I-Connect007

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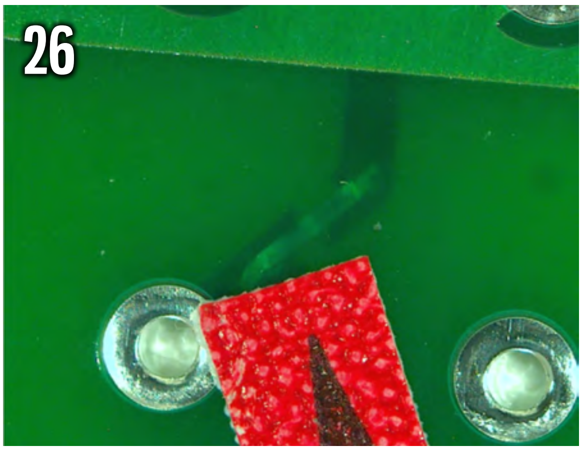
PCB007 MAGAZINE

THE LONG ROAD TO INDUSTRY STANDARDS

PCB007 MAGAZINE

Industry Standards

The flag standard became the symbol of the "rule of law" and a rallying point for those who supported that particular institution. It's no small wonder, then, that the term has expanded to include other systems that function as law by mutual agreement. The process of reaching that agreement can be a long, arduous road to travel. In this issue, we look at standards both as processes and rallying points.



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SHORTS:

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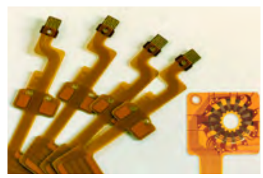

DEPARTMENTS:

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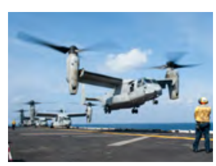

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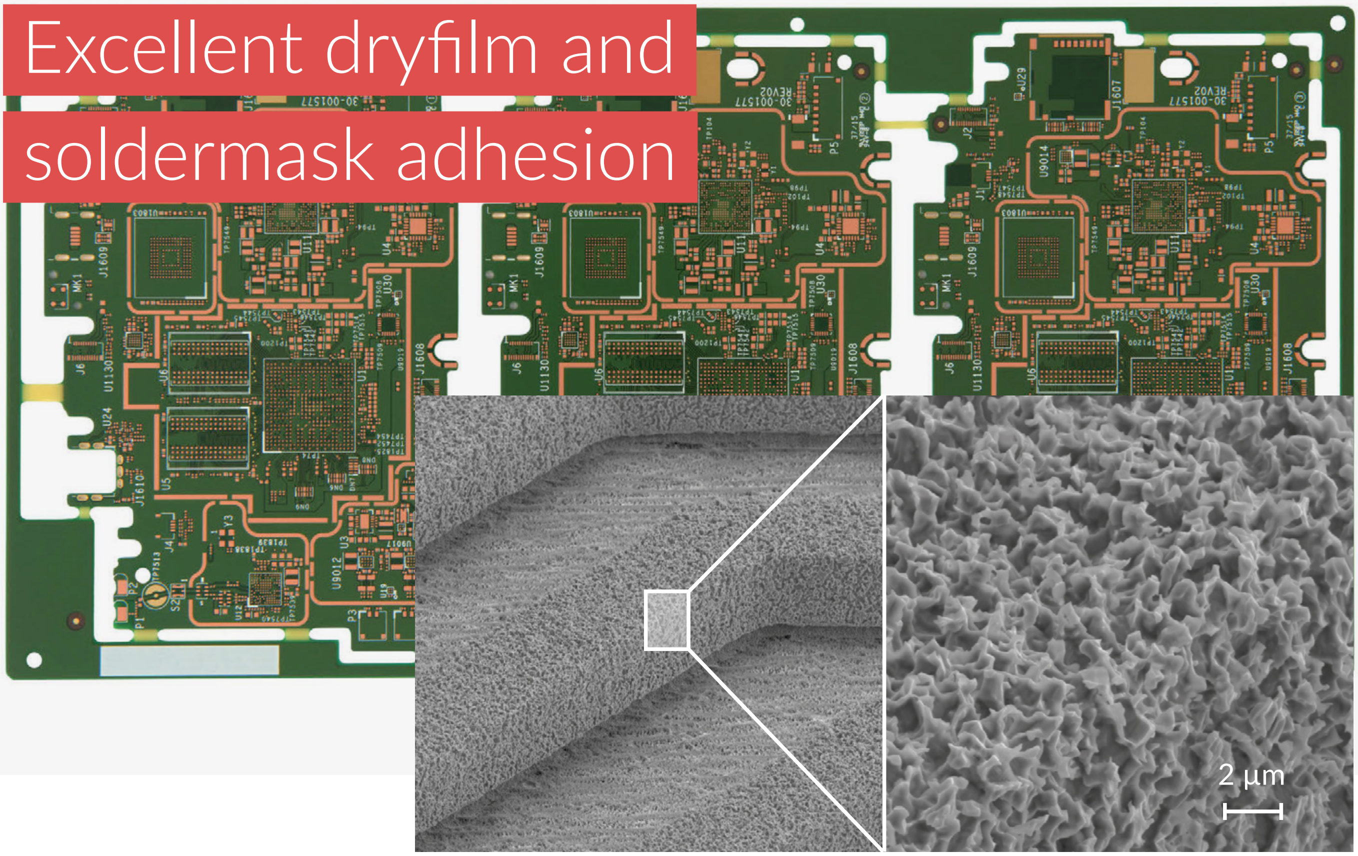

Pic. 1: CupraEtch® SR8000 etched Cu

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Carrying the Flag

Nolan's Notes
by Nolan Johnson, I-CONNECT007

This issue of *PCB007 Magazine* concludes our month-long look at industry standards. We wrap up by "waving the standard" in celebration. Of course, that phrase immediately piques the interest of us wordsmiths. Why, after all, do English speakers use "standard" as a synonym for a flag?

The etymology of the word "standard" starts to answer that question. It is widely recognized and cited by scholars that by the mid-twelfth century, standard referred to "a flag or other conspicuous object to serve as a rallying point for a military force." Numerous etymologists suggest that the Franks (a Germanic tribe from the Rhine river regions) introduced the word "standhard," which meant to stand fast or firm. The "standhard" was a flag attached to a pole or spear, standing upright in the ground.

Tracing the history of flags and standards leads us to this quote from Encyclopedia Britannica [1]: "In Europe, the first 'national' flags were adopted in the Middle Ages and the Renaissance…Toward the end of the Middle Ages, flags had become accepted symbols of countries, kings, organizations, cities, and guilds." The flag's dimensions became significant as well. Britannica continues, "Flags were subdivided according to their shape and purpose into standards, banners, guidons, pennons, and streamers. Of the main types, the standard [2] was the largest, and from its size, was intended to be stationary. It marked the position of an important individual before a battle, during a siege, throughout a ceremony, or at a tournament. For the monarch, it marked the palace, castle, saluting base, tent, or ship where he or she was actually present."

The flag standard became the symbol of the "rule of law" and a rallying point for those who supported that particular institution. It's no small wonder, then, that the term has expanded to include other systems that function as law by mutual agreement. The process of reaching that agreement can be a long, arduous road to travel. In this issue, we look at standards both as processes and rallying points. Follow the standards, and your results will be both better and compatible with the rest of the industry.

First, Mark Goodman and Alun Morgan present "Is It Time to Shake Up Materials Standards?" Then, Marc Carter discusses "Using Industry Standards as Another PWP Manufacturing Tool." Alifiya

Arastu, Jeff Beauchamp, Harry Kennedy, and Ruben Contreras from NCAB Group present, "Standards: Why We Have Them and Live by Them." Sprinkled amongst the full-length features are quick pointers to some valuable standards pieces published by I-Connect007 earlier this month: Jan Pedersen and Ray Prasad in "To Improve the Standards Process, Get Involved," Graham Naisbitt with "The Long Road to a New Standard," and Leo Lambert on "So Many Committees, So Little Time."

Dr. John Mitchell writes on "Maintaining a Strong Economy Through Workforce Development," and Todd Kolmodin addresses "Understanding the Fine Print." Jean-Pierre Theret's article on "The Future of 'Substances and Materials in Products' Data Exchange Formats as Standards" is next followed by Juha Saily's "New High-speed 3D Surface Imaging Technology in Electronics Manufacturing Applications." Mike Hill continues with Part 2 of, "The Past 15 Years: Changes to MIL-PRF-31032 Certification" and Mike Carano details "Working With Flexible Circuits."

Already this month, our issues on standards have created quite a lot of conversation among readers. In the end, creating standards is a collaborative, and dare we say *democratic,* process. The wider the range of voices and the deeper the expertise that becomes involved in the standards process, the better the outcome for us all. And if you'd like to have a conversation on standards or anything else related to our industry, we're always listening. Contact me or any of the rest of the I-Connect007 editorial team at editorial@iconnect007.com. We'll look for your name on future standards documents. **PCB007**

References

1. Encyclopedia Britannica, "Flag."
2. Encyclopedia Britannica, "Standard."

Nolan Johnson is managing editor of *PCB007 Magazine.* Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing. To contact Johnson, click here.

The Ecosystem of Industry Standards

by the I-Connect007 Editorial Team

Standards are a community and governmental process, if you will, formalizing methods and techniques to allow for consistency and repeatability across the industry. Thus, there are many participants in the standards definition processes from individual volunteers to corporations to industry organizations—all participate in the standards processes in some way.

I-Connect007 reached out to representatives from several industry standards organizations and talked with them about how they participate in the standards process. Along the way, these conversations clarify which group does what, how they all work together as well as clarify and dispel a couple of industry myths.

Join us for some interview excerpts from IPC's Dave Bergman, iNEMI's Marc Benowitz, and NextFlex executives Scott Miller and Wilfried Bair.

This article was published in the September issue of *SMT007 Magazine.* Click here to read the full article.

Is It Time to SHAKE UP Materials Standards?

Feature Interview by the I-Connect007 Editorial Team

The I-Connect007 team spoke with COO Mark Goodwin and Technology Ambassador Alun Morgan from Ventec International Group about standards. They describe how they feel current standards do not sufficiently recognize the needs of end customers today with new processes and materials being shoehorned into old standards based on dated ideas of classifications, and how this makes choosing the right material challenging for designers. They suggest implementing a simpler system that is based on performance.

Barry Matties: Mark, please start with what you see as issues around the standards.

Mark Goodwin: There are two particular areas: one is very product-specific, and the other is standard-specific. I'll start with the product-specific one. We have an increasing global market for thermal management products, insulated metal substrates, thermally conductive laminates, and prepregs, and we have no industry standards for comparing test methods to allow an end user to adequately compare the thermal performance of those materials. It's the Wild West out there on those products. The other area for me is IPC-4101—the slash sheets—where there is a hang-up on resin chemistry rather than functionality; there's a whole history to that. And the world has moved so far forward, the specification has not kept up, and it needs an industry effort to reconfigure and realign that specification. Those are the starting points for me.

Alun Morgan: We consider standards from two perspectives. One is a mandatory side, so that means both fire and electrical safety, which are pretty clear and there's very little compromise. The other is performance standards or classification standards, which Mark alluded to, such as IPC-4101 or IEC series, where the intention is to define a standard or specification that gives designers a choice within a range of performance for materials; that's somewhat broken now. The problem with these standards is that you have a different hierarchy of standards. You have the top end with international bodies, such as IEC and ISO, and at the lower end, industry associations sitting under


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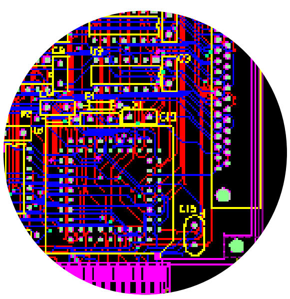


national standards bodies, publishing specifications developed by industry consensus, and that's one of the problems.

If you have a room full of suppliers of a product, for example, and you say, "Let's write a standard that applies to all of our customers," you end up with the lowest standard that they can all live with and that you can drive a bus through, more or less, in terms of what the real requirement is. An example I was discussing this morning was a standard about FR-4 materials, for example, which says that you have to have a dielectric constant maximum value of 5.2. If you turned up with a product that had a Dk of 5.2, virtually nobody would be able to use it because the requirements have moved on. Typically, you'd want to be looking in the low fours or even the threes now; that's the standard.

Alun Morgan

That's the issue that we're faced with because the standards and specifications are generally based on the old NEMA standards, which were developed in the 1950s and 1960s based on things like simple resin chemistry, epoxy resins, phenolic resins, polyimide resins, etc. And they've been extended to cover a whole explosion of new materials. The industry has expanded massively, and we still shoehorn our new products into these old standards based on dated ideas of classifications. What we need is a more performance-based approach now, saying, "I'm a designer and design boards for satellites that go into orbit. These are the kind of things that I need."

As a board designer, I'd find it very hard to know how to choose a material based on the standards that are available. And for some areas, such as IMS materials, there aren't any agreed-upon standards either. That's quite normal; standards usually take two to three years to go into print from the first idea.

Matties: If this approach is sensible where it's application-specific standards, what's the catalyst for change? How's that going to happen?

Morgan: It's the designer's requirement. The designer goes to his board shop and says, "I want to build a board to go under the hood of a car; what material shall I use?" They ask the board shop, and that's the problem; they're not accessing all of the materials or options available to them because they don't know, and they have no way of selecting now.

Matties: If the designers, as a body, said, "We want to change the methodology and the way that the standards are done with IPC," and the members buy in, do you think it would happen?

Morgan: I think it would. IPC does run automotive and other specific forums now. Somebody has to recognize that this way of specifying standards doesn't work anymore and they have to start again, but that's a huge decision because there's a lot of investment there. There are also a lot of people who have been fighting this stance for years, including me, since the 1980s. We've come to a point now where they're not fit for purpose and need to be reimagined to meet the needs of today's OEMs.

Goodwin: To some degree, there is a window of opportunity if we can somehow put this out there to make it happen because there are some disruptive elements in certain sectors now. Automotive is one with the move from internal combustion engines to electrically powered vehicles, including the new players that are coming in with a less traditional business model, such as Tesla and others lining up to be in that market. The same is also true in commercial aerospace. A lot of those people come from a more modern technology background, not a traditional technology background, and they will take different views. There is a chance there. Where we'll struggle, of course, is places like the military where they never change anything because the perceived risk is too big for everyone. Nobody wants to sign off on it.

Morgan: Yes, the military is hesitant to change, but people in the automotive and electromobility segments are interested. Designers want a bit of help. I gave a talk/consortium in January this year, and it was fantastic. There was a great group of people there who wanted to hear something about this because they look down the standards list to try and pick the material for an application that's going to work. They don't know because there's such a range of materials. You have thousands of them now.

Somebody could say, for example, "We're an automotive OEM, and we want an international standard that we can use rather than using our industry-specific standards. We have one group that we call under-hood, one that we call cabin, and one that's mission-critical." Then, you define within the industry the areas of concern; under-hood, for example, would need to have a high thermal performance. As an industry, you could say to the designers, "What do you need?" and they would come to that kind of group. You would have confidence that it would work.

Goodwin: I'm sitting here counting up the number of slash sheets in IPC-4101, I'm up to 97, and now I'm giving up. If, as a designer, I have an interest in epoxy woven glass, and there are 21 slash sheets or more for epoxy woven glass. How am I supposed to work my way through that? This is the problem, and if, for example, we took the resin chemistry definitions out of the specification, you take away half of these slash sheets in one go because there will be one brominated epoxy and one unbrominated epoxy for each Tg range.

Andy Shaughnessy: Designers can't possibly know the differences between all of them and understand them all, and they're not all manufactured with the same process.

Goodwin: Right, and not even a laminator could decipher this. If you put six members of the IPC Materials Committee in a room, you'd have at least seven opinions.

Morgan: It's impossible, and that's the issue. These standards came out of the old DoD MIL standards. The DoD decided not to run it anymore, so they were taken over by IPC. They started off great when there were three or four resin systems, which was pretty simple, but things have moved on.

Goodwin: Agreed. The way the specification is written has nothing to do with polymer/resin chemistry.


Mark Goodwin

Morgan: It was a convenient way when there were only a handful of systems. There was phenolic resin, which was generally married with paper as a reinforcement; there was epoxy resin, generally married with glass fiber; and there was the high-end polyimide, high-temperature resin married with glass. Everything was shoehorned into those three. It's entirely sensible the way it was set off, but not anymore. A specialist is not going to understand all of it, so as a designer, you don't have any hope. It's time to define what all of this stuff means. All that matters is how it works and performs.

Goodwin: All that matters is electrical, physical, and thermal performance.

Morgan: The rest doesn't matter at all. We're looking under the hood too much, specifying chemistry and all kinds of stuff. But who cares? You need to be able to categorize it somehow.

Goodwin: A simple first step, though, would be to move to the performance characteristics we already have around electrical and thermal performance, and remove this link to the under-hood, the resin chemistry. That would be a very big and relatively simple step to take with no performance risk for the end user because the performance is defined.

Nolan Johnson: We have end users who are essentially designers, but the authors in charge of this process tend to be on the manufacturer side; they have a different set of criteria they consider important. The audience here, the designers, aren't particularly well represented in the standards process.

Morgan: There is vested interest as well. In every single meeting I used to go to, the whole intention was to make sure your materials were included in all of the specifications. There's a vested interest to make sure that your stuff, whatever you supply, meets the standard that you've all agreed upon, which is why it's for the manufacturers.

Goodwin: To add to that, having been to certain meetings with very specific discussions about standards, there are no definitions of some terms, so it's not even a standard.

Morgan: These are like methods for specifying or process standards, so they're not standards in the way that IEC standards are. So, you're right that they're not primary standards; they are the lowest common denominator.

Goodwin: It's like the secondary resin thing; there is no published definition. And when I talk with people, everyone takes their own view.

Morgan: It's fun for me as a materials technologist to discuss this with people who don't have the first idea what any of this is, and that's what happens. All they know is that it suits their company to say a certain thing, and that is a problem you always get. I suppose IEC standards do somewhat better because they are international. You don't have companies represented there; you have countries represented, so a country would decide who its experts are and put them forward. An additional issue is that the people who do this work are getting older, and they're a limited pool.

Matties: The more we discuss it and make it visible to the industry, the more energy it will have.

Morgan: There was a time when people said, "Shut up. Don't talk about this. We don't want to hear it." But now they're saying, "We agree with you, but we don't know how to do it."

Goodwin: It is moving forward.

Morgan: It's being discussed a lot now, and I talk about it every chance I get, and other people are too now, so it's coming around.

Matties: If we, as an industry, embraced this concept to go with a performance-based standard, what timeframe would we be looking at for a full conversion?

Goodwin: The first step, in my opinion, would be to remove all references to resin chemistry from the existing specification. That could be done relatively easily. IPC could become about performance, so removing the chemistry would be a great step forward. In the end, is it a REACH compliant chemistry, for example? Yes or no is all we need to know.

Morgan: What I'd probably tend to do is to leave the system currently as it is because to rewrite it is going to be pretty hard. I'd prefer to start again. I'd leave the stuff in there that we have, start with a new initiative, find a group of people who have an interest in this, and then write at least a basic set. You could then have one for low-loss or high-frequency electronics and one for high reliability. Imagine maybe four or five categories of general performance, not even application-specific at this stage. And then say, "If we go to write a specification for high reliability-based materials, what kind of things do you want to put in there? What are the properties?"

