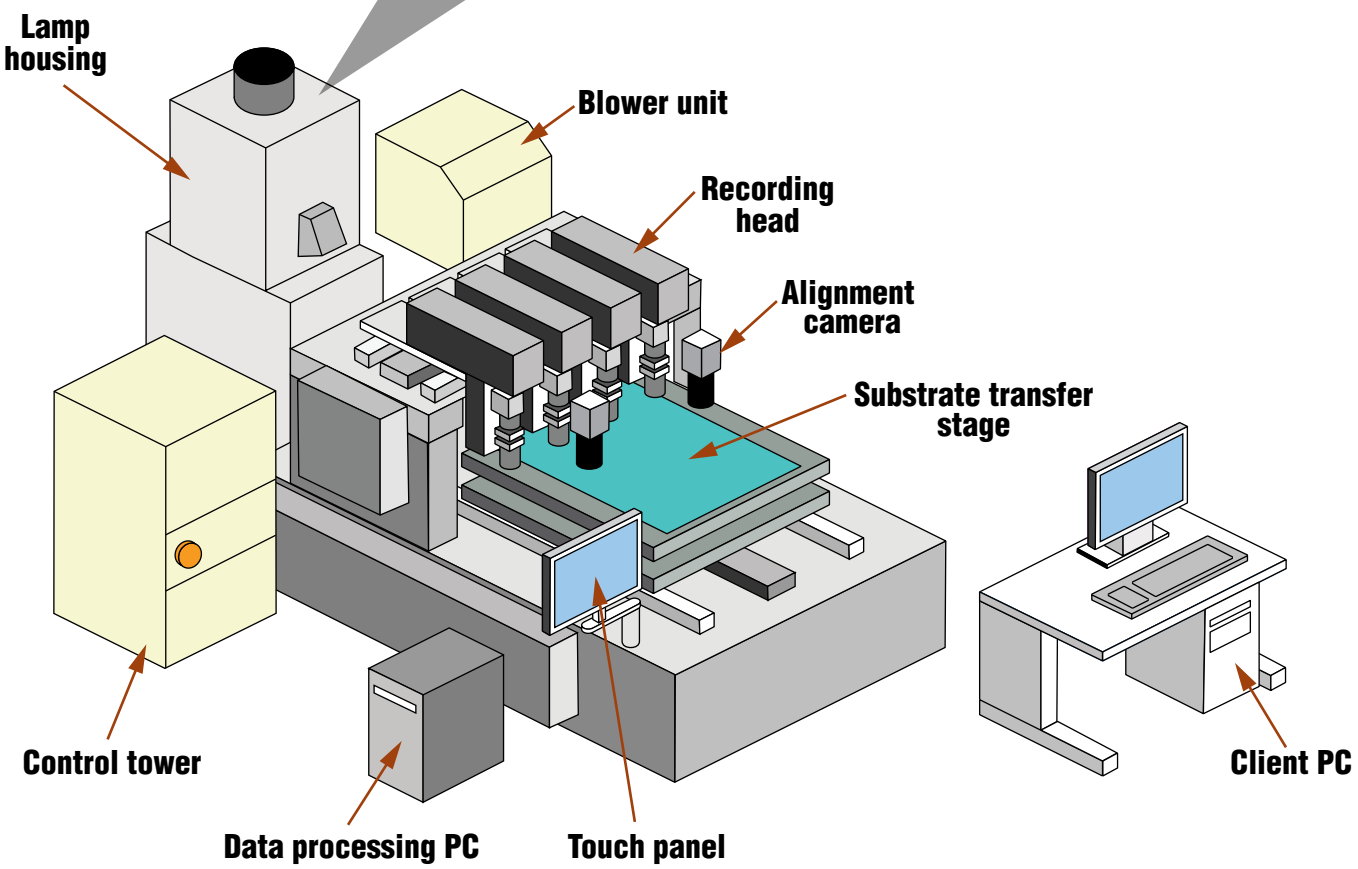

Closing the Innovation Gap

The Chemical Connection

by Christopher Bonsell, CHEMCUT

In Nolan Johnson's September 2022 column, "New Era Manufacturing," he referred to the carriage whip manufacturing businesses that met their fate by failing to adapt while other carriage businesses with more robust product applications remained standing. He said this relates to our industry in the sense that the needs of our world are evolving, that the wants and needs of PCB fabricators and their customers are bound to change. There will always be a demand for PCBs, since it is the foundation of modern technology, but market challenges are inevitable. PCB fabricators are dealing with increasing material and labor costs, all while major quick-turnaround jobs are declining. The questions we must ask are: Where do we go from here? How can PCB fabricators overcome these challenges and get an edge in the market? How can we best adapt?

First, let's look at how our industry has adapted. There have been many advancements in automation technology applications since we entered the fourth generation of the Industrial Revolution. We are introducing robotics and advanced data analytics to our PCB fabrication processes. This has certainly been a step in the right direction for us to combat the before-mentioned obstacles. Although automation brings a lot to the table, will it ever be enough? For some fabricators, it may seem sufficient. However, this may be a relatively short-term solution. But we must address the growing issue of where we will find engineers who will innovate and influence PCB manufacturing technology—before it eventually throttles the growth of the industry.

I was also interested in Paige Fiet's September 2022 column, "Let's Make Manufacturing 'Cool' Again." She wrote that the new generation of engineers is not as interested in manufacturing anymore, as she made mention of the large shift toward computer science where generally there is a higher status and cozier

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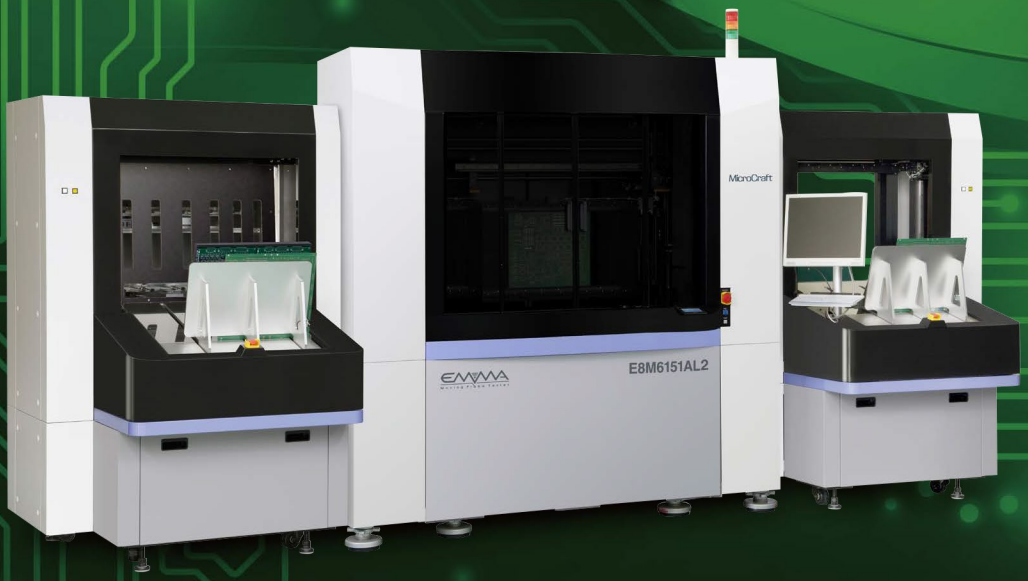

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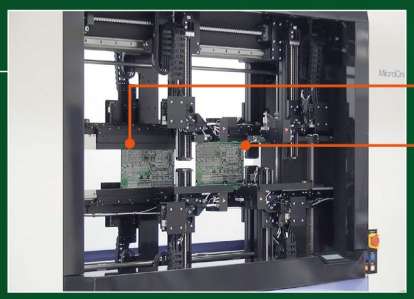

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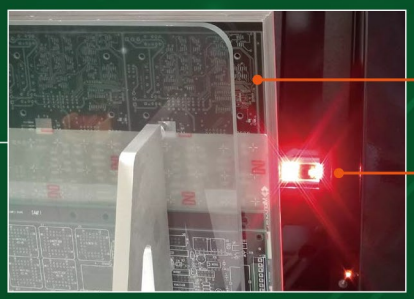

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jobs. Although that field is gaining popularity, don't write off manufacturing just yet. There is plenty of interest in manufacturing in the electronics industry, just not in the field of PCBs. The semiconductor industry is keeping the newer generation interested in manufacturing jobs. I believe the main influencers are education and awareness.

The semiconductor industry is keeping the newer generation interested in manufacturing jobs. I believe the main influencers are education and awareness.

I attended IPC APEX EXPO for the first time this year and since then I have noticed a recurring theme among those who get involved in PCB manufacturing: Before they started working in the field, most did not have much awareness of our sector. In fact, before I became a process engineer at Chemcut, I was one of them. This was primarily because I was not exposed to it in college. While I was aware that my chemical engineering degree could be applied to the semiconductor industry, I did not associate it with circuit boards. At my university, there were even a handful of professors who specialized in semiconductor research, so it seems that students are more exposed to semiconductors than to PCBs. This appears to heavily influence where these students choose to take their careers.

If our industry wants to adapt for the better, it must start from the ground-up—starting where students get exposure to our industry. More exposure means more scientific developments and progress in PCB technology. If more students are made aware of the opportunities in the PCB industry, we can bring in fresh, new minds that will look at our manufacturing limitations from different perspectives. The more interest in PCB manufacturing we can bring to young engineers, the better. Although it is necessary to gain overall interest in PCBs, it's important that we steer some in the direction of engineering capital equipment (i.e., printers, etchers, platers, etc.). If PCB manufacturers are to get an edge in the market, it is likely to come from advancements in fabrication technology. This is because innovation in this area will effectively lead to greater opportunities in PCB quality, productivity, and overall profit. In principle, if the equipment manufacturers grow and innovate, so should the rest of the industries they support. Making the upcoming generations interested in all aspects of PCB fabrication may just be the adaptation our industry needs to handle the changing wants and needs of the market. Once the new generation gains interest in our industry, PCB manufacturers should have a bright future ahead of them.

That leaves us with the question of how we can best appeal to the next generation and get them interested in PCBs. Creating outreach programs and other similar efforts are likely the way to go because half of the battle is bringing awareness of how PCBs are made. I propose that the other half of the battle is introducing the nuances of our industry and the current matters we would like to improve. If you are trying to appeal to young engineers, the best way to do that is to give them a challenge and show them there is still plenty of room for intellectual growth in our industry. **PCB007**

Christopher Bonsell is a chemical process engineer at Chemcut. To read past columns, click here.

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Induction Junction, What's Your Function?

Testing Todd

by Todd Kolmodin, GARDIEN SERVICES USA

Historically electrical test has processed product with passive inductor features without really knowing what they were, other than causing continuity threshold violations. This is usually due to the long traces that exhibit higher resistance than the 10- or 20-ohms threshold. Typically, these have been delaying traces or heater traces. Usually, a waiver of allowance is made for these high resistive traces and business carries on as usual.

However, there can be a lot more going on than just a long or coiled trace. Figure 1 shows a typical heater scenario. As you can see in the illustration, each is a single net with a long trace. The characteristic of this design is specific, and the entire trace is necessary. The problem is whether any of the long trace shorts to itself. In a standard continuity test, this defect will go undetected as a short to itself and will not present a change in resistance significant enough to fault. However, the circuit itself now fails against its intended design.

There are two possible solutions to capturing this defect. The 4-wire Kelvin Test may capture the small change in resistance, but with this much copper the accuracy of the test may be compromised to the point that the change would have to be too significant to trigger a fault. The other option is testing the inductance of the network. There is technology available to perform this test on a flying probe. Pre-programmed values can be provided to the machine and when the test encounters this device it will check the value and compare to expected. This test records all values and can provide a report for post-test analysis.

Now, in my above example we discussed a very basic scenario of a heater or timing trace.