Goodwin: I want to have a relatively high Tg.

Morgan: Exactly. What should the T-260 be? It should be an hour minimum. What about the Tg? Let's say 175 minimum. What about the Dk? We don't care about that too much, so let's put a value of 4.5 maximum. You'd go through all the list of all the things that we

know about and come up with a general standard. Then, you do the same for other areas. Regarding low loss, what does that matter? We don't care about the Tg. Okay, let's put it at 120 minimum. What about Dk? We want to have 4 as a maximum. You do that as a first step, and then you start to match products into those categories. Next, you'd work down those categories later to make them more specific to particular industries.

As a designer, you'd probably be able to find a very nice group of materials or specification standards that would meet your exact requirements.

Goodwin: That's true because when you talk to a PCB company, the only thing they care about is if they comply with the IPC slash sheet number the customer has called out. But it becomes joining the dots. Managing it with this limited number of specifications would be a huge step forward.

Morgan: It's also not very efficient because some people overspecify, of course, because they find it the easiest. Someone says, "What's the best laminate to use?" "Oh, polyimide is the best one. I would use polyimide for everything." It's entirely wrong, but that's what the military has been doing for years. They thought it was the best because it's soldier-proof in the field and we'll use that for everything. Honestly, I sympathize entirely with people trying to choose materials now. With all of the new materials that we have put into this old formula, they just add another line.

Goodwin: Or worse still, IPC is adding categories to accommodate new materials and largely not because of their performance. It's because somebody's achieving that performance in a different way (i.e., resin chemistry). At least one slash sheet number is being discussed because of that, and that's nuts, in my opinion.

Morgan: This classification based on basic chemistry is broken. Anybody who has any particular performance requirements that are in any way demanding will go to the board shop and say, "Here's my design. What should I use?" That isn't how standards should work at all. You should be able to say, "Here's what I'm designing and the performance I need. I need to choose within this exact category of material. Any material meeting that standard that will do the job for me," and you can't say that right now.

Matties: You mentioned you're starting to identify the product by application, which is a help to the designers, but it's not necessarily identified by the standard because there isn't a performance standard.

Goodwin: It has nothing to do with the standard; it's about recognizing the need of our end customers.

Morgan: For example, a customer comes to Mark and says, "We're building a 5G network here. What kind of material should we use?" Mark pulls a datasheet out and says, "Here are the ones that fit that space." Or the customer says, "I want to do some thermal management on one of my boards. What should I use?" and Mark, again, gives a sheet to them with all of the products that meet that category, and that's the way it's nice to see it moving. Otherwise, you end up with so many products that you can't narrow it down.

Goodwin: I just scrolled down to the detail of IPC slash sheets, and it's interesting. The headlines are not even performance. The headlines are woven glass, then the resin system, flame retardant, and fillers, and we get to things like Tg, CTE, etc. All of the performance stuff is lower down the hierarchy of characteristics than the other stuff. It's completely the wrong way around, in my opinion.

Morgan: To the analogy of the smartphone again. Who cares whose chip is in there? All you care is that it works. If someone says, "I want to buy a new cellphone." You don't say, "Would you like a Qualcomm or an ARM chip in there?" They'd say, "I don't care about that."

Matties: When you do make a recommendation for an application-specific material, do the designers go back and then compare it to some standard, or what's their course of action?

Goodwin: Increasingly, in high-end applications like high-speed digital, RF, or even thermal management, people are specifying vendor-specific material solutions now.

Matties: That's the trend, not even application-specific, because they know that vendor services that application.

Goodwin: They know it meets some of the characteristics they require. Again, if we get into thermal management—even to some degree Dk and Df—there are so many different test methods out there for these things that you can't compare datasheet values readily anyway.

Morgan: The reason they choose the product is because they know it worked on a similar design last time. It's as simple as that.

Matties: If we had a simple index, then they would be able to make some smarter choices on an application-specific category as well pricing, supply chain, etc. because those become competitive factors.

Goodwin: The classic example you tend to see for someone who's involved in managing supply chains is you're working with a PCB company, and someone says, "My drawing says I need this product from company X in the U.K." Now, company X has no supply chain into the U.K., so what do they do? This is coming at it from the other angle. There's no easy solution without having performance-based standards to meet everybody's requirements and make the supply chain work from one end to the other efficiently in terms of logistics, cost, and performance.

Matties: It sounds like a good approach, but that question or call to action is getting the industry to adopt a new methodology.

Morgan: The market needs to be more efficient. They should have a list of stuff they could choose from, that they know all of which would work because it's been standardized and specified that way. Even as manufacturers, we love to have people specify our products, but that is not efficient. There should at least be another choice.

Goodwin: There's a huge contradiction in this as well from a supply chain perspective. When you get involved with the big OEMs, and they start talking to you about risk management, continuity of supply, etc., you get down to some that are specifying one product from one treater in one factory, there is no risk management in that at all.

Shaughnessy: I wonder if there's a role for designers in setting these standards. They're not going to know about chemical composition and all of that, but it seems like designers should be involved since they're the ones who have to make sense of it all.

Goodwin: They should be involved somewhere, particularly with elements of electrical performance and physical properties that influence product performance. Everybody has a part to play, but the focus should be on performance, not the composition of the products.

Matties: Thank you for joining us today. It's greatly appreciated.

Goodwin: No problem, Barry.

Morgan: Thank you. PCB007

Using Industry Standards as Another PWB Manufacturing Tool

Better to Light a Candle

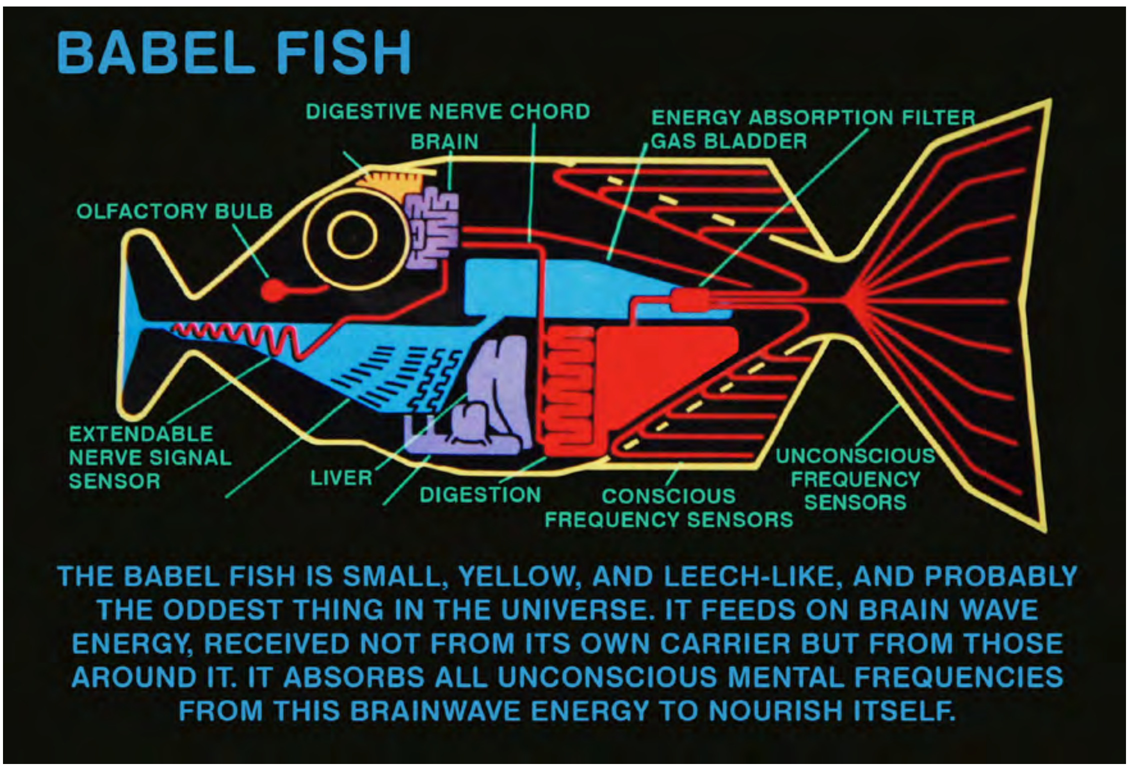
Feature Column by Marc Carter, AEROMARC LLC

Some people will say, "Standards are so boring!" To that, I might respond, "Well, that's kind of the point." When you're in production manufacturing, a "boring" day (i.e., everything works smoothly with no disruptions, and everybody shares clear expectations) can be a welcome relief from your usual. But what should we do with all of these standards anyway?

Standards bring everybody to the same understanding without having to re-negotiate everything with each new transaction. One book excerpt [1] states, "By using mutually accepted preexisting standards, two parties to a contract need not recreate every technical definition or requirement for every transaction, greatly facilitating commerce." You can think of international consensus standards as the industrial equivalent of the "Babel Fish."

Historically, standards came about to facilitate and enhance commerce. "I will buy 50 feet of your 0.5-inch rope if it holds up 200 pounds" is pretty meaningless if there's no agreed measure of "foot," "inch," or "pound." The earliest standards were based on what leaders set (i.e., the size of the king's foot or the width of his thumb], but these only worked within that kingdom while that king lived. Once you left that kingdom, most trading time was spent establishing "goodness" and "worth" (i.e., bartering).

It doesn't matter what the industry is; quick, efficient repetitive trade across distances mostly depends on voluntary, consensus-based



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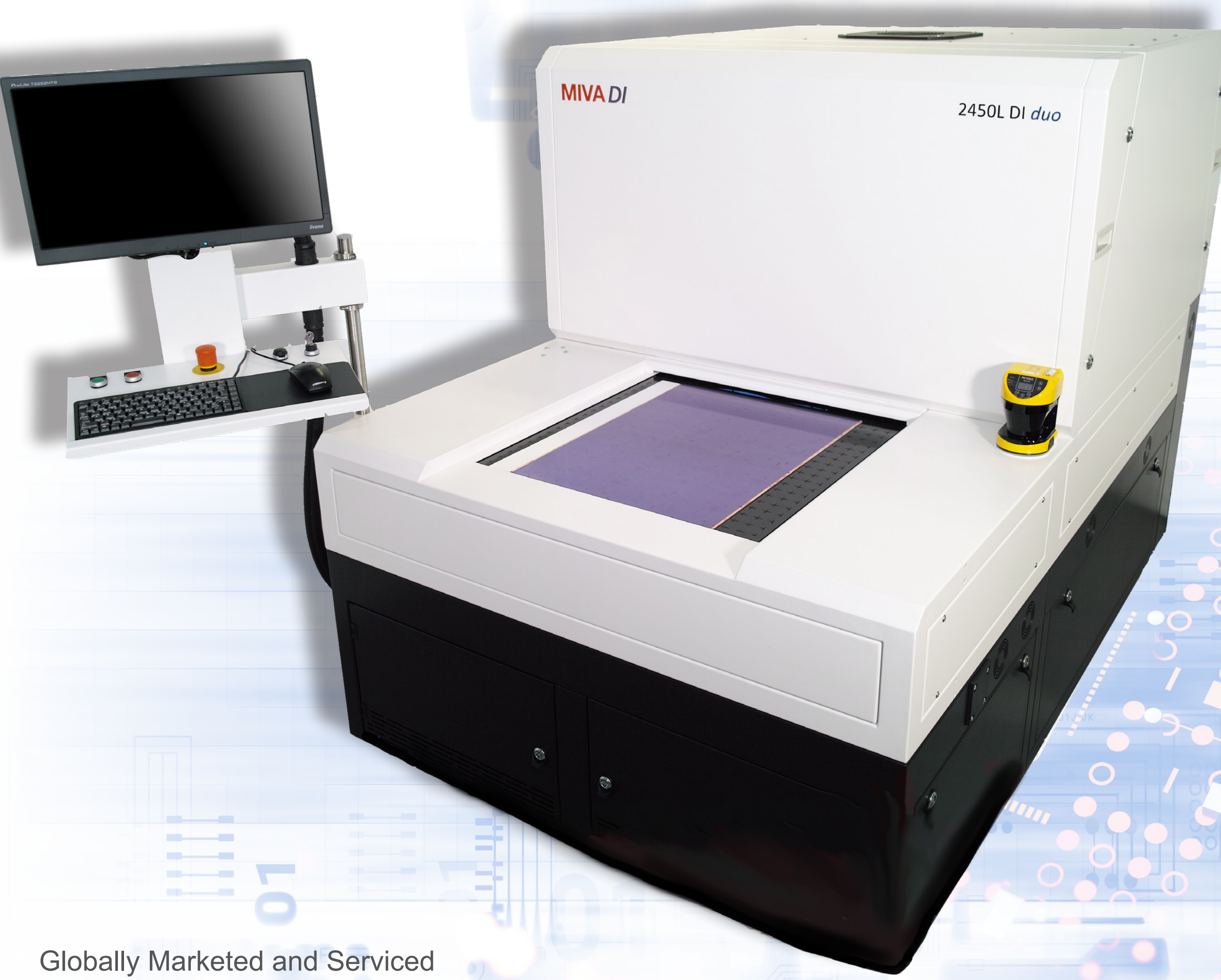

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standards that describe the trade goods. Standards must:

- Define the goods sufficiently so that buyers can have faith it will serve the purpose
- Be voluntarily accepted as binding by both parties (e.g., the term "voluntary" being included in contract language)
- Describe what to measure, how to measure, and (generally) what measure is acceptable to both parties
- Be useful and achievable, or they won't be used

The Process

Today, consensus-based standards are ensured by rigidly enforced and internationally audited procedures so that input from all possible sides of a deal—as well as inputs from "knowledgeable neutrals"—are fairly represented. Though the participants in a standards group are typically chosen, standards development organizations (SDOs) generally strive for balanced committees. Users, sellers, technologists, and academia professionals all are invited to participate, and all inputs must be debated, considered, and answered (even if they end up formally rejected by vote).

The standards created should reflect the wishes of the people who show up to work on the process, so companies (or country representatives for some organizations) often participate to ensure their interests are represented. Human beings and businesses being what they are, not everyone who shows up to help create or update a standard has "the fair and equitable treatment of all parties" as their primary motivation. Sometimes, we have to do the standards over until we get it right.

You'd think that, for something destined to ease communication and understanding, what comes out of the process wouldn't look as much like Sanskrit to most of the world. But precision and clarity do not always apply to the language of the definition. An example of the obtuse (to outsiders) language is "embedded component printed board (ECPB)." From IPC-7092 [2], this is, "The general term for a completely processed printed circuit and printed wiring configuration, which contains an internal base-core that includes embedded formed or placed components (this includes an embedded component base-core, or sequentially-laminated HDI configurations using embedded component base cores with additional layers)." I had a hand in this one, so I'm just as guilty as anybody else. Geeks in any field have their own language.

Why Can't We All Just Get Along?

In an ideal world, there would be one universally accepted catalog of standards, but the real world differs. In your career, you may encounter overlapping—and sometimes contradictory—standards related to your business:

- DoD, MIL, or MOD: Documents prepared by a country's military
- ECA: Documents prepared by the Electronic Components, Assemblies, Equipment, and Supplies Association (ECA) of the Electronic Industries Alliance (EIA); EIA ceased operations in 2011, but standard activities under the EIA Standards Council (ESC) continue under the auspice of the Electronic Components Industry Association (ECIA)
- IEC: Documents prepared by the International Electrotechnical Commission (IEC)
- IECQ: Documents prepared for a quality assessment system for electronic components supported through the IEC
- IPC: Documents prepared by IPC—Association Connecting Electronics Industries
- JEDEC: Documents of the Solid State Technology Association of the EIA
- JESD: Standards prepared by the Joint Electron Device Engineering Council (JEDEC)
- JPCA: Standards prepared by Japan Electronics Packaging and Circuits Association (JPCA)
- J-STD: Joint-industry standards (standards followed by more than one association)
- Proprietary standards, company-generated standards, and industry-qualification documents that use the aforementioned standards as their basis (NADCAP, etc.)

Operating in an IPC Standards Environment

Mark Twain is quoted as saying, “Those who respect the law and love sausage should watch neither being made.” For those of us operating in (or working with) the North American printed circuit business, you’ll undoubtedly have at least some involvement with IPC standards. In printed circuits, much of the world—and nearly all of North America—has settled on consensus-based standards, as painful, noisy, contentious, and imperfect as that process may be. Current standards are generated by a process that has evolved over the past 60+ years managed by IPC as the “lingua franca” of the business. IPC standards are not universal (with a nod to the International Electrotechnical Commission [IEC] and others), but they are recognized everywhere.

There are literally hundreds of IPC standards covering general (e.g., printed board acceptability) to very specific applications (e.g., specifications on copper-invar-copper core structures), both historic and current. One of your first tasks (if not already spelled out for you by your customer) is determining which are applicable. A snapshot of some of the possible applicable standards is shown in Figure 1.

An extremely oversimplified view (design layout through outgoing quality control) of a simple multilayer PCB could involve as few as the following (probably not, but let’s keep it simple for this discussion):

- Design/Layout: Netlist/interconnect routing, IPC-2221, IPC-2222
- Methods Engineering: Process sequence, in-process test, IPC-2222, IPC-6012
- Process Engineering: Process control capable of meeting IPC-6012
- Quality: Customer documentation, IPC-6012, IPC-A-600

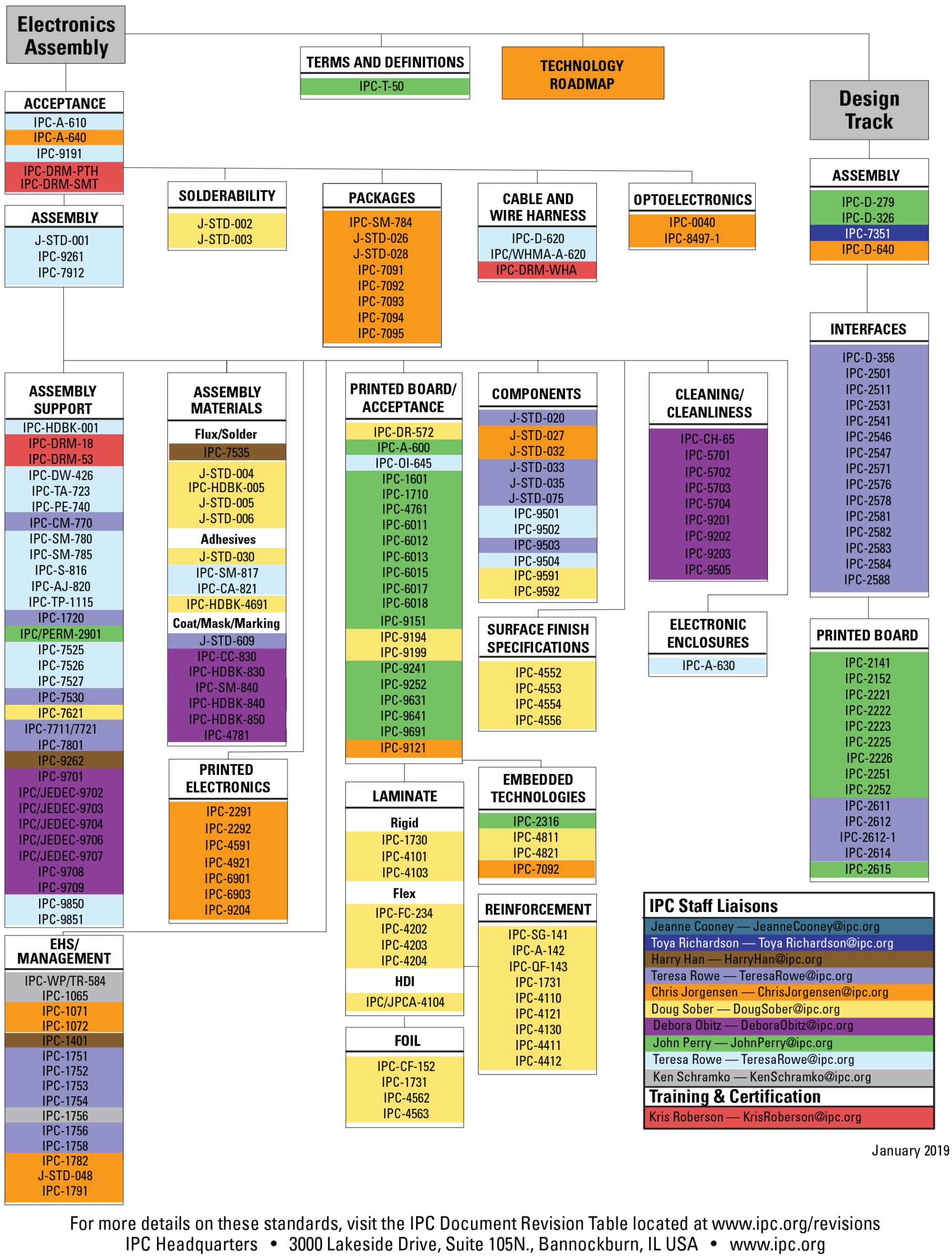


Figure 1: IPC standards tree.