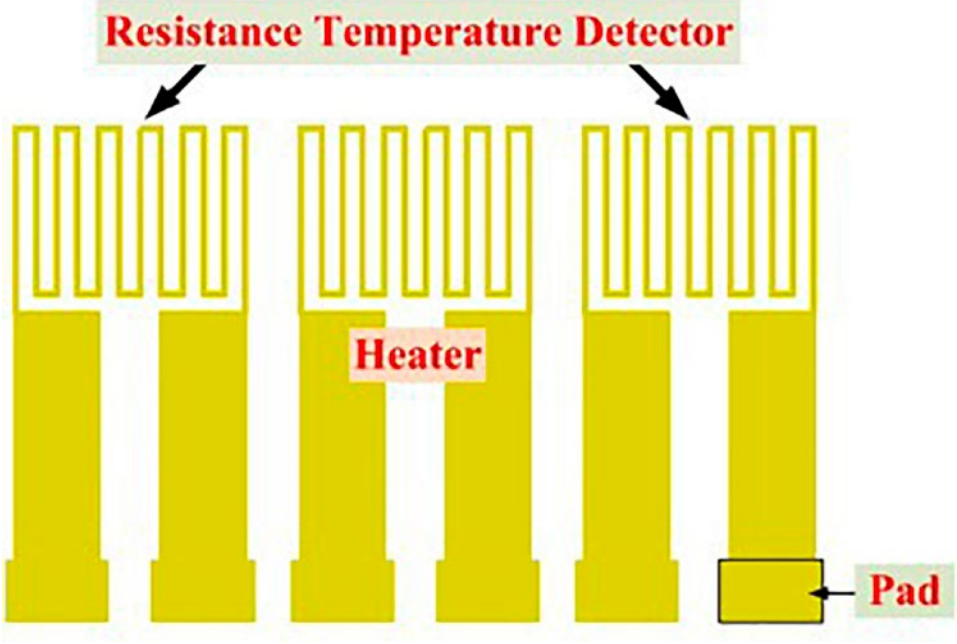

Figure 1: Heater trace.

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However, inductors can play a very active role in circuit design. So, strap in and take your Dramamine because the ride now gets a little bumpy.

Inductors or coils usually play a role as transformers or sometimes electromagnetic motors. Using a primary and secondary winding, these devices can step-up or step-down voltages or create an electromagnetic field that can spin an armature in a motor assembly. However, in PCB design they can do some very interesting things. The primary and secondary of a coil are created by making "turns" of a wire around a form or core. The ratio of the number of turns in the primary to the number of turns in the secondary determines the characteristics of performance. We don't see the use of transformers on a PCB per se, but they perform other functions quite well.

Although coils can be used to boost or augment voltages, they are primarily used to manipulate signals. This is particularly important in RF designs. In high-speed digital or RF circuits, stray RF or parasitic components are extremely detrimental to product performance. Here is where the inductors play a very important role. When you play in the RF arena you deal with VSWR, reactance and attenuation. Remember that I said a coil is a device that has a core and a primary and secondary winding?

Well, an active coil could be created using just the PCB. PCB manufacturing uses dielectrics between layers (hey, a core material) and depending on the design, an inductor can be made. We can run a trace between layers, say 1 to 3, back to layer 1, back to layer 3, and so on until we have the number of "turns" we need. We do the same for the other winding. We have created a primary and secondary winding around a core. An inductor! Todd, you say, that's all fine and good but what are we doing?

As it sits, we can boost a signal or impedance match a circuit with that. But we don't stop there. If we add resistance or capacitance to this circuit, we start getting into reactance. Coils act differently when coupled with resistors or capacitors. We start playing in the world of inductive reactance and capacitive reactance. This is where it gets important with RF and microwave applications. Reactivity plays a significant role. Whether the circuit has inductive reactivity or capacitive reactivity depends on the matching. In an RF application, if the inductive reactivity equals the capacitive reactivity the circuit resonates, and full power is presented to the feed point of the transmitting port or antenna (if applicable).

Figure 2 illustrates a Smith Chart where reactivity is plotted. When either inductance or capacitance in the circuit is higher than the

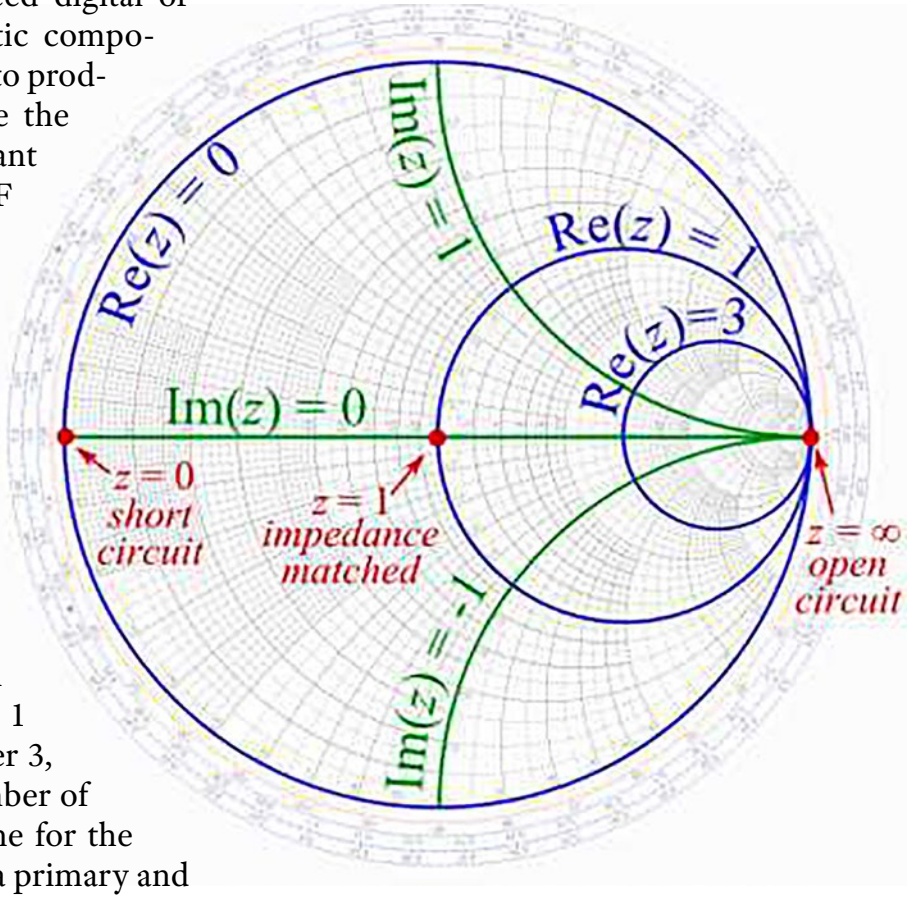


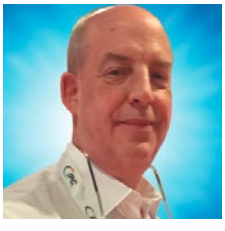
Figure 2: Smith Chart.

other, the reactivity changes and influences the performance. If the circuit is more inductive, current in the circuit will lead the voltage by a phase angle specific to the amount different from resonance. Conversely, if the circuit is more capacitive the voltage will lag the current by a phase angle specific to the difference from resonance.

Still with me? What has this all got to do with the PCB? We have a coil on the PCB. Now, if we had capacitance in parallel to the primary winding, we could make some magic. By adding capacitance to the inductor, we can create filters. Specifically, filtering can be done to signals that stop certain frequencies from passing or allow only a specific range of frequencies to pass. These are called "band pass" and "band stop" filters. So, when using a coil (inductor) with a capacitor/resistor, we are doing what is called "tuning the circuit." This allows the predetermined signals to process optimally, while stopping or eliminating parasitic signals.

What does this all mean? The inductance in a passive or active inductor within the PCB is critical to final performance. Therefore, the standard electrical test of the coil's primary and secondary windings cannot be satisfied. A short within the primary or secondary windings may not trigger a fault but will affect the performance of the tuned circuit. Thus, measuring the proper inductance of the coil is critical. Although an inductor circuit may pass the standard opens and shorts test, it does not mean that the circuit is stable.

That is why inductance should be tested whenever buried coils or inductors are manufactured within the PCB with specific end results expected. **PCB007**



Todd Kolmodin is VP of quality for Gardien Services USA and an expert in electrical test and reliability issues. To read past columns, click here.

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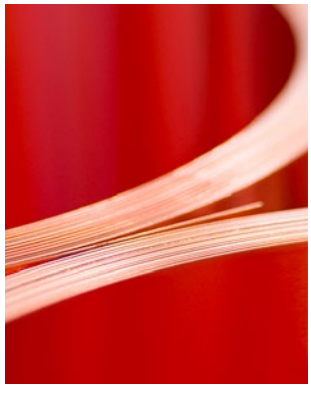
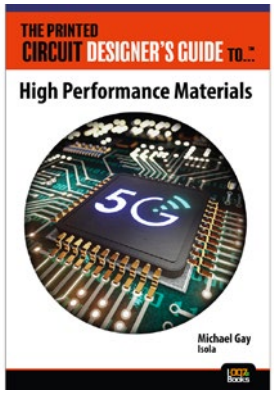
The Printed Circuit Designer's Guide to... High Performance Materials

Chapter4: Copper Foil

Copper foil is the standard conductive layer used for metal-clad laminates, although other options are available. There are two main types of copper foil used for PCB boards today: electrodeposited (ED) foil and rolled annealed (RA) foil. ED copper foil is produced by a continuous process which yields a well-controlled product in mass volume and low cost as compared to RA copper foil. ED copper foil has a wide range of thicknesses, from 5–400 µm, for PCB applications. IC substrate application requires an ultra-thin foil which is supplied on an 18–72 µm copper carrier and range in thicknesses from 1.5–5 µm.



Rolled annealed foil yields a very smooth surface where the process deforms the copper crystalline structure to achieve thickness. Unfortunately, the foil is only available in a 25" wide format. Most processes are designed around a 50" wide machine direction of the glass using large hydraulic presses with platen sizes to accommodate the 50" glass width. Use of the RA foil reduces productivity and results in higher cost. With the development of newer smooth ED foils that are as smooth as RA foil, the need for RA foil and the associated cost has been largely mitigated.



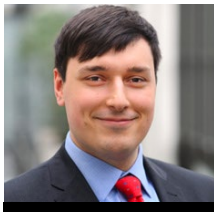
Continue reading.

TOP TEN

EDITOR'S PICKS

EIPC Technical Snapshot: Novel Laser-based Manufacturing Processes in Automotive Electronics

"Summer is over, now it's back to work!" This was the opening line of the invitation to the 18th EIPC Technical Snapshot webinar, Sept. 14, following the theme of advances in automotive electronics technology, introduced and moderated by EIPC President Alun Morgan.

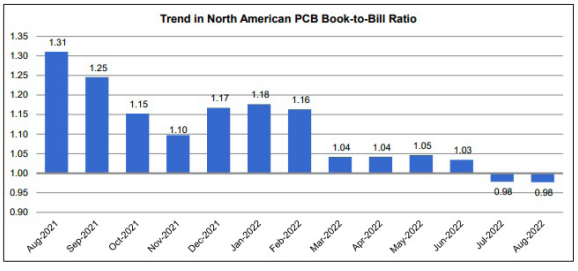

Jonas Mertin


Christopher Rocneanu


Dr. Ralph Birnbaum

North American PCB Industry Sales Up 15.1% in August

IPC announced the August 2022 findings from its North American Printed Circuit Board Statistical Program. The book-to-bill ratio stands at 0.98.



The Chemical Connection: The Etch Factor

One of the biggest obstacles that PCB manufacturers face is etch factor. Etch factor is the ratio of downward etch to sideways etch and poses challenges to PCB fabricators because it limits PCB design. It can determine how fine of a line you can etch, and it can even affect how close together you can have features.

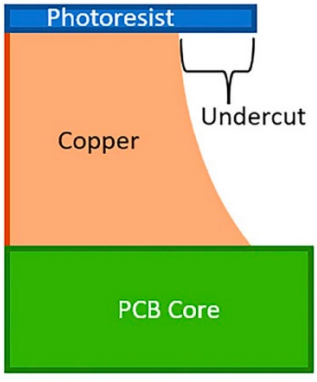
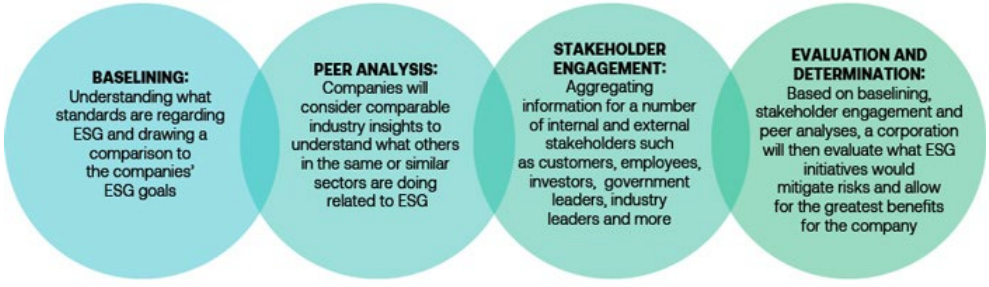


Figure 1: Diagram of undercutting on a PCB.

IPC: Companies Are Intentional About Tracking Environmental and Social Risks

Leading companies in the electronics manufacturing industry are highly intentional about their environmental, social and governance priorities, with climate change and energy use among the most closely scrutinized issues, an IPC analysis shows.