The functional sequence of creating a circuit assembly is presented herein as a strict linear progression from function to function. As we (should) have learned from Dr. Who and the great American philosopher Lena Horne, "It Ain't Necessarily So." Properly done, there will be backward and forward interactions between the functions throughout the process with feedback informing both of the current actions of the functional team but also correcting and fine-tuning their future actions (ideally, that is).

Next Time

In my next article, I'll take the reader through a (grossly oversimplified) sequence of how these standards are applied and interpreted in each of the functions previously listed with examples and excerpts. **PCB007**

References

1. Clyde F. Coombs Jr. & Happy Holden, *Printed Circuit Handbook, Seventh Edition,* McGraw-Hill, 2016, p. 1,585.
2. IPC-7092, "Design and Assembly Process Implementation for Embedded Components."

Marc Carter has worked in the electronics interconnection industry since 1984 in a variety of roles in fabrication and assembly materials, processes, environmental compliance, and supply chain management activities around the world. He has had the honor and privilege of working with and learning from many of the true giants of the electronics manufacturing industry. Marc was a long-time user of standards in the manufacturing world and served as a staff liaison at IPC, a national representative to IEC TC119, an alternate rep on TC91, and a liaison to ECIA, JPCA, and other standards development organizations.

To Improve the Standards Process, Get Involved

by the I-Connect007 Editorial Team

Jan Pedersen, senior technical advisor at Elmatica, and Ray Prasad, president of Ray Prasad Consultancy Group, spoke with the I-Connect007 team about the current state of PCB standards and where the process might need improvements, including the many difficulties around transparency, slow updates, limitless numbers of variations, and a variety of other topics.

This interview was published in the September issue of *SMT007 Magazine.* Click here to read the full article.

The Long Road to a New Standard

by Barry Matties

Graham Naisbitt, chairman and CEO of Gen3 Systems, has spent decades leading cleanliness testing standards in a number of different standards organizations like IPC, IEC, and ISO around an assortment of testing methods, such as CAF, SIR, and even introducing a new standard this year for his own testing method–process ionic contamination testing (PICT). Naisbitt breaks down his long involvement with standards and where they stand currently.

This interview was published in the September issue of *SMT007 Magazine.* Click here to read the full article.

MilAero007 Highlights

BAE Systems to Enhance F-35 Electronic Warfare Capabilities ▶

BAE Systems has received a Block 4 Modernization contract award from Lockheed Martin to enhance the offensive and defensive electronic warfare (EW) capabilities of the F-35 Lightning II fifth-generation fighter aircraft.

Missile Defense Agency's Long-range Discrimination Radar Reaches Major Milestones ▶

The radar system will serve as a critical sensor within MDA's layered defense strategy to protect the U.S. homeland from ballistic missile attacks.

Artificial Intelligence and Space Exploration ▶

From utilizing machine learning to advancing space exploration, optics technology leads the chart toward our scientific and outer-space frontiers.

Digicom Electronics Introduces Power Converter for On-site Aircraft Maintenance ▶

Digicom Electronics Inc. has launched a new portable, lightweight, 400-Hz power converter.

Innovators from NASA, Lockheed Martin Space, and Lenovo to Keynote SMTA International 2019 ▶

The SMTA will be featuring three inspiring keynote presentations scheduled during SMTA International, September 22–26, 2019 in Rosemont, Illinois, USA.

National Security in a Quantum World ▶

Imperial College London's security institute recently hosted an event on how advances in quantum technology, which applies quantum science in real-world applications, are poised to have a huge impact on national security.

Extending Field of View in Advanced Imaging Systems ▶

The military relies on advanced imaging systems for a number of critical capabilities and applications from intelligence, surveillance, and reconnaissance (ISR) and situational awareness to weapon sights. These powerful systems enable defense users to capture and analyze visual data, providing key insights both on and off the battlefield.

AGI and ANSYS Collaboration Streamlines Hypersonic Weapon Design ▶

To engineer the U.S. military's next-generation missile defense system, Analytical Graphics Inc. (AGI) and ANSYS are incorporating high-fidelity, multiphysics simulations with multi-domain mission-level modeling into early stages of missile defense system development—effectively enabling warfighters to combat high-speed, highly maneuverable hypersonic weapons.

Alta Devices Scaling up Solar Production to Disrupt Economics of Small Satellite Manufacturing ▶

Alta Devices is scaling up solar production to meet the growing demand for low-earth orbiting (LEO) small satellites (SmallSats), which will all rely on the sun for power.

NASA Asks American Companies to Deliver Supplies for Artemis Moon Missions ▶

In another major step toward landing American astronauts on the lunar surface by 2024, NASA is asking industry to respond to a Request for Proposals to deliver cargo, science experiments, and supplies to the Gateway.

Standards: Why We Have Them and Live by Them

Feature by Alifiya Arastu, Jeff Beauchamp, Harry Kennedy, and Ruben Contreras
NCAB GROUP

Have you ever designed a board but received feedback that it couldn't be manufactured unless changes were made? Or maybe you've designed a complex board and sent it to the factory only to find out that the manufacturer didn't build the board to your expectations? PCBs are becoming more complex, factory options are growing, and expectations for product life cycles are becoming longer.

Why Do We Need Standards?

As a designer, you now have to think about more than just the software used for design. To ensure that you have a robust design, you must understand how to design for manufacturability (DFM), design for the environment (DFE), design for reliability (DFR), design for test (DFT), etc. Considering all of this means that designers also have to be aware of the expectations and, in some cases, the correct terminology necessary to make this happen.

The Institute of Printed Circuits (IPC) was founded in 1957 to develop standards for the fledgling PCB industry. Many years later (somewhere in the '90s) the name was changed to IPC–Association Connecting Electronics Industries to better reflect the expanded membership of the assembly folks and the need for standards for that end. Through the use of IPC standards, board designers can design robust PCBs that achieve the necessary requirements and minimize their time to market and have confidence in a reliable board when the end product is used in the field.

But is the use of standards really that important? Absolutely. Consider the impact of producing PCBs without defined standards (Figure 1). For example:

- We would not always receive a product that meets our expectations
- We would experience the risk of various interpretations of the same aspect

Figure 1: Without proper specification of a standard, there may be various interpretations.

- We would not be able to secure the correct quality level
- We would not be able to compare "like-for-like" products or factories
- A guaranteed time to market would be based on chance rather than good factory selection and good design

Now that we can all agree that we need standards, are IPC standards effective? Yes! Through the implementation of IPC standards, the designer, manufacturer, and end customer see some of the benefits in Figure 2.

One of the most important things to notice is that using IPC standards as the minimum benchmark helps save the designer and manufacturer time before the product is built, during the manufacturing process, and after the final product is assembled, which results in saving money. There are multiple documents within IPC standards, and when used together, these documents should lead both manufacturer and customer to consistent terms of quality and acceptability. These documents also allow the customer and manufacturer to work together to set the criteria for acceptance of products that use newer technologies.

If you're reading this and wondering how to start understanding standards and acceptability, there are many resources to help you. IPC's website can help you learn more about the organization and how to become a member. Also, engineers at NCAB Group can help you to learn which IPC standards you should consider depending on your end application.

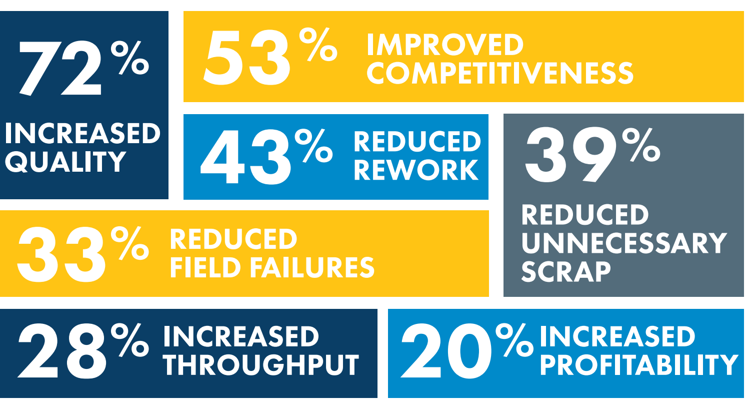


Figure 2: Benefits of users who implement IPC standards. (Source: TechValidate survey of IPC users, January 2018)

We have certified IPC Trainers to teach your engineers about the acceptability of printed boards, and you can work with NCAB to produce your next PCB. Based on the 120+ million PCBs we ship annually, we've identified multiple steps in our PCB production process where we go beyond IPC specifications (we will discuss some of those specifics later).

Risk/Awareness

When we look at what can happen from failing to require, reference, or follow specifications, there are a few considerations. The material produced can suffer from poor reliability. The cost to produce the PCB can be higher than needed, or subsequent builds of the same design can be inconsistent. It is critical to reference relevant industry specifications such as those released by IPC. Designs must contain a complete and concise specification that does not allow for interpretation as well as an adequate baseline to make sure that both the customer and supplier are on the same page.

A common example we see is a requirement for copper weights not referencing IPC minimums as detailed in the IPC-6012 and IPC-600 specifications. For instance, a fabrication drawing for a six-layer design has copper requirements of 2 oz. for all layers. No additional information for copper thicknesses is detailed or external specification referenced. This fabrication data goes to the manufacturer to be built, and some of the delivered PCBs show failures post-assembly. During root-cause analysis of the failures, it is noticed there is variance in the copper thicknesses delivered. This could potentially be caused by failure to reference the IPC copper thickness chart for internal and external conductor thickness in the fabrication data, allowing your manufacturer to interpret the requirement. Theoretically, this could result in external copper thickness ranging from 47.9 µm to 78.7 µm, depending on what the fabrication house considers as 2 oz. finished copper.

As a minimum, general specifications—like the ones issued by IPC—should be referenced in fabrication data to prevent a consistent baseline for building. We also recommend creating a robust general specification to bolster these baseline requirements. In addition to this, knowing your PCB manufacturer's standards are the only way to guarantee your PCBs will be built correctly and consistently every time.

When moving parts to a new manufacturer, a solid specification will help to ensure the PCBs received are consistent with what you have already been getting. Our many years of experience in the industry have taught us that unit cost is not the only concern; longevity and the reliability of the final product must also be a top consideration.

Enhanced Standards

While IPC standards are a solid foundation, our specifications dictate requirements that, in some instances, are above and beyond what IPC requires. However, we manage to do this in a way that adds extra layers of protection to the product. We consider this to be the lowest total cost.

One of our own standards that we emphasize is that all holes will be plated per IPC-6012 Class 3 requirements. This applies to all boards, even if they are not a medical product. This puts a strong foundation on the circuit board. When the circuit board goes through the thermal cycles, the board will want to expand in the Z-axis; a poorly plated hole will most likely be the weak link that will cause the board to fail. Figure 3 shows a good copper deposit through the hole, ensuring the minimum requirement of nominal 25 µm is consistent through the hole.

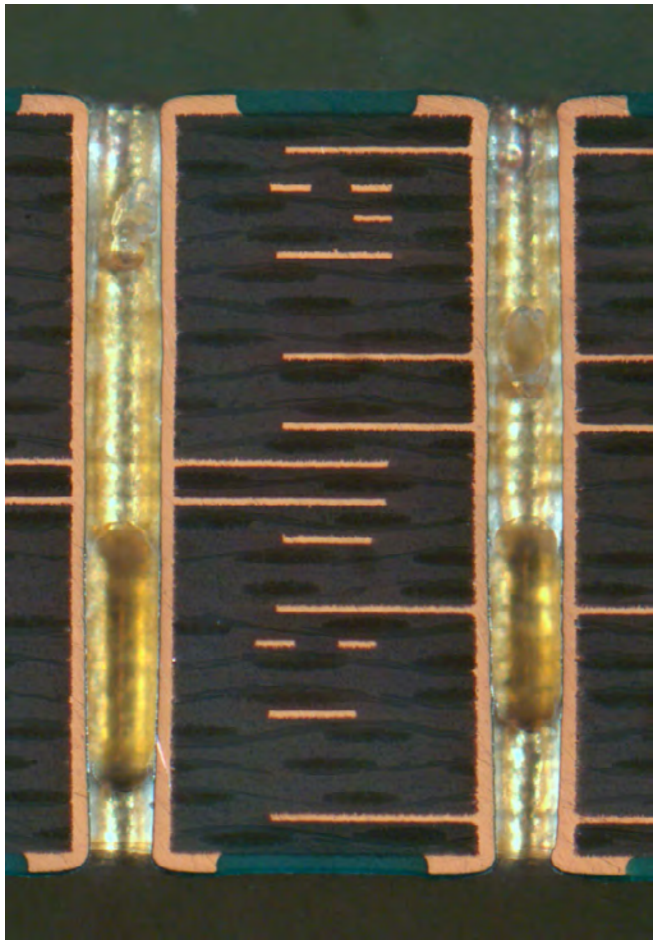


Figure 3: Good copper deposit through the hole.

Figures 4a and 4b show very thin copper through the hole, which is possibly reduced by micro-etching before the surface finish but lower than IPC. Figure 4b shows where thin copper has facilitated barrel cracking; this has caused an open circuit within the via hole.

Another standard we stress is no track welding or open circuit repair. We have found that a repaired circuit almost always has an impact on the finished product, whether on the impedance required or, in some cases, on the overall reliability of the repaired trace. If

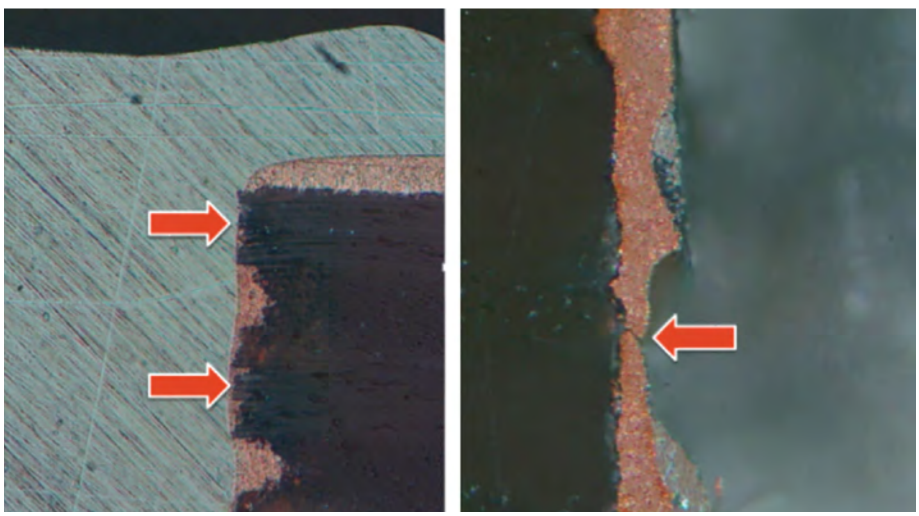


Figure 4: (a) Very thin copper through the hole; (b) thin copper has facilitated barrel cracking, which has caused an open circuit within the via hole.

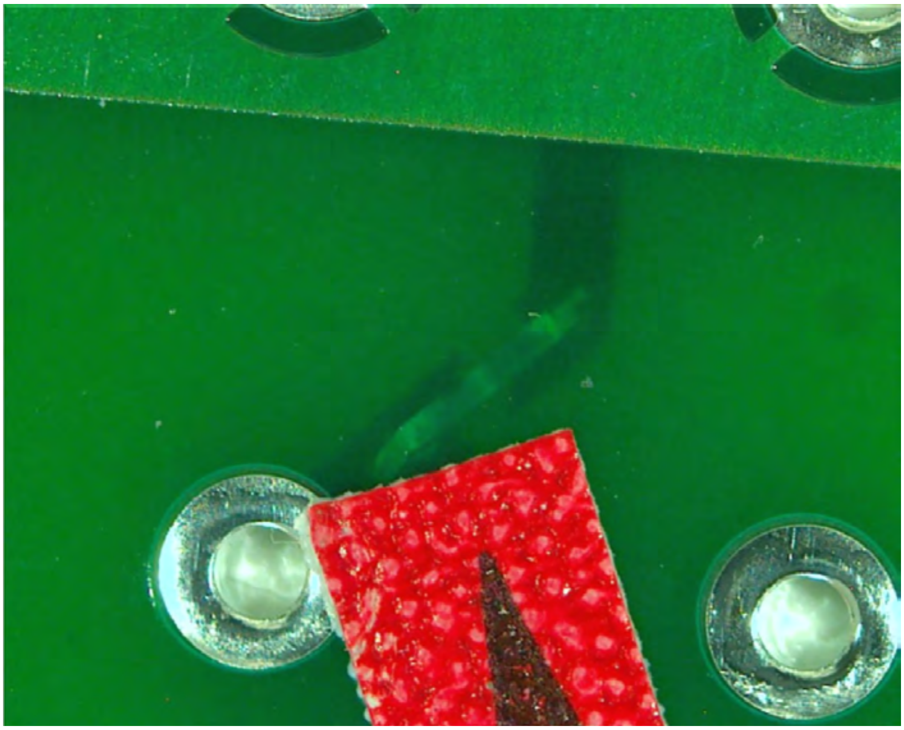


Figure 5: An inner layer repair under magnification from the surface.

the repair happens to be on an internal layer, it is not visible but will still affect the finished product. Figure 5 shows what an inner layer repair looks like under magnification from the surface; it's hard to find with the naked eye.

When viewed with the aid of a backlight, it can be seen that there has been an open circuit on the inner layer track and this has been track welded/repaired. Even if the repair is reliable, the track is reduced by more than the acceptable IPC allowance. The track weld provides a track that is 65% thinner than it should be. In Figure 6, the red lines show how thick the track should be.

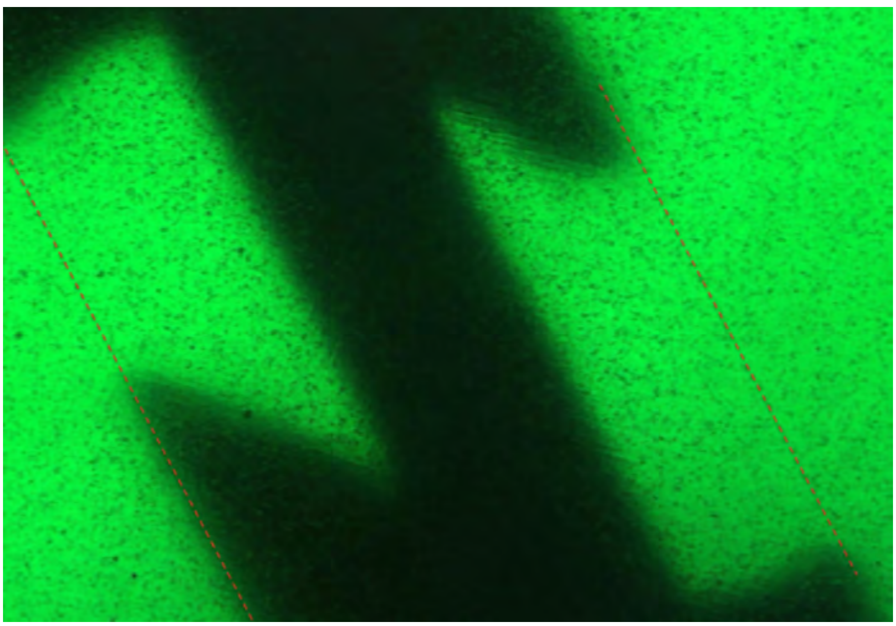


Figure 6: The red lines show how thick the track should be.

We also have our own requirements, such as a specific minimum solder mask thickness and a cleanliness requirement that is above what IPC requires. We have defined tolerances for profiles, holes, and other mechanical features—all of which will contribute to the reliability and the longevity of the finished product. This becomes that much more important when you realize that the finished product may have a life depending on it.

Verification of Standards

Designing and manufacturing a PCB at the lowest total cost does not necessarily mean price. A product built to specifications by a PCB producer with knowledge and experience—including an established and proven set of standards—will ultimately produce a product that will withstand its intended lifecycle. The best way to reinforce the different standards put on PCBs is by testing the performance and quality of the end product. This can be done using cross-sectional testing as well as more in-depth testing of chemical properties seen on the board after manufacturing.

NCAB gathers performance data on all their productions to further analyze the key performance indicators of main processes within the facilities.

With this data, changes can be made to ensure the reliability of all products in further cycles. It's also the reason that all of NCAB's products are 100% electrically tested at least once in the manufacturing process. This guarantees that if any boards had defects, there are multiple checkpoints to confirm they can be found.

NCAB also has a secondary inspection team in the factories to make sure that the product is in line with procurement data. The extra constraints put in place by NCAB are part of the general standards that all boards must pass through before they reach the customer. All of these strict requirements on standards help to achieve an internal quality performance goal of 99.3%. The quality of the finished board is one of the best ways to verify the standards placed in each step throughout the process.

Conclusion

Reliability and quality are essential to be competitive in the market and vital to your company's reputation and success. Standards produce electronic assemblies that meet strict quality tests, which will eventually reduce delays and any rework or scrap. Furthermore, by applying a set of standards, it can maximize the yield of products, ensure better functionality and compliance with regulations. NCAB has developed its own set of standards, which ensure that the end products will be at their optimal performance by keeping quality in mind every step of the way. **PCB007**

Alifiya Arastu, Jeff Beauchamp, Harry Kennedy, and **Ruben Contreras** are field application engineers at NCAB Group.


Arastu


Beauchamp


Kennedy

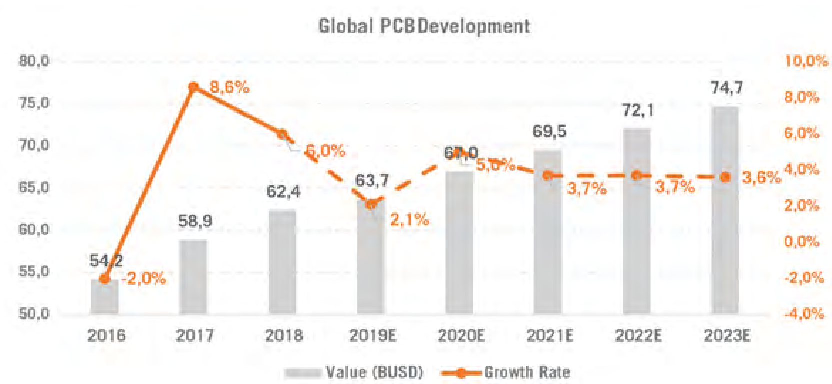

Contreras

NCAB 2019 Market Report: Competition Is Heating Up

Nolan Johnson talks with Chris Nuttall, chief operations officer and VP of technology, about NCAB Group's most recently released market report. Johnson and Nuttall discuss some of the market drivers and conditions the industry can expect to close out in 2019 as well as what to prepare for in 2020.

According to Nuttall, as the industry finished 2018, it saw the landscape change—most notably, the trend was one of a reduction in spending on consumer electronics, which has been widely publicized. "We moved into 2019 with more of cloud, servers, and networking products picking up some of the slack that the reduction in consumer electronic spend had caused," said Nuttall.

Nuttall continued, "Then, everything changed when the tariffs arrived. We've seen a level of uncertainty creep in and start to influence the changing global economies and global trade to a degree where even equipment sales are slowing. We've seen the industry forecasting smaller increases, and the numbers are suggesting that with changes on the horizon—such as tariffs in the U.S. and China or changes within the European Union—it might get bumpier as we move through this year."



Nuttall also noted that even though the industry expects this year to be tougher, there was a little more optimism moving into next year, but a lot of that optimism depends on two elements: the health of the changing global economies and the development of some of the more high-tech electronic industries. (Source: I-Connect007)

To read the full interview, click here.

Electronics Industry News and Market Highlights

India PC Market Registers Strong Growth in 2Q19

The India traditional PC market (inclusive of desktop, notebook, workstation) shipped 3.4 million units, recording a solid 49.2% year-on-year (YOY) growth, according to IDC's Asia/Pacific Quarterly Personal Computing Device Tracker, 2Q19.

M&A in Defense and Security Market Reaches Record High of $130 Billion in 2Q19

Mergers and acquisitions (M&A) activity in the defense and security domains was valued at $130 billion during the three months to June 30, 2019, according to Jane's by IHS Markit.

Active Electronic Components Market to Witness Growth at 10% CAGR by 2022

The global active electronic components market is projected to touch $330 billion by 2023. These components are the heart as well as the soul of electronics and are vital aspects of electronics.

Chinese Smartphone Brands Take 62% of Southeast Asia's 30.7 Million Shipments

The Southeast Asian smartphone market reversed its several quarters of decline by shipping 30.7 million units in the second quarter of 2019, up by 2% year on year.

Installed Base of Aftermarket Car Telematics Devices to Reach 150M in 2023

According to a new research report from Berg Insight, the number of active aftermarket car telematics units will grow at a compound annual growth rate (CAGR) of 20.6% from 58.7 million at the end of 2018 to 150 million at the end of 2023.

2Q19 Revenues of NAND Flash Brands Trending Flat From 1Q19

According to DRAMeXchange, end demand in the smartphone, notebook PC, and server markets have recovered from the traditional offseason 1Q19, bringing total NAND flash bit consumption growth to 15%.

Spending on Customer Experience Technologies Will Reach $641B in 2022

Worldwide spending on customer experience (CX) technologies will total $508 billion in 2019, an increase of 7.9% over 2018, according to the inaugural Worldwide Semiannual Customer Experience Spending Guide from International Data Corporation (IDC).

IHS Markit U.S. Manufacturing PMI Posted 50.4 in July

The seasonally adjusted IHS Markit final U.S. Manufacturing Purchasing Managers' Index (PMI) posted 50.4 in July, broadly in line with 50.6 in June. The latest reading signaled a fractional improvement in the health of the manufacturing sector but also indicated the slowest overall expansion since the height of the financial crisis in September 2009.

Global Commercial Drones Market to Reach 36% CAGR by 2018-2022

Technavio analysts forecast the global commercial drones market to grow at a CAGR of more than 36% from 2018 to 2022.

Conductive Polymers Market to Cross $6 Billion by 2025

The conductive polymers market share is set to rise from $3.5 billion in 2018 to around $6 billion by 2025, according to Global Market Insights Inc.

Maintaining a Strong Economy Through Workforce Development

One World, One Industry

by Dr. John Mitchell, IPC—ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

Currently, the American worker has been the primary beneficiary of unprecedented economic growth in a strong U.S. economy. According to June's job numbers, the unemployment rate is at 3.7%, and job growth continues in an upward trend. Today, there are more job openings than Americans looking for work.

As members of the electronics industry, we work in a quickly evolving technological field illustrated by continual change and advancement. We must have a workforce that is ready to meet these advancements. We are firmly committed to providing growth and opportunities for American workers as we plan for a future where we don't know what the jobs will be. Filling roles that don't even exist yet is a unique challenge, but it is part of the work we do on a daily basis.

One year ago, the Trump administration asked business leaders to sign the Pledge to America's Workers to ensure more growth and opportunities for America's workers. IPC signed this pledge, committing to creating one-million workforce training opportunities over five years.

Now, we are celebrating the early success of the President's pledge. Recently, acting SBA Administrator Chris Pilkerton traveled to the upper peninsula of Michigan to meet with Calumet Electronics, an IPC member, and one of only 200 remaining PCB manufacturers in North America. Committed to U.S. manufac-

To ensure credentialing programs match industry needs, IPC has implemented a jobs task analysis (JTA), which identifies the core competencies and skillsets needed to perform every role in the industry. Our skills audit reveals that too often, today's manufacturing workers lack essential knowledge and skills, including a foundation in math, basic technology, and problem-solving. By knowing the traits needed for workers' success, we can make changes to our credentialing program, which now serve over 100,000 individuals a year and receives input from leading electronics companies and IPC members, like L3 Technologies, General Electric, Raytheon, and TTM Technologies.

turing, Calumet understands that its workers are its greatest asset. Calumet is growing its workforce, and its training programs to provide long-term career paths for workers and early-career engineers.

While we recognize these laudable achievements, there is plenty more to do for U.S. workers. In today's advanced manufacturing facilities, workers have less interaction with manual tools and greater reliance on computer-managed machinery. More and more, low-skilled jobs will be replaced by automation as companies try to keep pace with overseas competitors on costs and efficiencies. It is critical that employers and organizations help upskill and train workers to work alongside machines.

To solve today's and tomorrow's workforce challenges, we need to accelerate the growth of industry-credentialing programs that are most closely aligned the workplace needs. Within electronics manufacturing, we have seen that industry credentials are as valuable—and in some cases, more valuable than high school or college diplomas—because industry-credentialing programs reflect the needs of employers. Workers who obtain credentials are more likely to secure work and be successful in their new positions.

IPC is also reaching out to the emerging workforce with the IPC Education Foundation, which makes connections between our industry and students in high schools, technical schools, and universities by participating in STEM events, sponsoring curriculum in high school electronics programs, and providing programs that teach students the how-tos of electronics assembly.

By following the model of Calumet Electronics, and by reaching out to the future of our workforce by sponsoring a myriad of educational opportunities for students, we can solidify the strength of the electronics industry for decades to come. **PCB007**

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

Understanding the Fine Print

Testing Todd

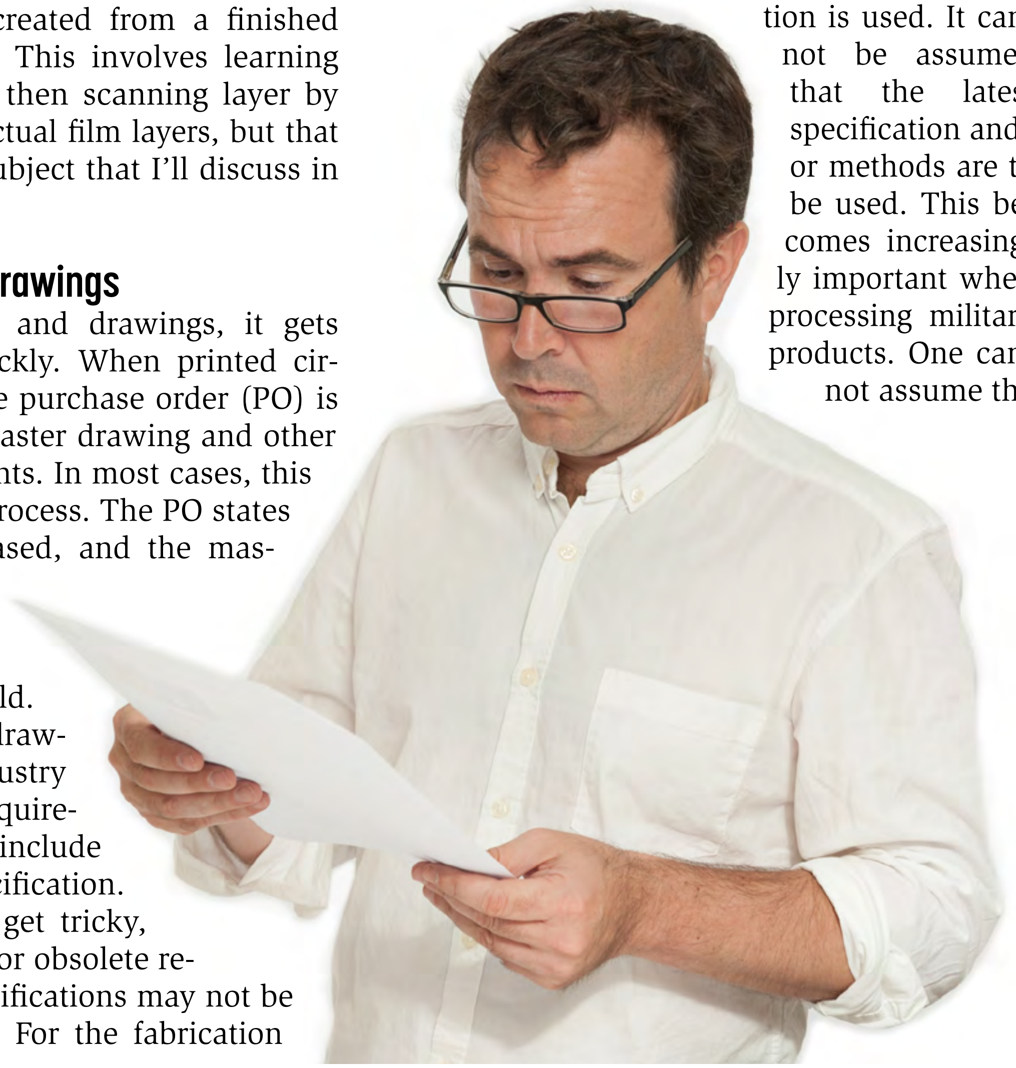
Feature Column by Todd Kolmodin, GARDIEN SERVICES USA

New technologies are emerging each day with more stringent requirements than the past. Also, reversals in obsolescence programs bring products back to the market for which the original documentation and/or requirements are ancient compared to today's standards; in some cases, this documentation is even lost. Further, it is not uncommon to find that original artwork isn't available or that the part must be recreated from a finished circuit board sample. This involves learning a netlist profile and then scanning layer by layer to recreate the actual film layers, but that is a whole different subject that I'll discuss in a future column.

Specifications and Drawings

With specifications and drawings, it gets complicated very quickly. When printed circuits are procured, the purchase order (PO) is sent along with the master drawing and other deliverable requirements. In most cases, this is a straight forward process. The PO states what is being purchased, and the master drawing outlines the specifics and instructions on what is required for the build. Usually, the master drawing will specify industry specifications and requirements, which may include a special OEM specification. This is where it can get tricky, especially for historic or obsolete rebuilds. These old specifications may not be available. Now what? For the fabrication house, this often requires consulting with the OEM and either obtaining the lost document or acquiring a deviation or waiver for the lost document.

Even though the product may be a new build, there's a chance that the master drawing calls out for an older specification. Diligence is required by the fabrication house to make sure that the proper specification is used. It cannot be assumed that the latest specification and/or methods are to be used. This becomes increasingly important when processing military products. One cannot assume the



latest build specification is to be used. Older designs by OEM military contractors may call for older revisions of say MIL-PRF-31032, 55110, and 50884. For electrical test (ET), this can be especially significant.

Advances in test technology have brought new methodologies that were not allowed or even known in the older revisions of specifications. Just because the latest revision of a specification allows the use of these technologies, one cannot assume the new options apply. If an older specification is called, the requirements of that specification shall be used. This can be challenging for a third-party ET contractor.

Advances in test technology have brought new methodologies that were not allowed or even known in the older revisions of specifications.

Many times, the ET contractor may have access to the master drawing only when the order is being processed. Job-specific notes may be added to the ET database for future reference, but special notes may be lost when the job returns to the fabrication house. This is where it is crucial to save the notes or retain a copy of the master drawing. Most ET contractors will have NDAs with their fabrication houses, so this isn't usually a problem. However, this becomes extremely important when the fabrication house or ET contractor is audited and allows absolute traceability and assurance that the product was built and tested as originally designed.

Certificate of Compliance Documents

This brings up another item that comes up quite frequently on the certificate of compliance (C of C) documents for ET. What specification should appear on the C of C for ET is a confusing topic. A master drawing may state, "Build to IPC-6012D." Should the ET C of C state IPC-6012D? The answer is no. If the C of C were to say IPC-6012D, it could be interpreted that the ET C of C is certifying the entire build, which it is not; it is only certifying the product was tested.

Reading the fine print in most build specifications will state that ET shall be in accordance with IPC-9252; that is the specific specification regarding ET of unpopulated printed wiring boards. The exception is when the aerospace and military avionics addendums are called from either 6012C or 6012DS. These require atypical test parameters outside of the standard 9252, and those specifications should appear on the C of C, in this case.

Military

Just because MIL-PRF-31032 is the current specification does not mean that it is automatic. Many military master drawings call out MIL-PRF-55110. MIL-PRF-55110 is alive and well, and if called, shall be used. But there is a vast inventory of military products out there that was designed long before the release of MIL-PRF-31032. Reorders of these products will require adherence to the older specification. Fabrication houses and ET contractors must be aware of this and adjust build and test methodologies to be compliant with the specification.

Another common issue is with MIL-PRF-31032 and the performance "slash sheets." An ET C of C is non-compliant if it just states MIL-PRF-32032. The Defense Logistics Agency (DLA) is very specific on this issue. A build to MIL-PRF-31032 must also state which applicable slash sheet the product was built to and also tested. This will be MIL-PRF-31032/1, /2, /3, /4, /5, or /6 with their appropriate revision and amendment level if applicable. The fine print here is that if the performance class (slash sheet) is not provided in the procurement and/or master drawing, this must be remedied before build and test. Failure to do so can (and will) result in a nonconformance during a DLA audit, so be forewarned.