Electronics Industry Calls for U.S. Presidential Determination on Key Components Under Defense Production Act

The electronics industry is calling on U.S. President Biden to address urgent industrial base vulnerabilities and deliver on the promise of the CHIPS Act by prioritizing domestic development of printed circuit boards and integrated circuit substrates under Title III of the Defense Production Act.

The New Chapter: With a Little Help From My (IPCEF) Friends

About a year ago, student Hannah Nelson began engaging in leadership activities that would both improve her skills and provide opportunities for others to flourish in the electronics field. Soon after, a friend asked if she would be interested in leading their IPC student chapter. A chapter advisor suggested reaching out to the IPC Education Foundation (IPCEF) for support. That's when the momentum happened.

Punching Out: Mid-Year PCB and EMS North American M&A Update

Mergers and acquisitions in North America in the PCB and EMS sectors during the first eight months of 2022 were down compared to the same period in 2021. In the PCB sector, we counted four deals in 2022 compared to seven during the first eight months of 2021. In the EMS sector, we are aware of 10 completed deals so far in 2022 compared to 13 during the same period in 2021. Activity remains very strong in 2022.

Hire or Be Hired! The jobConnect007 Help Wanted Pages

If you're looking for a job in the PCB industry, jobConnect007 is the first place you should look. In the pages of I-Connect007's monthly magazines and newsletters, there are job openings for positions that span the circuit board supply chain: senior PCB designer, supplier quality manager, service engineer, field service technician, technical marketing engineer, to name a few.

IBIDEN Group Switches to 100% Renewables in Southeast Asia

IBIDEN Co., Ltd. is pleased to announce that in August 2022, its production subsidiary IBIDEN Philippines, Inc. converted its electricity consumption to renewable energy sources.

ILFA Invests in the Expansion of its PCB Lamination Capacities

During the LAUFFER Technology Days, ILFA Managing Director Thomas Michels and LAUFFER Managing Director Christof Lauffer announced a close cooperation, sealed with a joint letter of intent.

Career Opportunities

Is your team growing?

Find industry-experienced candidates at I-Connect007.

For just $750, your 200-word, full-column ad will appear in the Career Opportunities section of all three of our monthly magazines, reaching circuit board designers, fabricators, assemblers, OEMs, suppliers and the academic community.

In addition, your ad will:

- be featured in at least one of our newsletters
- appear on our jobConnect007.com board, which is promoted in every newsletter
- appear in our monthly Careers Guide, emailed to 26,000 potential candidates

Potential candidates can click on your ad and submit a resume directly to the email address you provide, or be directed to the URL of your choice.

No contract required. Just send over your copy and company logo and we'll do the rest!

Contact barb@iconnect007.com to get your ad posted today!

+1 916.365.1727

I-Connect007
GOOD FOR THE INDUSTRY

smt007 pcb007 pcb design007

Career Opportunities

CHEMCUT

Electrical Engineer

Located in State College, Pennsylvania, Chemcut, a world leader in wet processing equipment for the manufacture of printed circuit boards and chemical etching of various metals, is seeking an electrical engineer.

Objectives:

The electrical/controls engineer will not only work with other engineers, but interface with all departments (manufacturing, sales, service, process, and purchasing). The engineer will design customer systems, creating electrical and control packages, while focusing on customer requirements.

Responsibilities:

- Process customer orders (create schematics, BOMs, PLC programs, relay logic controls, etc.)
- Startup and debug customer equipment on production floor
- Interface with engineering colleagues and other departments, providing input & direction
- Provide electrical/control support to customer service
- May require occasional travel and overtime

Qualifications:

- Bachelor's degree in electrical engineering or an EMET degree
- Machine control design experience a plus
- Good communication skills working in a team environment
- Strong ability to work independently with minimal supervision
- PLC and HMI experience a plus (ex. Studio 5000 Logix Designer, Factory Talk)
- Experience with AutoCAD, Microsoft Word, and Excel

Chemcut benefits include: Medical, dental and vision Insurance, life and disability insurance, paid vacation and holidays, sick leave accrual, and 401K with company match.

To apply, please submit a cover letter and resume to hr@chemcut.net.

apply now

EMA Design Automation®

Technical Marketing Engineer

EMA Design Automation, a leader in product development solutions, is in search of a detail-oriented individual who can apply their knowledge of electrical design and CAD software to assist marketing in the creation of videos, training materials, blog posts, and more. This Technical Marketing Engineer role is ideal for analytical problem-solvers who enjoy educating and teaching others.

Requirements:

- Bachelor's degree in electrical engineering or related field with a basic understanding of engineering theories and terminology required
- Basic knowledge of schematic design, PCB design, and simulation with experience in OrCAD or Allegro preferred
- Candidates must possess excellent writing skills with an understanding of sentence structure and grammar
- Basic knowledge of video editing and experience using Camtasia or Adobe Premiere Pro is preferred but not required
- Must be able to collaborate well with others and have excellent written and verbal communication skills for this remote position

EMA Design Automation is a small, family-owned company that fosters a flexible, collaborative environment and promotes professional growth.

Send Resumes to: resumes@ema-eda.com

apply now

Career Opportunities

TAIYO AMERICA

Field Service Technician

Taiyo Circuit Automation designs and manufactures the world's finest dual sided soldermask coating and vertical drying equipment. Since 1981, we have served the printed circuit board industry with highly reliable innovative machinery, engineered to exceed.

PRIMARY FUNCTION:

The Field Service Technician is responsible for troubleshooting and providing technical services on Taiyo Circuit Automation's mechanical and electro-mechanical products and systems.

ESSENTIAL DUTIES:

1. Identify mechanical issues and implement process control solutions for process improvement and new projects
2. Consult with maintenance, operations, engineering, and management concerning process control and instrumentation
3. Specify, install, configure, calibrate, and maintain instrumentation, control system and electrical protection equipment

QUALIFICATIONS/SKILLS:

1. 3 years of experience with equipment, preferably in PCB or related electronics industry
2. 3 years of experience in similar process industries with hands-on experience in operations, maintenance and project implementation—OMRON, Koyo, Allen Bradley experience preferred
3. Experience in installation and calibration of process control elements and electrical measurement devices
4. The ability to read and understand electrical, pneumatic diagrams and control systems

REQUIRED EDUCATION/EXPERIENCE:

1. High school graduate
2. Associate degree in Industrial Engineering Technology, Mechanical or Electrical Engineering, preferred.
3. PLC experience

Email: BobW@Taiyo-america.com (Subject: "Application for Field Service Technician for TCA")

apply now

Altium®

DevOps Engineer

Altium is a publicly traded global company responsible for the most widely used PCB design software in the industry. Altium 365® is our cloud-based design and collaboration platform; it gives more power to every contributor in the electronics product chain, from the PCB designers to manufacturing. Our R&D teams are the driving force behind Altium 365 and all our technological accomplishments.