Conclusion

Overall, you must read the fine print when viewing specifications and drawings. Just because the master drawing states an IPC general build specification does not mean an ET C of C will state that specification. Most IPC specification call for IPC-9252 as the ET specification, and it is correct that the ET C of C state IPC-9252 revision, class, and test level. The only exception is for aerospace and military avionics special requirements. It is also not uncommon to see the IPC-9252 specification on an ET C of C along with an applicable military specification. Many military specifications also call for testing to be in accordance with IPC-9252. However, certified test for military products must state the applicable performance specification used to be recorded for annual reporting and information retention. **PCB007**

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

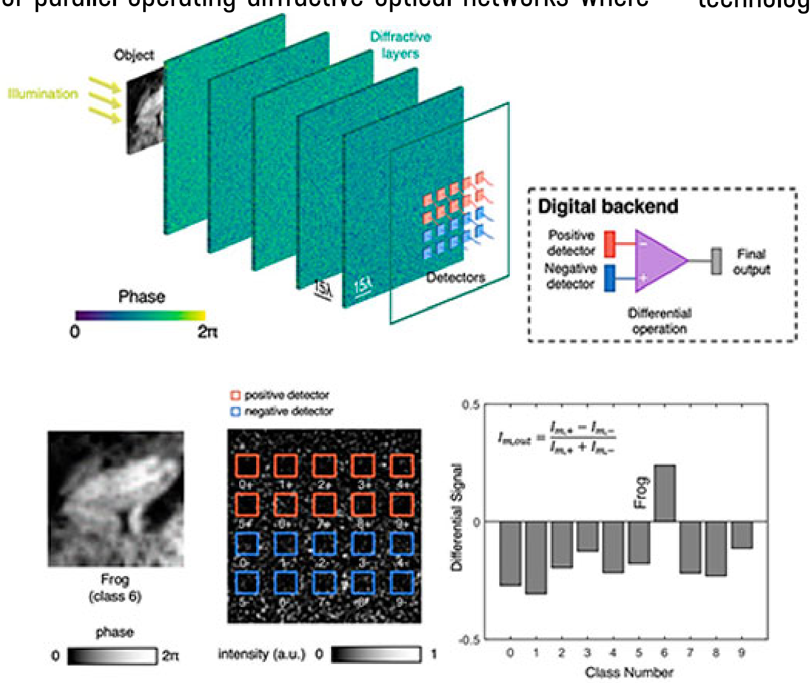
All-optical Diffractive Neural Network Closes Performance Gap With Electronic Neural Networks

A new paper in *Advanced Photonics,* an open-access journal co-published by SPIE, the international society for optics and photonics, and Chinese Laser Press (CLP), demonstrates distinct improvements to the inference and generalization performance of diffractive optical neural networks.

One of the key improvements discussed in the paper, "Class-specific differential detection in diffractive optical neural networks improves inference accuracy," incorporates a differential detection scheme combined with a set of parallel-operating diffractive optical networks where each individual network of this set is specialized to specifically recognize a sub-group of object classes.

According to SPIE Fellow Aydogan Ozcan of the University of California, Los Angeles, and one of the paper's authors, these results "provide a major advancement to bring optical neural network-based low-power and low-latency solutions for various machine-learning applications."

This latest research is a significant advance to Ozcan's optical machine-learning framework. The finessing of this technology is especially significant for recognizing target objects more quickly and with significantly less power than standard computer-based machine learning systems. Ultimately, it may provide major advantages for autonomous vehicles, robotics, and various defense-related applications, among others.



These latest systematic advances in diffractive optical network designs, in particular, have the potential to advance the development of next-generation, task-specific, and intelligent computational camera systems. The article authors are Jingxi Li, Deniz Mengu, Yi Luo, Yair Rivenson, and Aydogan Ozcan of the University of California at Los Angeles Department of Electrical and Computer Engineering and California NanoSystems Institute in Los Angeles, California, USA. (Source: SPIE)

Future of 'Substances and Materials in Products' Data Exchange Formats as Standards

Feature by Jean-Pierre Theret
DASSAULT SYSTÈMES

Abstract

To support regulations on hazardous substances in materials and products—such as the automotive EU end-of-life vehicle (ELV) directive, the Electronics and Electrical Equipment Restriction of Hazardous Substances (RoHS) regulations, and the EU Registration Evaluation Authorization and Restriction of Chemicals (REACH) regulation—industry sectors have defined and deployed various data exchange standards and cloud-based supplier portals to ease data collection in the supply chains and reduce burden in particular for small and medium enterprises (SME).

In particular, the electronics/electrical sector has developed the IPC-1752 standard offering an XML data exchange format to support the EU RoHS. The automotive sector has put in place two major tools: the International Material Data System (IMDS) used by most of the car manufacturers and their suppliers globally, and the China Automotive Material Data System (CAMDS). The International Electrotechnical Committee (IEC) under TC111 responsibility has defined the IEC 62474 standard as a child of several existing standards, including IPC-1752. Aerospace and defense with the heavy equipment industries have developed the new IPC-1754 standard in the IPC-175x series to support their specific requirements in particular to include process chemicals and declaration against any industry substance lists.

Industry sectors now seem ready to work on convergence to a unique material declaration standard covering data exchange for the above regulations for all product sectors. The "European Proactive Alliance" was launched in March/May 2018; it is an initiative to establish such a unique data exchange standard for reporting "Substances in Articles." The IEC 62474, IPC-1752A and IPC-1754 standards (or a harmonized IPC-175x series) are the candidates for this journey.

This article presents the set of requirements that the standard(s) would have to support in the coming years to become the global one for a large set of sectors, including automotive, chemicals, furniture, childcare products, electrical

and electronic, mechanical, metalworking and metal articles, home textiles, textiles and sporting goods as well as medical devices. Several options are presented and would have to be discussed with all the stakeholders in the coming months and years.

There are multiple purposes for this article: 1) socializing and promoting use of data exchange standards in all sectors at any level of the supply chain for a more accurate reporting of hazardous substances and materials in products for a better world, 2) identifying existing issues and coming challenges and proposing possible solutions to fix them for more effective reporting, and 3) proposing a long term perspective and plan to align all the stakeholders, including the legal authorities for providing to business an efficient reporting system.

Such a plan includes a new governance model that is more global and less North American-centric; a process-based approach to specify all support activities for related pieces of the standards, such as XML schemas and guidance documents; a harmonization of the IPC-175x standards series; and an enhanced development process inspired by ISO and IEC best practices. Another condition of success would also be to continue convergence between the IPC-175x and the IEC 62474 standard selected by many global companies and Japan. This is a new challenge that the IPC organization and the IPC-175x committees will have to meet in the medium term.

This article has been written to address a large industry audience per its purposes. First, it is an educational article that provides any business representative with a simplified, state-of-the-art description of the data exchange formats for standards covering substances and materials reporting in products and processes. It also includes a review of existing issues and new challenges shared with end users of the standards and companies represented by their trade associations with some solution proposals they could discuss. Finally, it proposes to prioritize the required changes to the standards with a long-term perspective for all stakeholders (standards development organizations and their committees, legal authorities in charge of regulatory lists and their data) to review, discuss, share, and include them or not in their strategic business plans.

Introduction: Product Environmental Regulations

For some years, environmental and social concerns are more intensively present in the media due to emotional impacts on people and more and more scandals with hazardous and very high concern chemical substances in our day-to-day products. Here is some negative news:

- Too many hazardous substances in consumer goods and industrial articles that cause diseases, such as biphenyl A in plastic containers, including baby bottles
- More and more material resources consumed for goods due to our consumption way of life; some critical material resources become rare in the Earth and have started to generate hard competition between some countries for high technology products, including renewable energy equipment and mobile phones with their lithium batteries
- More and more emissions of toxic substances in the air, ground, and water with a huge impact on humans, animals, and nature
- Too much produced waste due to this way of life and not enough recycled materials used by industries, single-use plastic products that pollute fields and oceans with significant effects on nature

Citizens are increasingly sensitive to these topics and their impacts on human health, particularly for their children; then media shows on the first page of their papers or webpages when new information comes along on proof of evidence about hazardous substances. Non-governmental organizations (NGO) are also strongly involved in this topic with lobbying for the substances from the SIN (substitute it now!) list recognized as Substances of Very High Concern (SVHC) restricted in Europe (Figure 1).

Figure 1: Substances of very high concern (SVHC).

The good news is that solutions exist and need to be promoted and adopted with low costs to all sectors, domains, and countries.

Since the 1970s in the Americas, and since the 1990s in Europe, the authorities have started to regulate these topics more and more; the actual regulations started in the 2000s:

- In the automotive sector, the end-of-life vehicle (ELV-2000/53) directive is restricting heavy metals at end of life and promoting reuse, recycling, and recovery (RRR–2005/64/EC) for products with minimum rates as designed (reuse and recycling rate: 80% minimum on 2006 for starting then 85% since 2016)
- In the electrotechnical sectors, the EU has restricted the use of certain hazardous substances in electrical and electronic equipment (RoHS, 2002/95/EC), as well as similar RoHS regulations in China, Korea, California; and the Waste Electrical and Electronic Equipment (WEEE–2002/96/EC) with EU RoHS regularly amended, in particular:
  - (EC) 2011/65: RoHS2 or RoHS recast to include CE marking and risk management for collecting proof of evidence
  - (EC) 2015/863: Amendment of EU RoHS directive to prohibit four phthalates used in plastics
- The United Nations (UN) Globally Harmonized System of Classification and Labelling of Chemicals (GHS, 2003) and the classification, labeling, and packaging of substances and mixtures EC Directive (CLP–1272/2008)
- Batteries and Accumulators and Waste Batteries directive (EC 2006/66) that prohibits heavy metals over specified thresholds
- EU REACH (Registration, Evaluation, Authorization, and Restriction of Chemicals) (EC 2006/1907) that aims, in particular, to identify SVHC to restrict some substances with possible authorizations for 4–12 years and to prohibit the most hazardous substances from the European market
- Cosmetics directive (EC 2009/1223), defining prohibited substances (annex II) and restricted substances (annex III); also, colorants allowed (annex IV) and preservatives allowed (annex V)
- Packaging (94/62/EC directive amended by 2005/20/EC directive) that prohibits heavy metals over specified thresholds of 0.01%

The U.S. has also adopted similar regulations:

- Toxic Substances Control Act (TSCA) Chemical Substance Inventory (FDA–Federal Drug Administration), Proposition 65 (California) on reporting of hazardous substances
- U.S. Dodd-Frank Act, including reporting of four conflict minerals—3TG (tin, tungsten, tantalum, gold)—from conflict areas in the Democratic Republic of Congo and surrounding countries

Those environmental regulations may be classified into four categories:

1. Hazardous materials and substances (EU ELV, various RoHS, EU REACH, POP, TSCA, Prop65)

2. Material efficiency and circular economy (ELV/RRR, WEEE, Waste Framework Directive)
3. Substances emissions: Green House Gases (GHG), including CO_2 emissions (global warming) and other substance emissions
4. Ethical sourcing (U.S. conflict minerals; similar EU regulation coming in 2021)

Brief History of the Data Exchange Formats

Trade associations have anticipated or worked during these regulations, putting in place standard data exchange formats and sectorial tools that could be used by their supply chains to reduce the burden to fulfill their regulatory duties (Figure 2).

Multiple historical material declaration standardization activities have occurred in the electronic products sector:

- In 1998, a consortium of computer and consumer electronics companies created a supply chain information standard that included some material data
- In 2005, the Joint Industry Guide (JIG) 101 was issued followed by the Japan Green Procurement Survey Standardization Initiative (JGPSSI) data exchange standard/tool in January 2006
- The IPC-1752 material declaration data exchange standard was issued in 2007 and was designed to work with the JIG-101 standard
- IEC began work in 2006 to create a material declaration standard applicable to the entire electrotechnical product sector to describe both what data is required to be included and how to exchange the data; the IEC standard also had a purpose to obtain data as an input for environmentally conscious design and not only for restricted materials, and IEC 62474 edition 1.0 (ed1) was issued in 2012 and edition 2.0 (ed2) is expected to be issued in late 2018 or early 2019
- JIG-101 was updated in 2009 (edition 2.0), 2010 (Ed 3.0), and again in 2014 (edition 4.0); JGPSSI was updated twice in 2006
- IPC-1752 was amended to version 1.1, then revised to A in 2010, amended in 2012 and 2014, and the latest step for convergence with IEC 62474 in May 2014

The IEC created WG1 to create IEC 62474 in 2006 with the intent to have a standardized approach for the full electronics industry. WG1 considered IPC-1752, JIG (joint industry guide) [1], JGPSSI [2], IMDS ,and RosettaNet [3] as starting points. WG1 considered what it be-

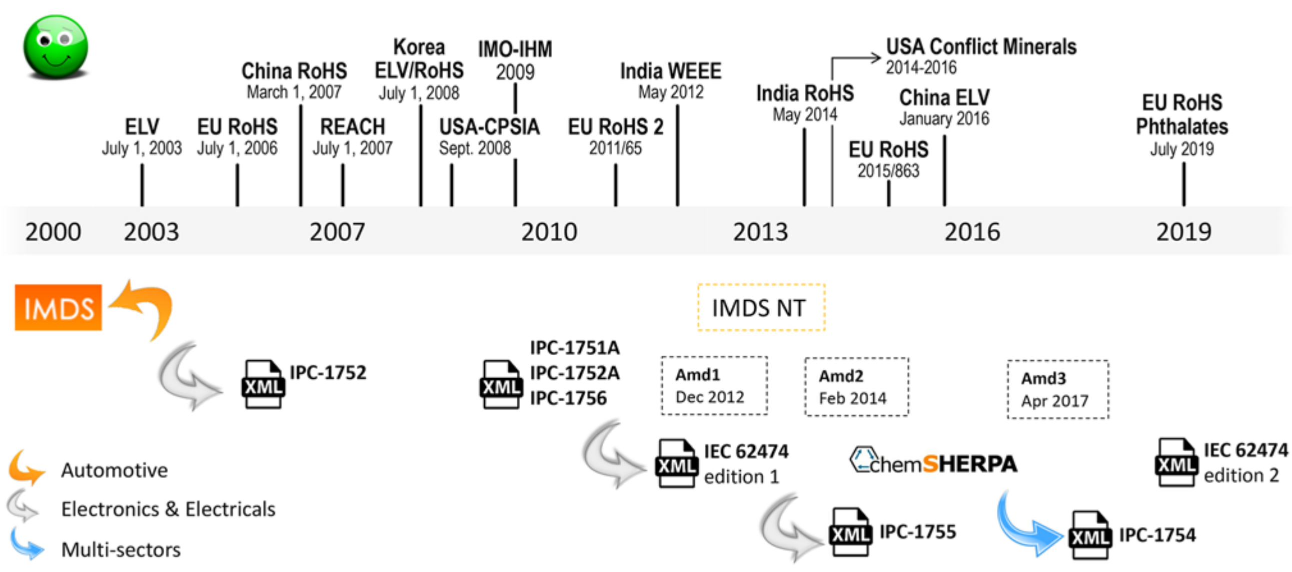


Figure 2: Data exchange standard formats and tools (except commercial tools).

Panasonic

Under development

Halogen-free Ultra-low transmission loss Multi-layer circuit board materials

Halogen-free MEGTRON6

NEW

Laminate	R-5375(N)*	R-5375(E)
Prepreg	R-5370(N)*	R-5370(E)

*Low Dk glass cloth type

Features

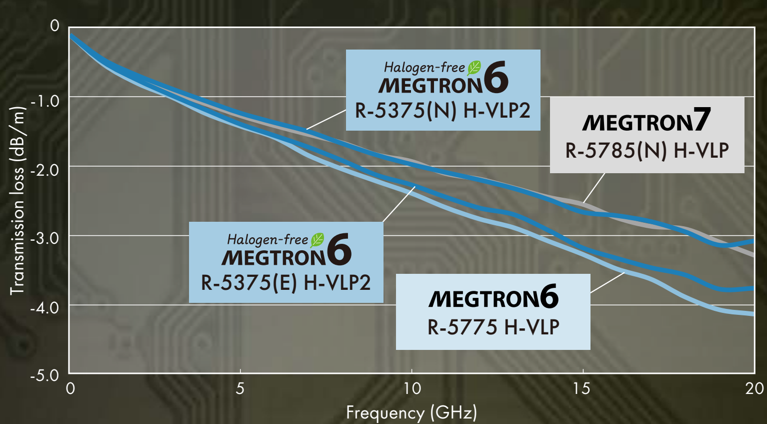
- Excellent HDI and thermal performance **with Halogen free**
- High speed and ultra-low loss material
- Low transmission loss

@10GHz	Dk	Df
R-5375(N)	3.3	0.003
R-5375(E)	3.8	0.005
R-5775	3.8	0.005

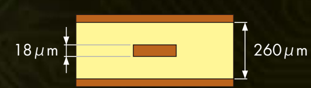
Applications

- ICT infrastructure equipment, High speed networking(High-end server/ router, Optical network, switch), High layer count PCB, etc.

Transmission Loss



- Construction



Line length	200mm , 100mm
Line width	125μm
Impedance	50Ω
Inner Cu treatment	No-surface treatment
Core	0.13mm
Prepreg	#2116 56% x 1ply

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lieved were the best parts of each standard, including IPC-1752, as it developed a standardized model for the electronics industry. As a data exchange model, IPC-1752 did not meet the IEC need for a complete solution, both what to report and how to exchange this data through the supply chain. When IEC formed WG1 in 2006 to create the IEC 62474 standard, IPC 1752 only covered how to exchange data through the supply chain; it referred to the JIG list for what to report (JIG-101 list specified what substances and substance groups to report with reporting thresholds, but it did not specify how substances and substance groups get declared through the supply chain).

Also, IPC as a trade association does not represent the complete electronics product sector and is not part of the World Trade Organization (WTO) as is ISO and IEC. Similarly, JIG did not provide a complete solution, as it included what to report: the JIG-101 substances list. JGPSSI from Japan was another material declaration exchange standard and tool. Neither JIG nor JGPSSI allowed for being able to report information for the purpose of environmentally conscious design. The substances and substance groups that JIG and JGPSSI specified to be declared were based on substance restrictions.

Again, IEC 62474 was designed to be able to provide declarations more broadly as an input to environmentally conscious design (ECD). ECD considers more than whether a substance is restricted or prohibited from use. ECD also looks at resource use as part of the data needed to be considered during a life cycle assessment. So, the IEC 62474 solution created material classes, which can be reported and used as a data input for life cycle assessments. Material classes are a grouping of materials (and substances) that may provide information on resources, independent of hazards, independent of reviewing for regulatory compliance. Material class reporting makes no mention or determination of materials or substances as good or bad.

WG1 included many stakeholders, including co-conveners from IPC-1752, JGPSSI, and JIG. The IEC model is a flexible approach that allows relatively rapid updates of the content to be reported (declarable substances and substance groups, material classes) and the data exchange method (the XML schema) through the creation and maintenance of the IEC 62474 database. IEC validation team (VT) 62474 maintains and updates this database based on the requirements of IEC 62474. This means that changes to what to report and how to report based on IEC 62474 do not require a change to the standard and can be done generally within three months. The IEC VT 62474 has successfully made at least two updates per year since 2012. IEC 62474 is currently on version 16 for substance lists and version 7 for data exchange and has started the update process for versions 17 and 8, respectively. The rules for IEC 62474 declaration have a fundamental principle to ensure that there is always enough information to calculate compliance—this is a bit stricter than either IPC-1752A or IPC-1754.

The original intent was that these other standards would sunset after IEC 62474 edition 1.0 was issued. IEC 62474 should become the foundation of IPC-1752; IPC-175x would overlay additional features that industry needed but were not included in IEC 62474, such as manufacturing information, exemptions, pre-defined query statements, etc. IPC and several industry associations (e.g., iNEMI) were also pushing for harmonization with the international standard. This happened with both JGPSSI and JIG. IPC chose not to do this. The 2-18B committee decided to maintain full control of their IPC-1752 standard, especially with regard to the simplified Class C declaration; it had the flexibility to reveal only a limited amount of information that the supplier wanted to reveal. Meanwhile, IEC 62474 has a declaration hierarchy with "base requirements" for declarable substances list (DSL) substances (very similar to the IPC-1754 class F) and "additional requirements" for other substances (similar to IPC-1754 class G). Figure 3 illustrates the IEC 62474 journey.

In June 2000, a consortium of automotive companies introduced the International Material Data System (IMDS) for material declarations of suppliers into the automotive industry,

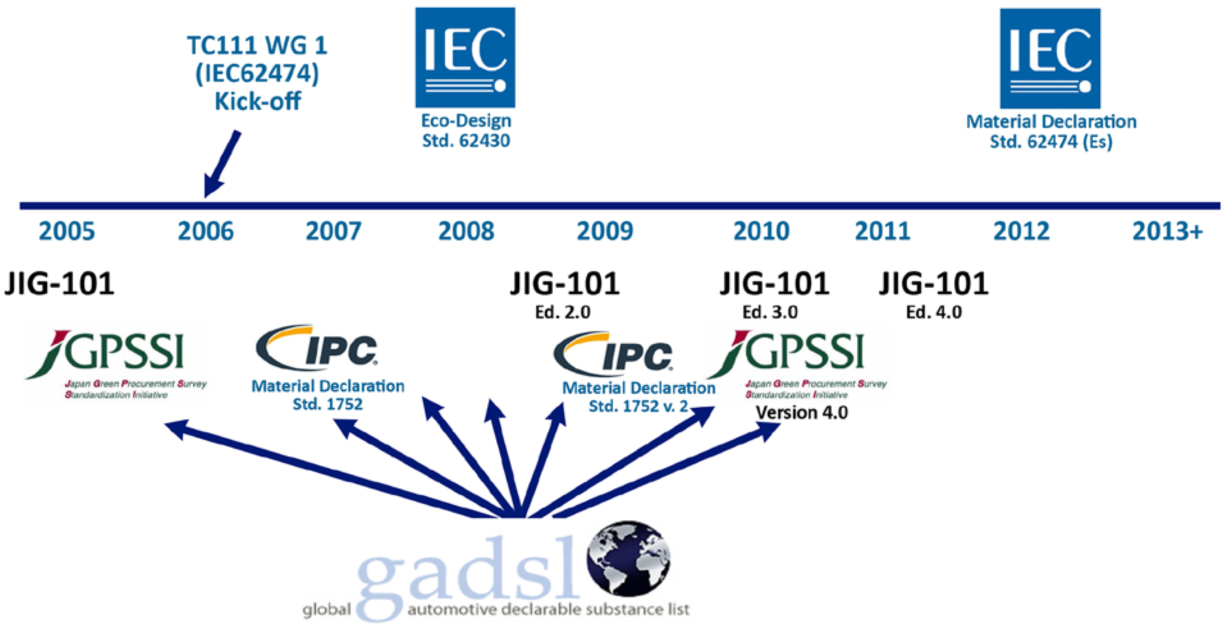

Figure 3: The IEC 62474 journey. (Source: IEC TC111 WG1)

using its GADSL tool. IMDS was rebuilt with new technology (NT). Currently, IMDS includes a "process chemicals" substances list, but a new list will be issued by the Global List of Automotive Process Substances (GLAPS). China has put in place its own system for the automotive sector: the China Automotive Material Data System (CAMDS).

In 2012, the aerospace and defense (AD) sector started their work on defining their requirements for their specific needs to address the EU REACH regulations (EU RoHS was out of their scope, except for ground equipment and systems). They include reporting the process chemicals to address their long-life products and the associated obsolescence technology risk if one critical substance for their surface treatments came under REACH authorization. On 2015, they decided to implement the new IPC-1754 standard in the IPC-175x series to benefit the IPC-1751 foundation. The heavy equipment (HE) sector joined this initiative in 2016 and added EU RoHS support requirements.

Covering for Substances and Materials Data Exchange Formats

On one side, the trend is surely more and more regulations on hazardous substances and materials in products due to the current situation. On the other side, the EU REACH update of the candidate list every six months has changed the approach for companies to support such regulation moving from homemade tools supporting the stable ELV and RoHS regulations to more out-of-the-box tools with more interfaces to collect the suppliers' data either directly or with services from data providers and their databases for commercial off-the-shelf (COTS) components.

Some sectors have established their sectorial unique substances list to simplify globally the reporting against all applicable regulations for their sector. Such substances lists include all regulated substances but also the substances that could become regulated in the short or medium term to avoid unnecessary update of their supplier declarations that costs money and time. Figure 4 shows the most used sectorial lists.

Recent European Directives have been updated:

- European RoHS update (EC 2015/863) with four phthalates (used in particular in plastics) added into annex II

- Automotive
    - **GADSL:** Global Automotive Declarable Substance List
    - **GLAPS:** Global List of Automotive Process Substances
- Hi-Tech & Medical Devices
    - **IEC 62474:** Declarable Substances and Declarable Substance Groups List (has replaced former JIG lists) by IEC TC111
    - **COCIR:** Merge regulatory and industry lists
- Childcare Products
    - **ENPC:** Merge regulatory lists
- Railway
    - **RISL:** Railway Industry Substances Lis, by UNIFE
- Cosmetics
    - **COSING :** Annex II and III
- Shipbuilding & Offshore
    - **IHM :** Inventory of Hazardous Substances for end of life of ships over 500 G, by IMO, Hong Kong 2009 convention
- Aerospace & Defense
    - **AD-DSL:** Aerospace and Defense Declarable Substance List

Figure 4: Sectorial substances lists.

- European Waste directive (EC 2018/851) defines new REACH "right to information" for recyclers and to the public on demand with all SVHC in products; manufacturers shall declare them to the ECHA authority and EU member states shall ensure the articles suppliers provide relevant information to ECHA

New directives are coming on circular economy, material efficiency, and critical materials resources.

The proposed coverage for the materials and substances declaration for products includes a data exchange format for the declaration supporting the regulations and sectorial requirements based on inventories of substances and materials in products and their properties, whether they are articles under REACH or not, substance or mixture (like formulated products), or raw materials. It also includes rules and data exchange formats for any data lists used in the context of such declarations: regulated/declarable substance lists (RSL/DSL), substance classes and materials classes, applications, exemptions and authorizations, product types, and use descriptors (as defined by ECHA).

Some of the above regulations are clearly in that scope: various RoHS, EU ELV, EU REACH, US TSCA, California Proposition 65, and all sector-specific prohibited and/or declarable substances lists.

Other than the previous regulations on recycling and recovery performance of products in automotive (ELV/RRR) or in electrotechnical (WEEE), batteries and packaging could also benefit from such data exchange formats that may include data on materials weight and classification in products. Those regulations could be partially covered by standards, such as IPC-1752A class B or IEC 62474 material classes.

U.S. and EU regulations on conflict minerals rely on conflict minerals declarations (CMD) from the supplier companies regarding their smelter suppliers; they are supported by the specific IPC-1755 and conflict mineral reporting tool (CMRT) standards based on a spreadsheet. They could also benefit from the material declaration standards, such as IPC-1752, IPC-1754, and IEC 62474:

- Product statements may include a query on presence of conflict minerals (for instance, the "3TG": tungsten, tin, tantalum, and gold); the aerospace and defense query list, version 1.0 (see iaeg.com) contains this query: "Product contains conflict mineral(s) that could be stated 'true,' 'false,' or 'unknown' under the IPC-1754 standard"
- Substance declarations could be established against a conflict minerals declarable substance list (DSL); if any substance is declared, that could trigger another reporting process regarding CMDs

The proposal coverage includes the raw materials and mixtures because the safety data sheets (SDS) that describe them are, most of the time, provided on paper or in a PDF [4]; this practice is not an efficient way to collect and to process the SDSs. Some XML standards already exist for supporting safety data sheets for raw materials and mixtures, such as SDScomXML [5]. This standard fully covers the 16 sections of the SDS and requires a large amount of work and time while for the scope of the above regulations; only sections 1, 2, and 3 of SDS are of primary interest and could be supported with the IPC-1754 and IEC 62474 standards.

Sectorial Data Exchange Standards

Standards are either data exchange formats (such as IPC-1752, IPC-1754, or IEC 62474 XML format), sectorial tools developed by global or regional trade associations (IMDS, CAMDS), or by authorities (chemSHERPA [6] by Japan METI). Table 1 includes a list of those standards.

Our interest is only about data exchange formats, but trade associations are responsible to promote their tools to use the existing standard data exchange formats for their human-to-system, or system-to-system communication. This is the case today for some commercial software and chemSHERPA using the IPC-1752 and IEC 62474 standards.

Materials and Substances Product Declarations

The EU REACH regulation refers to "article" as a designation for products falling under its article 39, which raises one of the main mandates for a supplier or manufacturer when delivering their products to the market or a specific customer to declare the SVHC if present in the article over the threshold of 0.1% of substance mass over the article mass.

In this article, we talk more generally about any product that could be such an article, but also a substance or a mixture (out of the scope

Formats Tools	Portal	Technology	Description (Data Exchange Standards)
IMDS	Yes	Cloud	Automotive portal for all OEMs (proprietary)
CAMDS	Yes	Cloud	Automotive portal in China (proprietary)
IPC-1752		XML	Materials & substances reporting for EEE Products by IPC
IEC 62474		XML	Materials & substances reporting for EEE products by IEC
IPC-1755		XML	Conflict minerals declaration
CMRT 5.0		Spreadsheet software	Conflict minerals declarations
IPC-1754		XML	Materials and substances reporting for complex products against DSL by IPC, A&D, and HE sectors
IPC-1751 IPC-1753 IPC-1758		XML	Additional standards for packaging, test lab report, and business information
chemSHERPA		XML	Promoted by Japan/METI (IEC 62474 compliant chemSHERPA XML schema)

Table 1: Existing data exchange standards, formats, and tools.

of REACH article 33) or any raw material delivered with their SDS, a standard data sheet with 16 standardized sections as defined by the Global Harmonized System (GHS). It could be a sample for test laboratories to provide their report about its substance composition, or any specific products (like packaging or battery) with specific reporting requirements.

Declaring hazardous materials and substances in a product could be done in several ways:

- Declare if your product contains or does not contain some hazardous substances or materials targeted by the regulations; such a declaration called Regulatory Compliance Declaration (RCD) establishes the compliance of the product regarding a given regulation. This is typically what is used for EU RoHS regulations; the declaration should include the precise version of RoHS and optionally some exemptions that are relevant for the product
  - The main advantage of this type of compliance declaration is the protection of the manufacturer intellectual property (IP) with no communication for all of the materials and substances used in the products
  - Disadvantages are if the regulation changes (new restricted substances or materials, exemptions expire), manufacturer declarations have to be updated
- Declare the materials and/or substances present in the product, either with partial material declaration (PMD) usually against a substances list (SL) or with a full material declaration (FMD). SL could be authored by any legal organization (either countries or groups of them, like the Europe Council) or trade associations representing the industry sectors. Substance lists may specify the substance to be either prohibited or restricted for some applications (RSL) or just declarable (DSL)
  - The main advantage is that FMD does not require updates; partial material declaration is also stable for a given substances list
  - Disadvantages are providing substances composition could affect manufacturer IP. Tolerance could be accepted to hide some substances that are considered as confidential to protect the IP, only if those substances are not declarable against the regulations or the sector lists

Manufacturers have access to various declaration types to achieve their regulatory mandates or their customer requirements.

Current Issues and Future Challenges

One of the main issues for the product declarations exchange in the supply chains is that manufacturers communicate their declarations in portable document format. That causes a lot of burden in the companies to request, collect, store, update, and extract the content and use these paper forms or electronic portable document format files.

One solution may be to use data exchange formats. Many spreadsheets, forms, or online tools are available for this, but the best option is to use data exchange formats as standard to exchange either compliance declarations or composition declarations for the products. The trend for the last 10 years is to use the XML language (eXtended Markup Language) for such standard.

Data exchange formats, such as IPC-1752 and IEC 62474 XML standards (the most used), are already in use by manufacturers and their supply chains to exchange such declarations. Other XML standards are also available to cover specific needs: SDScomXML format used for communicating the SDS; IPC-1755 standard for conflict mineral declaration (CMD); IPC-1753 for laboratory report declaration; IPC-1758 for ship, pack, and packaging materials declaration; and the new IPC-1754 standard issued in May 2018 that allows declaring substances in products against any DSL (for instance, EU REACH Candidate List, or the aerospace and defense declarable substances list, AD-DSL) but also substances used in processes or process chemicals. Those substances are not present in the product put onto the market but may cause an obsolescence technology risk to the product manufacturing if they become under authorization by EU REACH, for instance.

Using such an XML standard is a good practice for human-to-human, human-to-system, or system-to-system data exchanges. It reduces manual work to collect and extract the data of hundreds or thousands of declarations.

These last years, some progress has been made to harmonize the most used of these standards, including IPC-1752, IEC 62474, and the IPC-1754:

1. The IEC 62474 Maintenance Team (MT) has created Edition 2.0 to eliminate incompatibilities between IEC 62474 and IPC-1752
2. The IPC-1752 committee authors a unique identifier and authority for the lists provided in the appendices of this standard (RoHS, ELV, REACH, IEC 62474, etc.)
3. All elements in the lists shall be granted a unique identifier under IPC-1752 amendment 3 as an optional feature and under IPC-1754 version 1.0 as a mandatory feature, including substances not granted with a CAS number or EC number; this specific substance identifier (ID) shall be granted by the authority of the list

But the current or "coming soon" versions (IEC 62474 edition 2, issued beginning of 2019) of those standards still present issues either regarding the data exchange format of the declaration itself, the structure of the lists, or the various data used in the declaration or in the list. Table 2 shows a draft inventory of some of those issues as established by the AFNOR (France) T80A standard committee.

Objectives for Product Declarations Reporting

Ideally, substances and material product declarations could be reported with a single data-exchange format as a standard. This would ensure the same content and harmonization in all supply chains with inter-sector data exchanges. Also, it would reduce the burden and cost in supply chains and ease the support of such formats by the solutions providers that offer tools and data (regulatory definition, declarations for COTS products, etc.). This would be very difficult to achieve considering the strong positions of the sectors and their companies that have invested a long time on their standard.

Another way consists of continuing harmonization and convergence between standards with establishing a common body at the end of

Main Issues	Possible Solutions
Substances with no ID (CAS, EC)	Authorities provide ID for all substances • IPC-1754 specifies substance ID mandatory for all substances in DSL • IEC 62474 Ed2 provides CAS, EC, or other identifier, such as a DSL entry identifier
Various names/synonyms for the same substances without any authority	• Provide authority for any substance name • Pro: Multiple names or synonyms are defined under multiple authorities or DSL
Same ID for exemptions belonging to different lists with different specifications.	
No ID for applications	
No standard/norm for substances classifications or families; exhaustive list of substances not established	• Cons: Specification of OEM lists is not 100% transparent • Cons: Not decidable if a substance with CAS belong to a substance classification or not
No standard/norm for materials classifications cross industry	
"Positive list" (authorized substance) vs, "negative" (restricted or prohibited substances) used in cosmetics	• Not supported by data exchange standard today
Update of supplier product chemicals and the corresponding declarations	• Use contract term for this • Adjust requirement for tracking this change (category 3 to category 2)

Table 2: Main issues with current standards. (Source: AFNOR T80A)

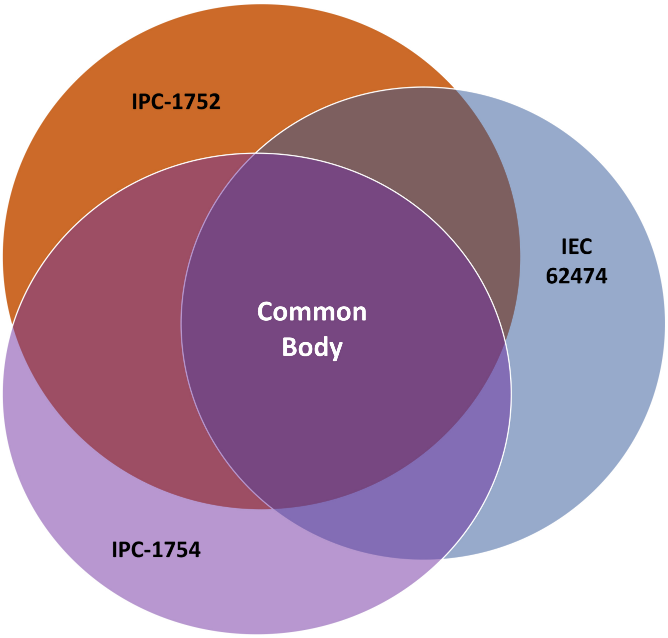

Figure 5: Common body for data exchange formats.

the journey; each standard will still offer specific features depending on the various sectors' needs (Figure 5).

A second option could be to consider the IEC 62474 international standard as the common body and have sectorial standards adding on top of it their specific capabilities to cover sectors' needs.

A third option would be to stay "as is" with the achieved convergence IPC-1752A Amendment 3 and the IEC 62474 edition 2 to give some time for solution providers to adapt their tools and clearly understand and share why a full convergence is not feasible.

This first main objective is a necessary condition to provide good standards to businesses, but this is not enough to achieve effectiveness for the reporting process. In parallel, a second main objective would have to be established on the performance of the reporting data, process and system—for instance, with a progressive approach with three staged objectives defined as follows:

1. Data Accuracy [7]: The reporting process could not perform well without good data quality, in particular, the data accuracy for DSL definition and the substances and materials in product declarations against such lists.
2. Effective Reporting [8]: How could we achieve good reporting with quality and on time?
3. Efficient Reporting System [9]: To report with quality, on time, and on cost with the minimum burden, reporting should be considered with a systemic approach, and all stakeholders would be responsible, including the governments themselves and any substances list authority.

Data Exchange Formats and Substances Lists Harmonization for Better Accuracy

The first stage to ensure data accuracy is to harmonize the way all standards manipulate the data.