- The primary role of the DevOps Engineer is to help continue our transition to a cloud-based SaaS model as part of the production engineering team
- The team's top priorities are product reliability, security, feature delivery, and automation
- DevOps is responsible for the CI/CD process, streamlining automation for provisioning and deployment, scalable infrastructure, uninterrupted service, other DevOps activities

Required Skills and Experience:

- Analysis, troubleshooting
- 4+ years' DevOps/SRE/ Linux/Windows
- AWS (EC2, RDS, S3, Storage, Route53, and network appliances
- Architecting and securing cloud networking

Altium offers a culture built and managed by engineers. We don't micromanage; we define the goals and give engineers the freedom and support to explore new ideas for delivering results. In doing so, we all have a hand in shaping the future of technology.

https://careers.altium.com/

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Career Opportunities

Supplier Quality Manager

Headquarters, New Hartford, NY

JOB SUMMARY:
The Supplier Quality Manager is responsible for maintaining and improving the quality of Indium Corporation's supplier base as well as compliance with identified quality standards and risk mitigation. This position will work cross-functionally with Supply Chain, Operations, and our suppliers. The role will ensure that the quality levels of all Indium Corporation suppliers and products meet customer requirements while supporting the company's growth, vision, and values.

REQUIREMENTS:

- Bachelor's degree in business, supply chain or a science-based discipline
- Minimum 3 years in a supply chain role supporting or leading supplier quality
- Obtain and/or maintain International Automotive Task Force (IATF) auditor certification within first 3 months of employment
- Able to work independently or lead a team, as needed, to meet goals
- Excellent oral and written communication skills
- Knowledge of quality standards
- Proficiency in MS Office

apply now

Technical Service & Applications Engineer

Full-Time — Midwest (WI, IL, MI)

Koh Young Technology, founded in 2002 in Seoul, South Korea, is the world leader in 3D measurement-based inspection technology for electronics manufacturing. Located in Duluth, GA, Koh Young America has been serving its partners since 2010 and is expanding the team with an Applications Engineer to provide helpdesk support by delivering guidance on operation, maintenance, and programming remotely or on-site.

Responsibilities

- Provide support, preventive and corrective maintenance, process audits, and related services
- Train users on proper operation, maintenance, programming, and best practices
- Recommend and oversee operational, process, or other performance improvements
- Effectively troubleshoot and resolve machine, system, and process issues

Skills and Qualifications

- Bachelor's in a technical discipline, relevant Associate's, or equivalent vocational or military training
- Knowledge of electronics manufacturing, robotics, PCB assembly, and/or AI; 2-4 years of experience
- SPI/AOI programming, operation, and maintenance experience preferred
- 75% domestic and international travel (valid U.S. or Canadian passport, required)
- Able to work effectively and independently with minimal supervision
- Able to readily understand and interpret detailed documents, drawings, and specifications

Benefits

- Health/Dental/Vision/Life Insurance with no employee premium (including dependent coverage)
- 401K retirement plan
- Generous PTO and paid holidays

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Career Opportunities

Electrical Engineer/PCB/CAD Design, BOM/Component & Quality Support

Flexible Circuit Technologies (FCT) is a premier global provider of flex, rigid flex, flex heaters, EMS assembly and product box builds.

Responsibilities:

- Learn the properties, applications, advantages/disadvantages of flex circuits
- Learn the intricacies of flex circuit layout best practices
- Learn IPC guidelines: flex circuits/assemblies
- Create flexible printed circuit board designs/files to meet customer requirements
- Review customer prints and Gerber files to ensure they meet manufacturing and IPC requirements
- Review mechanical designs, circuit requirements, assembly requirements, BOM/component needs/ and help to identify alternates, if needed
- Prepare and document changes to customer prints/ files.
- Work with application engineers, customers, and manufacturing engineers to finalize and optimize designs for manufacturing
- Work with quality manager to learn quality systems, requirements, and support manager with assistance

Qualifications:

- Electrical Engineering Degree with 2+ years of CAD/PCB design experience
- IPC CID or CID+ certification or desire to obtain
- Knowledge of flexible PCB materials, properties, or willingness to learn
- Experience with CAD software: Altium, or other
- Knowledge of IPC standards for PCB industry, or willingness to learn
- Microsoft Office products

FCT offers competitive salary, bonus program, benefits package, and an outstanding long-term opportunity. Location: Minneapolis, Minn., area.

apply now

Regional Manager
Midwest Region

General Summary: Manages sales of the company's products and services, Electronics and Industrial, within the States of KS, MO, NE, and AR. Reports directly to Americas Manager. Collaborates with the Americas Manager to ensure consistent, profitable growth in sales revenues through positive planning, deployment and management of sales reps. Identifies objectives, strategies and action plans to improve short- and long-term sales and earnings for all product lines.

DETAILS OF FUNCTION:

- Develops and maintains strategic partner relationships
- Manages and develops sales reps:
  - Reviews progress of sales performance
  - Provides quarterly results assessments of sales reps' performance
  - Works with sales reps to identify and contact decision-makers
  - Setting growth targets for sales reps
  - Educates sales reps by conducting programs/ seminars in the needed areas of knowledge
- Collects customer feedback and market research (products and competitors)
- Coordinates with other company departments to provide superior customer service

QUALIFICATIONS:

- 5-7+ years of related experience in the manufacturing sector or equivalent combination of formal education and experience
- Excellent oral and written communication skills
- Business-to-business sales experience a plus
- Good working knowledge of Microsoft Office Suite and common smart phone apps
- Valid driver's license
- 75-80% regional travel required

To apply, please submit a COVER LETTER and RESUME to: Fernando Rueda, Americas Manager

fernando_rueda@kyzen.com

apply now

Career Opportunities

pluritec®

MACHINES FOR PRINTED CIRCUIT BOARDS

Field Service Engineer

Location: West Coast, Midwest

Pluritec North America, ltd., an innovative leader in drilling, routing, and automated inspection in the printed circuit board industry, is seeking a full-time field service engineer.

This individual will support service for North America in printed circuit board drill/routing and X-ray inspection equipment.

Duties included: Installation, training, maintenance, and repair. Must be able to troubleshoot electrical and mechanical issues in the field as well as calibrate products, perform modifications and retrofits. Diagnose effectively with customer via telephone support. Assist in optimization of machine operations.