The IPC-1754 standard, issued in May 2018, implements a new rule that any data used to establish a declaration or a list is clearly identified by a unique identifier under a given authority ("UniqueID" type in the schema). Data groups like the query lists and the substance lists are also identified like this, plus a revision and a date ("UniqueIDextended" type in the schema). Other standards should follow and implement that rule; IPC-1752A with amendment 3 (amd3) and IEC 62474 with coming edition 2 have started to implement it with all their list elements identified by a unique "identity" (Table 3).

Some issues still exist:

- These IDs are optional in IPC-1752A amendment 3; they would become mandatory in the next revision B
- IEC 62474 DSL could contain a specific substance with a unique ID "7, Boric Acid," with two CAS values in the "CAS number" attribute (unique string: "10043-35-3, 11113-50-1")
- The IPC-1752A amendment 3 identifies the substance categories in their lists for Class C declarations (or "Regulatory Compliance Declaration"—RCD) with a 5-digit code; this is well-done for substance categories like in RoHS lists with heavy metals and flame retardants, but is limited for individual substances for RoHS phthalates or REACH Candidate Lists

Table B1 RoHS Substances

Unique ID Authority == IPC
Unique ID == EUROHS-0508
QueryList Revision == 1.0

Identity	Substance Category Name	Threshold
00001	Cadmium/cadmium compounds	0.01% by weight (100 ppm) of homogeneous materials
00002	Polybrominated biphenyls (PBBs)	0.1% by weight (1 000 ppm) of homogeneous materials
00003	Polybrominated diphenyl ethers (PBDEs)	0.1% by weight (1 000 ppm) of homogeneous materials
00004	Chromium VI compounds	0.1% by weight (1 000 ppm) of homogeneous materials
00005	Lead/lead compounds	0.1% by weight (1 000 ppm) of homogeneous materials
00006	Mercury/mercury compounds	0.1% by weight (1 000 ppm) of homogeneous materials

Class A QueryList statements

Identity	Statement
01	Product(s) meets EU RoHS requirements without any exemptions
02	Product(s) meets EU RoHS requirements except lead in solder and this usage may qualify under the lead in solder '7b' exemption (other selected exemptions may also apply)
03	Product(s) meets EU RoHS requirements by application of the selected exemption(s)
04	Product(s) does not meet EU RoHS requirements and is not under exemptions
05	Product(s) is obsolete, no information is available
06	Product(s) is unknown, no information is available

Table 3: Extract of "IPC-1752A Amendment 3, Appendix B, Table B1: RoHS Substances." (Source: IPC)

Identity	Substance Category Name	CAS number(s) published by ECHA	Threshold
Included in REACH Candidate List on 28 October 2008: Unique ID == EUREACH-1008			
00001	Triethyl arsenate	15606-95-8	0.1% by weight (1 000 ppm) of any article

Table 4: REACH candidate list substances with CAS numbers as provided by ECHA Table D1.

- The portable document format version of the list in appendices provides the CAS number of the individual substances, but not the XML schema of the list element, the "substance category" element (Table 4 and Figure 6); this is an opportunity for enhancing the data accuracy

The next section addresses some limitations of the structure of the lists with IPC and IEC standards and also lack of harmonization that is the primary issue.

The IPC-1751 committee (2-18) has put in place a subcommittee last year to work on an IPC-175x harmonization initiative. The purpose of this initiative is to establish the IPC-1751 as the common foundation of the IPC-175x series, to implement the schema with a modular approach to avoid duplication of schema elements, and for the end users to get the best from each standard and to be able to declare various sectionals from each standard

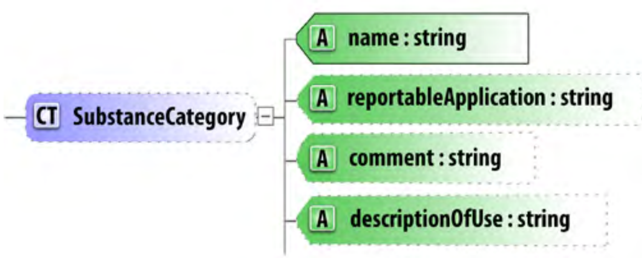

Figure 6: Substance category element in IPC-1752 Class C list.

in a single declaration to cover their business needs. There is a unique potential of the IPC-175x series to cover various product types (electronic products, complex products, packaging) with various declaration types (certificate or product statement, compliance declaration, composition declaration and laboratory report, partial and full material declarations) either for business-to-business (B2B) relationships, "request/reply" modes, or volunteer declaration by standard components manufacturers ("distribute" mode).

This IPC-175x harmonization initiative requires achieving different goals:

- Implementing each standard with a modular architecture based on the IPC-1751 schema as a foundation; each standard could extend an existing element, but no conflicting definition is authorized, like IPC-1754 extending elements from IPC-1751 and IPC-1752 standards
- Putting in place schema versioning and change management (traceability of changes)
- Harmonizing the IPC-1752 and IPC-1754 data lists: DSL and query lists (QL) in terms of their schemas; there is no reason for an authority to publish their data lists in various formats for every standard

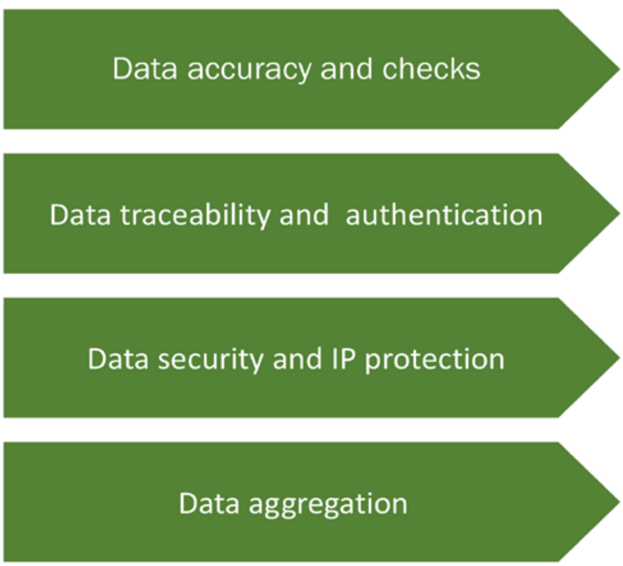

Figure 7: Data quality criteria.

Another issue to solve is that substance groups/categories are provided in IEC 62474 edition 1; IPC-1752A appendices B, C, and D; and AD-DSL 3.0 with a non-exhaustive list of individual substances. How can an SME company representative, without a chemistry background, decide if a substance not listed should be reported or not? To avoid this situation, a policy should be defined by this:

- Only substances identified as belonging to a substance group/category could be reported against a list that refers to this group/category
- The authority that issues a substance list is responsible to provide a unique identifier for each substance and for the substance group/category and the reportable substances that belong to the group/category

This harmonization should include a definition of common terms to designate the same data (substance group/category) and the standard use cases.

Other topics regarding data quality should also be addressed (Figure 7):

- Data checks to verify some sectorial rules about the substances, materials and product data
- Data traceability and authentication to be able to manage some regulations, like EU REACH authorizations
- Data security (protocol for communication) and supplier IP protection
- Data aggregation (how data coming from different sources with different requirements could be aggregated along the supplier chain)

Effective Reporting With Standards Convergence

The second stage is to build on top of the previous harmonization for better data accuracy, regarding the convergence of the standards and other recommendations for effective reporting of the product declarations.

As mentioned earlier in the issues section, IPC-1752 and IEC 62474 have already achieved

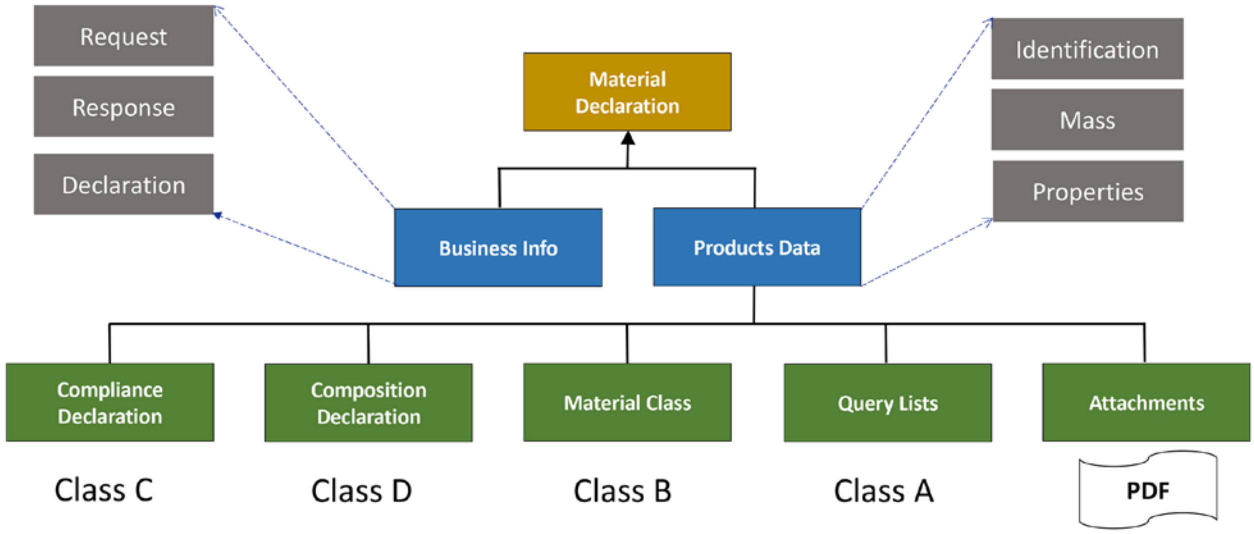

Figure 8: New structure of IEC 62474 Edition 2 standard.

first-phase convergence with IPC-1752A amendment 3 (April 2017) and IEC 62474 edition 2 (issued end of 2018); those standards now offer similar capabilities in terms of their use cases:

- There are two main declaration types specified in IEC 62474 corresponding to IPC-1752 Class C (compliance) and Class D (composition) declarations
- In addition, material classes may be declared; the material class concept is addressed by IPC 1752 by information for a Class B declaration
- IEC 62474 also provides for the ability to use query lists (Figure 8)
- IPC-1752A amendment 3 (amd3) has introduced a unique ID for all data used to establish their query lists and substances category lists. In Amendment 3, these data fields are optional to give time to solution providers to update their solutions; in the coming revision B, these fields would become mandatory
- Although conformance to the IEC 62474 standard requires the reporting to the IEC 62474 declarable substance/substance group list (including reportable applications and reporting thresholds), the schema in IEC 62474 allows material declaration reporting to any DSL, as long as that list has a list identity
- The IPC-1752 standard works with various regulatory substances lists (RoHS, JIG, REACH Candidate List and Restrictions List, IEC 62474) with their exemptions lists in various versions (RoHS, ELV) provided in appendices in portable document format and also in XML formats, either IPC-1752 or IEC 62474; for substance families with no CAS, non-exhaustive lists of substances with CAS from REACH details is also provided in portable document format appendixes
- With IEC 62474 Ed 2.0, IEC now maintains exemption lists for RoHS Annex III and IV and for China RoHS. IEC has the capability to add exemption lists for any other IEC member country based on its established change request process. Additions or changes to the exemption lists should be able to be done within a 3–4-month period from notice of an intended change
- The material class list referenced in IPC-1752 is currently maintained by IEC within the database maintenance process by the VT 62474

Now, it is quite easy to convert declarations from one standard to the other, and some companies collect either IPC-1752 declarations or IEC 62474 declarations then convert them. That could be considered as partial interoperability between those two standards.


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```
<Include>
  <Sectional name="ManufacturingInfo" />
  <Sectional name="MaterialInfo">
    <SubSectional name="A" />
    <SubSectional name="D" />
  </Sectional>
</Include>
```

Figure 9: IPC-175x sectionals and sub-sectionals.

Some differences still exist between IEC 62474, IPC-1752 and IPC-1754:

- IEC 62474 edition 1 does not include sectionals and sub-sectionals statements, while it exists in IPC-175x series and eases data quality check; for instance, Figure 9 shows an IPC-1752 declaration, including classes A and D plus manufacturing information
- IPC-175x series provides two levels of sectionals and sub-sectionals for IPC-175x standard to structure their declarations
- DSL structures and schemas are different:
  - IEC 62474 Edition 1 does not define a structured schema for the list provided in XML as a flat list of elements to be either an individual substance or a substance group
  - IPC-1752 DSL includes one single "substance category" element used for both an individual substance (with a unique ID, but neither CAS number nor EC number) and a substance group/category
  - IPC-1754 DSL includes one single substance element with a name and a CAS number for both individual substance and substance group; but no capability to expand the group with a list of their substances; considering coming AD-DSL 3.0 with such information, the IPC-1754 DSL schema would need to be extended to the same capability than the IEC 62474 and harmonized with IPC-1752 revision B
  - IEC includes two elements: one "specific substance" element for individual substances with their CA number and one "substance group" element for substances group or family; reference substances are an informative list of substances within a substance group to help the organization to determine what they need to declare when a given government substance restriction regulation references only a group of substances (i.e., substance group)
- IPC-1752 and IPC-1754 provide a "unique ID extended" element (identity, authority, revision, and date) to their lists while no such unique ID is provided by the IEC 62474 Edition 1—only a revision is provided, and the current is "D16.00"

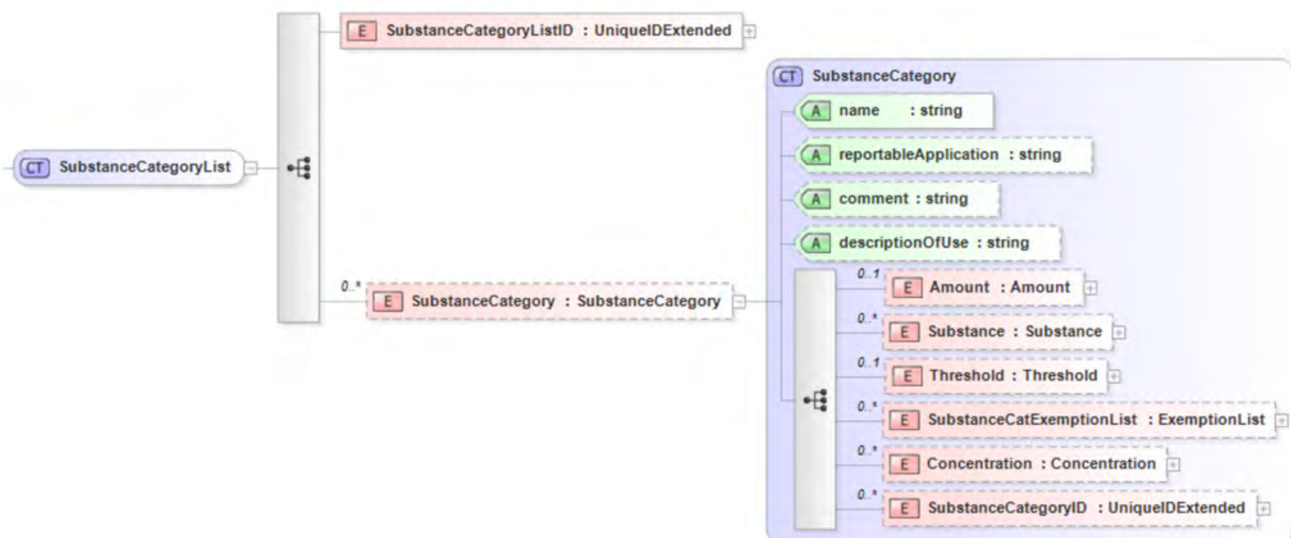


Figure 10: IPC-1752A Amendment 3 Declarable Substance List schema.

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<ReferenceSubstances>
<el>
<ID>R00001</ID>
<SubstanceGroup>Asbestos</SubstanceGroup>
<SpecificSubstance>Asbestos</SpecificSubstance>
<CASnumber>1332-21-4</CASnumber>
<CommonSynonyms></CommonSynonyms>
<Basis>Reference</Basis>
<FirstAdded>2010-04-02</FirstAdded>
<LastRevised>2015-07-15</LastRevised>
<Comments>This reference substance is part of a complete list the DSL entry</Comments>
</el>
```

Figure 11: IEC 62474 Edition 1 Declarable Substance List schema.

- In IEC 62474, a revision is made whenever any change in the substance (or data exchange part) of the database occurs with major revisions as the integer (to the left of the decimal point) and minor revisions to the right of the decimal point. The dates that given entries have been modified is contained within the database per specified substance because not everything changes with every update. The identity remains the IEC 62474 substance list and does not change with updates; this is a simpler approach

Figures 10–12 illustrate those differences with structures of IPC-7152, IEC 62474, and IPC-1754 DSL.

The next phase of convergence would include the following goals:

- Harmonized principles and use cases are shared for the common body by the standards
- A unique data structure and a unique corresponding schema (XML schema definition, or XSD) are established for the common body that means full interoperability between the existing standards; each standard may add their specific features on top of the common body—see previous options for the scope of this common body
- A unique substances and substance groups/categories list structure and a unique corresponding schema are established for any lists authored by any organization; this includes regulatory lists by governments. That means all standards are capable to work with the same RSL/DSL provided in a unique XML schema

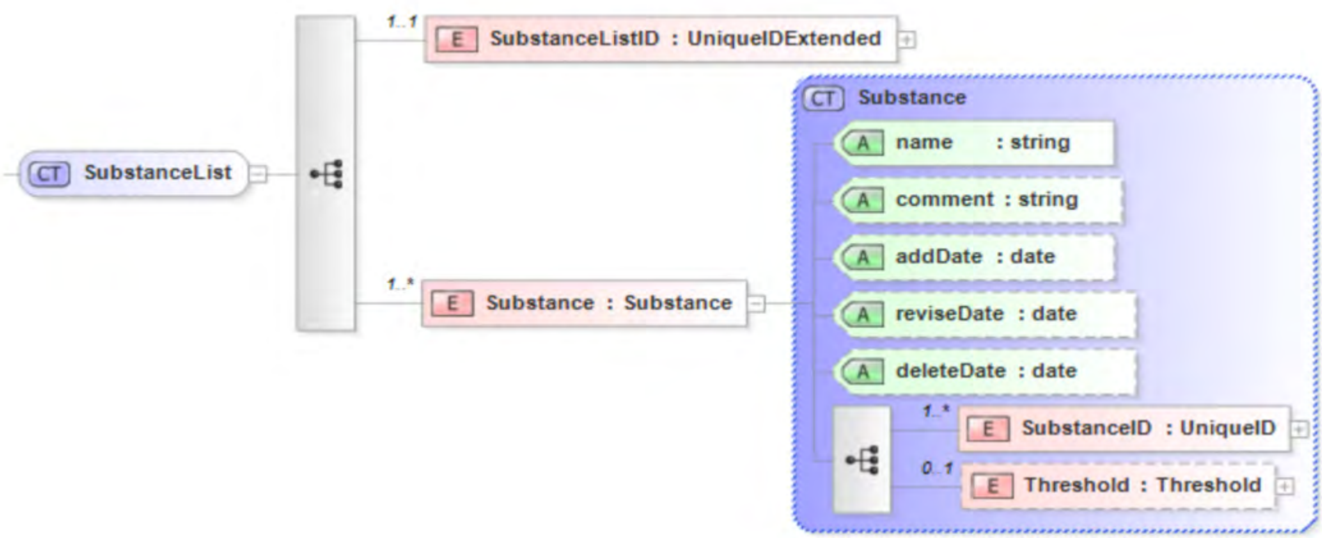


Figure 12: IPC-1754 Declarable Substance List schema.