A technical degree is preferred, along with strong verbal and written communication skills. Read and interpret schematics, collect data, write technical reports.

Valid driver's license is required, as well as a passport, and major credit card for travel.

Must be able to travel extensively.

apply now

Manncorp™

SMT Field Technician
Hatboro, PA

Manncorp, a leader in the electronics assembly industry, is looking for an additional SMT Field Technician to join our existing East Coast team and install and support our wide array of SMT equipment.

Duties and Responsibilities:

- Manage on-site equipment installation and customer training
- Provide post-installation service and support, including troubleshooting and diagnosing technical problems by phone, email, or on-site visit
- Assist with demonstrations of equipment to potential customers
- Build and maintain positive relationships with customers
- Participate in the ongoing development and improvement of both our machines and the customer experience we offer

Requirements and Qualifications:

- Prior experience with SMT equipment, or equivalent technical degree
- Proven strong mechanical and electrical troubleshooting skills
- Proficiency in reading and verifying electrical, pneumatic, and mechanical schematics/drawings
- Travel and overnight stays
- Ability to arrange and schedule service trips

We Offer:

- Health and dental insurance
- Retirement fund matching
- Continuing training as the industry develops

apply now

Career Opportunities

ventec INTERNATIONAL GROUP 騰輝電子

European Product Manager
Taiyo Inks, Germany

We are looking for a European product manager to serve as the primary point of contact for product technical sales activities specifically for Taiyo Inks in Europe.

Duties include:

- Business development & sales growth in Europe
- Subject matter expert for Taiyo ink solutions
- Frequent travel to targeted strategic customers/ OEMs in Europe
- Technical support to customers to solve application issues
- Liaising with operational and supply chain teams to support customer service

Skills and abilities required:

- Extensive sales, product management, product application experience
- European citizenship (or authorization to work in Europe/Germany)
- Fluency in English language (spoken & written)
- Good written & verbal communications skills
- Printed circuit board industry experience an advantage
- Ability to work well both independently and as part of a team
- Good user knowledge of common Microsoft Office programs
- Full driving license essential

What's on offer:

- Salary & sales commission--competitive and commensurate with experience
- Pension and health insurance following satisfactory probation
- Company car or car allowance

This is a fantastic opportunity to become part of a successful brand and leading team with excellent benefits. Please forward your resume to **jobs@ventec-europe.com.**

apply now

MivaTek Global

Field Service Technician

MivaTek Global is focused on providing a quality customer service experience to our current and future customers in the printed circuit board and microelectronic industries. We are looking for bright and talented people who share that mindset and are energized by hard work who are looking to be part of our continued growth.

Do you enjoy diagnosing machines and processes to determine how to solve our customers' challenges? Your 5 years working with direct imaging machinery, capital equipment, or PCBs will be leveraged as you support our customers in the field and from your home office. Each day is different, you may be:

- Installing a direct imaging machine
- Diagnosing customer issues from both your home office and customer site
- Upgrading a used machine
- Performing preventive maintenance
- Providing virtual and on-site training
- Updating documentation

Do you have 3 years' experience working with direct imaging or capital equipment? Enjoy travel? Want to make a difference to our customers? Send your resume to N.Hogan@MivaTek.Global for consideration.

More About Us

MivaTek Global is a distributor of Miva Technologies' imaging systems. We currently have 55 installations in the Americas and have machine installations in China, Singapore, Korea, and India.

apply now

Career Opportunities

INSULECTRO

Are You Our Next Superstar?!

Insulectro, the largest national distributor of printed circuit board materials, is looking to add superstars to our dynamic technical and sales teams. We are always looking for good talent to enhance our service level to our customers and drive our purpose to enable our customers to build better boards faster. Our nationwide network provides many opportunities for a rewarding career within our company.

We are looking for talent with solid background in the PCB or PE industry and proven sales experience with a drive and attitude that match our company culture. This is a great opportunity to join an industry leader in the PCB and PE world and work with a terrific team driven to be vital in the design and manufacture of future circuits.

apply now

Prototron Circuits

Sales Representatives

Prototron Circuits, a market-leading, quick-turn PCB manufacturer located in Tucson, AZ, is looking for sales representatives for the New England and Northern California territories. With 35+ years of experience, our PCB manufacturing capabilities reach far beyond that of your typical fabricator.

Reasons you should work with Prototron:

- Solid reputation for on-time delivery (98+% on-time)
- Capacity for growth
- Excellent quality
- Production quality quick-turn services in as little as 24 hours
- 5-day standard lead time
- RF/microwave and special materials
- AS9100D
- MIL-PRF- 31032
- ITAR
- Global sourcing option (Taiwan)
- Engineering consultation, impedance modeling
- Completely customer focused team

Interested? Please contact Russ Adams at (206) 351-0281 or russa@prototron.com.

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Career Opportunities

The Test Connection, Inc.

Rewarding Careers

Take advantage of the opportunities we are offering for careers with a growing test engineering firm. We currently have several openings at every stage of our operation.

The Test Connection, Inc. is a test engineering firm. We are family owned and operated with solid growth goals and strategies. We have an established workforce with seasoned professionals who are committed to meeting the demands of high-quality, low-cost and fast delivery.

TTCI is an Equal Opportunity Employer. We offer careers that include skills-based compensation. We are always looking for talented, experienced test engineers, test technicians, quote technicians, electronics interns, and front office staff to further our customer-oriented mission.

Associate Electronics Technician/ Engineer (ATE-MD)

TTCI is adding electronics technician/engineer to our team for production test support.

- Candidates would operate the test systems and inspect circuit card assemblies (CCA) and will work under the direction of engineering staff, following established procedures to accomplish assigned tasks.
- Test, troubleshoot, repair, and modify developmental and production electronics.
- Working knowledge of theories of electronics, electrical circuitry, engineering mathematics, electronic and electrical testing desired.
- Advancement opportunities available.
- Must be a US citizen or resident.

apply now

Test Engineer (TE-MD)

In this role, you will specialize in the development of in-circuit test (ICT) sets for Keysight 3070 (formerly HP) and/or Teradyne (formerly GenRad) TestStation/228X test systems.

- Candidates must have at least three years of experience with in-circuit test equipment. A candidate would develop and debug our test systems and install in-circuit test sets remotely online or at customer's manufacturing locations nationwide.
- Candidates would also help support production testing and implement Engineering Change Orders and program enhancements, library model generation, perform testing and failure analysis of assembled boards, and other related tasks.
- Some travel required and these positions are available in the Hunt Valley, Md., office.

apply now

Sr. Test Engineer (STE-MD)

- Candidate would specialize in the development of in-circuit test (ICT) sets for Keysight 3070 (formerly Agilent & HP), Teradyne/ GenRad, and Flying Probe test systems.
- Strong candidates will have more than five years of experience with in-circuit test equipment. Some experience with flying probe test equipment is preferred. A candidate would develop, and debug on our test systems and install in-circuit test sets remotely online or at customer's manufacturing locations nationwide.
- Proficient working knowledge of Flash/ISP programming, MAC Address and Boundary Scan required. The candidate would also help support production testing implementing Engineering Change Orders and program enhancements, library model generation, perform testing and failure analysis of assembled boards, and other related tasks. An understanding of stand-alone boundary scan and flying probe desired.
- Some travel required. Positions are available in the Hunt Valley, Md., office.

Contact us today to learn about the rewarding careers we are offering. Please email resumes with a short message describing your relevant experience and any questions to careers@ttci.com. Please, no phone calls.

We proudly serve customers nationwide and around the world.

TTCI is an ITAR registered and JCP DD2345 certified company that is NIST 800-171 compliant.

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Career Opportunities

ARLON ELECTRONIC MATERIALS

Arlon EMD, located in Rancho Cucamonga, California, is currently interviewing candidates for open positions in:

- **Engineering**
- **Quality**
- **Various Manufacturing**

All interested candidates should contact Arlon's HR department at 909-987-9533 or email resumes to careers.ranch@arlonemd.com.

Arlon is a major manufacturer of specialty high-performance laminate and prepreg materials for use in a wide variety of 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: 2015 registered, and through rigorous quality control practices and commitment to continual improvement, we are dedicated to meeting and exceeding our customers' requirements.

For additional information please visit our website at www.arlonemd.com

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eptac
TRAIN. WORK SMARTER. SUCCEED.

Become a Certified IPC Master Instructor

Opportunities are available in Canada, New England, California, and Chicago. If you love teaching people, choosing the classes and times you want to work, and basically being your own boss, this may be the career for you. EPTAC Corporation is the leading provider of electronics training and IPC certification and we are looking for instructors that have a passion for working with people to develop their skills and knowledge. If you have a background in electronics manufacturing and enthusiasm for education, drop us a line or send us your resume. We would love to chat with you. Ability to travel required. IPC-7711/7721 or IPC-A-620 CIT certification a big plus.

Qualifications and skills

- A love of teaching and enthusiasm to help others learn
- Background in electronics manufacturing
- Soldering and/or electronics/cable assembly experience
- IPC certification a plus, but will certify the right candidate

Benefits

- Ability to operate from home. No required in-office schedule
- Flexible schedule. Control your own schedule
- IRA retirement matching contributions after one year of service
- Training and certifications provided and maintained by EPTAC

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Career Opportunities

BLACKFOX
Premier Training & Certification

IPC Instructor

Longmont, CO; Phoenix, AZ; U.S.-based remote

Independent contractor, possible full-time employment

Job Description

This position is responsible for delivering effective electronics manufacturing training, including IPC Certification, to students from the electronics manufacturing industry. IPC instructors primarily train and certify operators, inspectors, engineers, and other trainers to one of six IPC Certification Programs: IPC-A-600, IPC-A-610, IPC/WHMA-A-620, IPC J-STD-001, IPC 7711/7721, and IPC-6012.

IPC instructors will conduct training at one of our public training centers or will travel directly to the customer's facility. A candidate's close proximity to Longmont, CO, or Phoenix, AZ, is a plus. Several IPC Certification Courses can be taught remotely and require no travel.

Qualifications

Candidates must have a minimum of five years of electronics manufacturing experience. This experience can include printed circuit board fabrication, circuit board assembly, and/or wire and cable harness assembly. Soldering experience of through-hole and/or surface-mount components is highly preferred.

Candidate must have IPC training experience, either currently or in the past. A current and valid certified IPC trainer certificate holder is highly preferred.

Applicants must have the ability to work with little to no supervision and make appropriate and professional decisions.

Send resumes to Sharon Montana-Beard at sharonm@blackfox.com.

apply now

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

CAD/CAM Engineer

The CAD/CAM Engineer is responsible for reviewing customer supplied data and drawings, performing design rule checks and creation of manufacturing data, programs and tools required for the manufacture of PCB.

ESSENTIAL DUTIES AND RESPONSIBILITIES

- Import Customer data into various CAM systems.
- Perform design rule checks and edit data to comply with manufacturing guidelines.
- Create array configurations, route, and test programs, penalization and output data for production use.
- Work with process engineers to evaluate and provide strategy for advanced processing as needed.
- Itemize and correspond to design Issues with customers.
- Other duties as assigned

ORGANIZATIONAL RELATIONSHIP

Reports to the engineering manager. Coordinates activities with all departments, especially manufacturing.

QUALIFICATIONS

- A college degree or 5 years' experience is required. Good communication skills and the ability to work well with people is essential.
- Printed circuit board manufacturing knowledge
- Experience using Orbotech/Genflex CAM tooling software

PHYSICAL DEMANDS

Ability to communicate orally with management and other co-workers is crucial. Regular use of the phone and e-mail for communication is essential. Sitting for extended periods is common. Hearing and vision within normal ranges is helpful for normal conversations, to receive ordinary information and to prepare documents.

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Career Opportunities

U.S. CIRCUIT

Plating Supervisor

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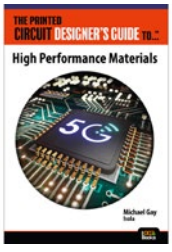

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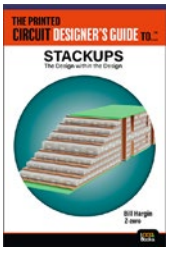

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PUBLISHER: **BARRY MATTIES**
barry@iconnect007.com

MANAGING EDITOR: **ANDY SHAUGHNESSY**
(404) 806-0508; andy@iconnect007.com

EDITOR | COLUMNIST COORDINATOR: **MICHELLE TE**
michelle@iconnect007.com

CONTRIBUTING 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

SALES MANAGER: **BARB HOCKADAY**
(916) 365-1727; barb@iconnect007.com

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

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

MAGAZINE LAYOUT: **RON MEOGROSSI**

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

CREATIVE TECHNOLOGIST: **BRYSON MATTIES**

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