- Standards better cover the request/reply management process and not only the declaration itself; standards are capable of managing a request state in the requester/supplier workflow (requested, reminded, escalated, submitted, rejected, approved, superseded)
- Standards should also be capableof managing a "completion state"—for instance, "prepopulated," "preliminary" (like in IMDS or chemSHERPA), or "complete." This would allow automatic system-to-system communication not only to collect the declaration but also to send material declaration requests for a set of products

Here are some recommendations to achieve these goals:

- Standards could include rules for the quality criteria of their data on top of the schema (XSD) that should stay as simple as possible; those rules could be implemented by the solution providers in their tools
- Standards could include features for a manufacturer to ease their supplier's product material declarations roll-up along their product bill of materials (BOM); this is typically a function offered by the enterprise resource planning (ERP) and product lifecycle management (PLM) tools, but not all companies—including SME in a low tier of the supplier chain—could afford such expensive tools
- Standards should include the capability to send a reminder request to a supplier for their declaration or to send an escalation request to a manager when declarations are not delivered by their due date
- Standards should support a pre-populated version of the declaration a requesting company could send to their suppliers to avoid error in key data used to sync their information system (IS), supplier ID, requester and supplier products ID, and request ID; this would ease data reconciliation when receiving the declaration and ensure better data quality
- Standards should support preliminary declaration (not 100% ready to be sent) like in IMDS or in chemSHERPA to allow early communication of declaration in the product development process; for instance, this could be useful with IPC-1752 class B declaration to establish the product weight balance as soon as possible in automotive or in aerospace sectors based on materials weight (even if substance composition is not well known); also, avoid latency in the reporting process

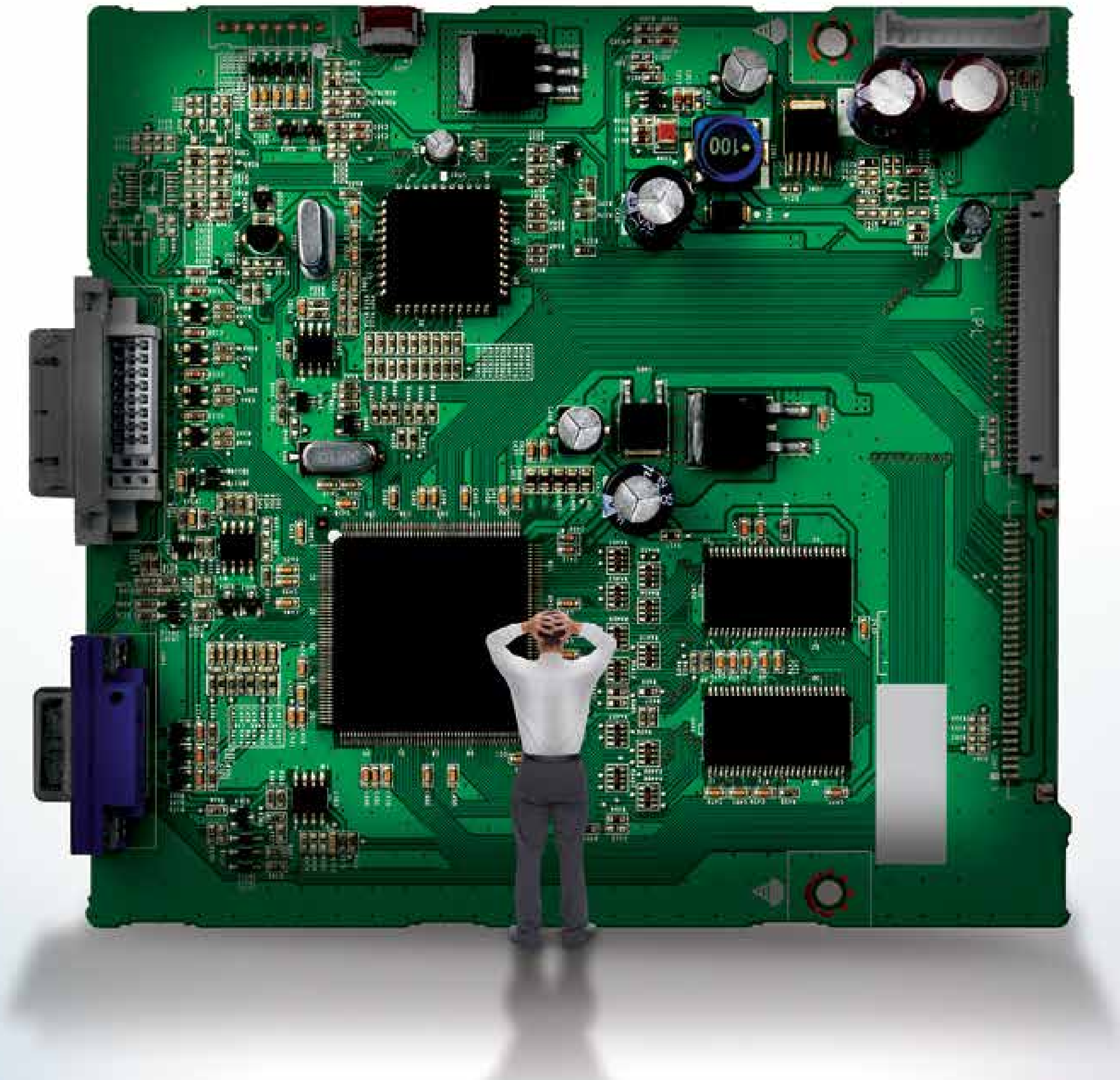
Achieving effective reporting is not only a matter of the standard capabilities; enabling the supply chains on the regulations and the standards and their supporting tools could be a win-win action by the large companies to their suppliers. The regulatory duties are often perceived as additional costs and no-value activities by the suppliers who do not have the required skills for them. Large companies and trade associations should turn that to a benefit for all the supply chain in terms of safety for workers and end users and good environmental brand image for a positive value.

Efficient Reporting Systems

The third and last stage of the proposal is about the reporting system efficiency against the hazardous substances and materials regulations, or how to perform such reporting with maximum quality and minimum resources (time and costs). This requires considering how the reporting stakeholders, at a systemic level, all interact with each other.

Efficiency prerequisites include two stages—data accuracy and effective reporting—and deals with performance to achieve the reporting activities. Overall, efficiency relies on 1) all participants in the data exchange flow to use tools to report their declarations; 2) tools to communicate together with system-to-system interfaces, and 3) tools to be configured and updated in automatic or semi-automatic ways with system-to-system interface with legal authorities and any other authority issuing a substances list as well as data providers.

Large companies may prefer their supply chain to have access to tools supporting



the data exchange standards—both formats and lists—to ease their reporting at low cost. Even for a simple three-component assembly, without any tools, it could cost much time to manage a request received from a customer, cascade them to suppliers, collect their declarations, and remind them and/or escalate them if there is no answer, roll up all declarations to establish the product declaration, send back declaration to the customer, and wait for their approval to close the initial request.

Figure 13 shows an example process for requesting/collecting substance declaration for a simple product BOM of four components) and a breather tube (BT01) manufactured by a Tier 3 company in the U.S. supplied to the EU.

Few tools are used today for requesting collecting, rolling-up, and checking the declarations; for instance, IMDS and CAMDS as standard tools for the automotive sector. Those tools should also interact with ERP and PLM systems; bottom-up data collection is usually well supported for such interfaces but not top-down from ERP and PLM to dedicated tools to manage declaration requests that are, most of the time, implemented with email notifications.

While the tools are in place for declaration exchange, the next step is to connect them to sources of the data lists (the RSL/DSL or the QL authorities' information systems). It is a pity today to be aware that all existing lists and their data (substance categories, applications, exemptions) getting regulatory news or data updates are a manual process or a service by data providers.

To reduce the burden for companies, legal authorities and other sectorial list authorities like trade associations would have to provide web services, or similar services, to automatize these activities with system-to-system communication:

- Subscription services to get information on new data list availability or new regulation updates
- Web services to get their substance lists and other data related to these lists: substance classifications, materials classifications, exemptions, applications, use descriptors (like the ones defined by ECHA)

Standard tool providers should also offer several ways for supplier companies to provide their declarations:

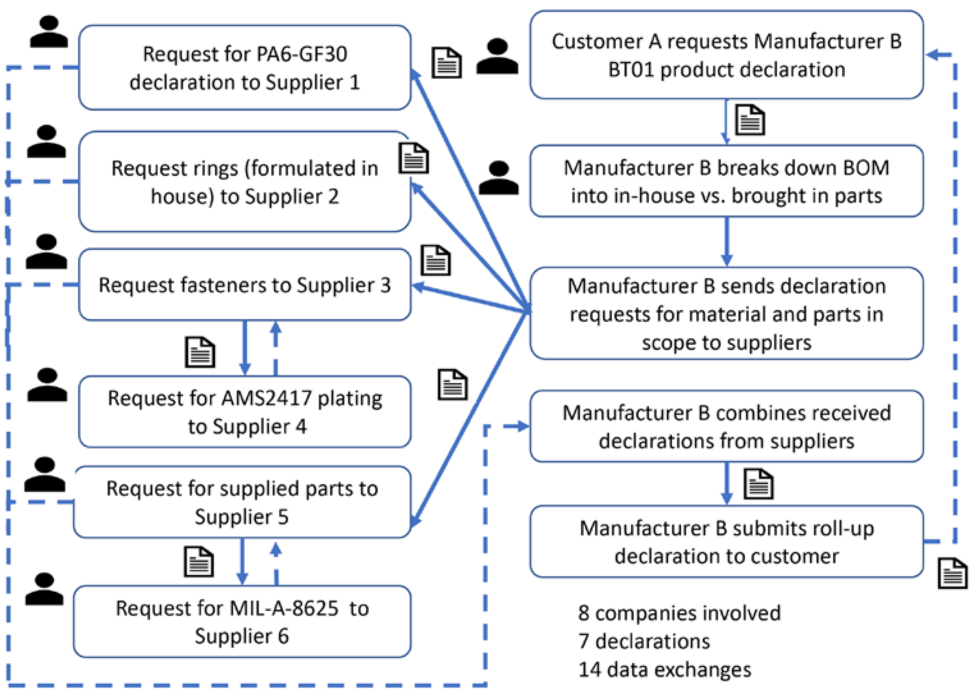


Figure 13: Declaration collection process for a simple product.

- A user interface for persons to post their declarations already established under a data exchange format
- An online editor for the supplier representative to build their declarations
- Web services or a similar mechanism for system-to-system communication between supplier IS and their customers as a requester of their declarations

Legal authorities (like ECHA) should offer similar services for companies to perform their "business to authorities" (B2A) duties.

Objectives for Standard Development Process

On IPC and IEC/ISO sides, approval processes identifying several phases for developing the standard; the corresponding milestones to get approval and states of the standard completion are pretty well-defined. This is the core process and a prerequisite in any quality systems like ISO9001. This is not enough to reach a good maturity level in standard development. We could consider a data exchange format in exchange markup language (XML) as a piece of software; then, referring to capability maturity models for software development (CMMi [10] or SPICE [11]), we should add more support processes to the repository to achieve a good quality of the standard and side pieces of it:

- **Configuration management:** All of the pieces that work together for a given version of the standard, including internal documentation (for development committee members) and external documentation (for end users)
- **Change management:** Managing all change requests and incident reports and keeping track of which ones have been implemented for a given version of the standard
- **Requirement management:** Keeping track of the initial needs and their changes over time to know why the standard is like this at a given time

Without these support processes in place, deployment of the standard would be difficult because the knowledge about it would be reserved to only the development committee members, which represents a small number of persons and companies regarding the potential number of end users.

Objectives for Standards Governance

Existing materials and substances in articles (and raw materials) data exchange standards—IPC-175x and IEC 62474—have defined their governance models according to their current scope: the single sector for IPC-1752 and IEC 62474, or two sectors for the IPC-1754 (Figure 14).

IPC has adopted an ANSI-like procedure and governance model for developing their standards: IPC Standardization Procedures (last version: October 21, 2015) that complies with ANSI Essential Requirements: Due process requirements for American National Standards.

That means for the IPC-175x standards development:

- Dedicated development committee (2-18x) for each of the IPC-175x standards that

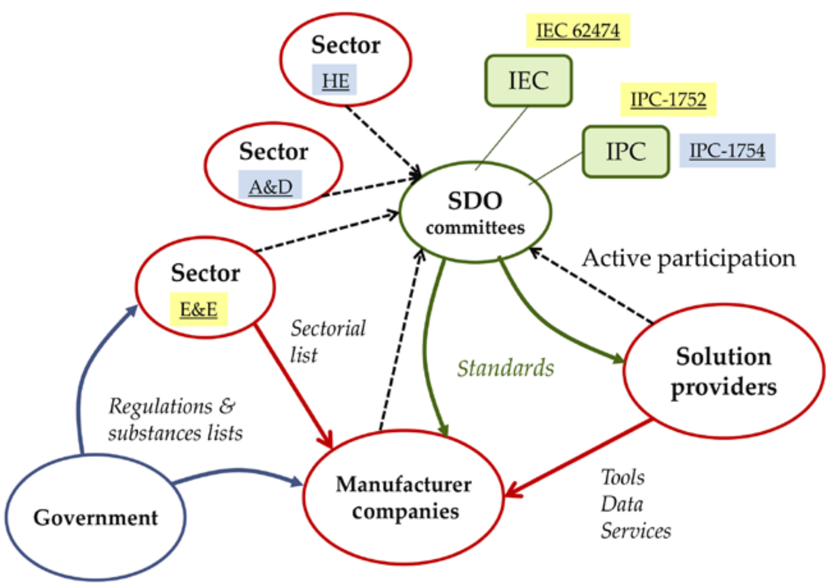


Figure 14: Current governance model for developing standards.

are open for free to "any person of interest (organization, company, government agency, individual, etc.) regardless of a membership in IPC"; only "active participation in committee" is required to participle for developing a standard, so any sector or company may participate in these committees by contacting the IPC liaison member of the committee
- Development of a standard is a 4-stage process: working draft (WD), final draft for industry review (FDIR), proposed standard for ballot (PSB), and adoption (Figure 15)
- Development processes regarding a new standard, a revised standard or an amendment
- Committee members are distributed in different "interest categories": users, suppliers, and general interest for the final ballot with a minimum of 65% positive vote for adoption
- Committees currently are mainly in the USA with two onsite meetings per year on the West Coast in the spring (recently, it has been San Diego, California) and in the Midwest in the fall (usually in Chicago, Illinois); that has mainly a North Americans regional representation with less European and Asian members at these meetings
- IPC standardization policy relies strongly on anti-trust and competition laws that explain the openness of the committees

The International Electrotechnical Committee (IEC) has adopted ISO like development procedures:

- ISO/IEC Directives, Edition 13.0 2017-05, Part 1—Procedures for the technical work
- ISO/IEC Directives, Edition 7.0 2015-07, Part 2—Principles and rules for the structure and drafting of ISO and IEC documents

IEC has the following highlights:

- The development of a strategic business plan that considers the business environment of the standard, evaluates progress on work programs and needs for revisions, and identifies emerging needs
- A project approach with defined and sequential stages and associated deliverables (in brackets): preliminary (preliminary work item—PWI), proposal new work item proposal (NP), preparatory (working draft—WD), committee (committee draft—CD), enquiry (enquiry draft—CDV), approval (final draft international standard—FDIS), and publication (international standard—IEC)
- Each project is led by a project leader or working group (WG) convener
- The structure of the work programs in various projects relates to different standards if needed, and an evaluation of the target dates for the various deliverables
- Only national body representatives may participate (P-members) or be an observer (O-members) for standard committees and subcommittees; even if not P-members or O-members, any national bodies can vote on inquiry draft and final draft

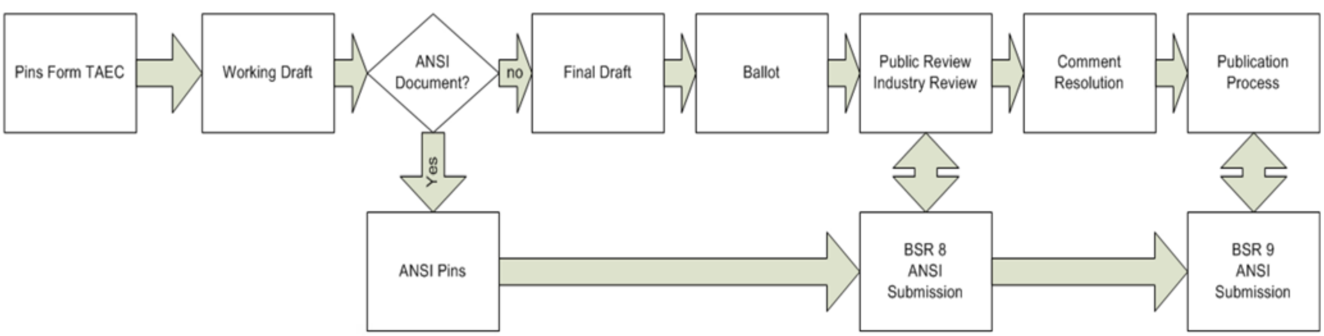


Figure 15: IPC standardization procedure [12].

- Capabilities to develop other deliverables that would prepare the final international standard: technical specifications (TS), publicly available specification (PAS), and technical report (TR)

Pros of IPC and IEC standard development procedures include:

- IPC standard committees are fully open to any person of interest
- IPC represents mostly the electronics/electricals sectors with the IPC-1752 data exchange format standard, but IPC has started to open up to other sectors with aerospace, defense, and heavy equipment that have developed the new IPC-1754 data exchange format for complex products in their sectors
- IEC has an expedited process using validation teams to update referenced databases, which can be updated quickly, generally within three months (versus the time to change a standard itself, which can take over two years)
- IEC works globally with well-distributed meetings in all regions

Cons of IPC and IEC standard development procedures include:

- IPC is North America-centric with ANSI procedure and U.S. on-site meetings that result in less attendance from European and Asian persons
- IEC is working with IEC/ISO rules with an organization of global, regional, and local committees with representatives at each level designated by the countries; it is not open at all
- IEC mainly represents the interests of the electrotechnical sector; TC111 committee and national committees like UF111 in France are not so accessible to other sectors representatives, but different organizations can get liaison status. Participation to the national committee (like UF111 under AFNOR in France) could require an expensive fee

Previous chapters have presented a proposal for the content or what should be the unique cross-sector standard. Here this is a matter of defining how to establish such a standard or standards:

- IPC-175x committees should become more global in their way of working with a two-level organization, including regional committees like the European Proactive Alliance that works with the global committee that should be more global with onsite meetings distributed in all regions: Americas, Europe, and Asia every four months, for example
- For IEC 62474 to be used broadly beyond the electrotechnical product sector, liaisons with other product sectors need to be approved so that non-electrotechnical industry representatives can participate in the validation team and maintenance team. With IEC 62474 requirements, the three other elements in the IEC 62474 database (the declarable substances and declarable substance groups, the reference substances, and the material classes) would remain specific to the electrotechnical sector; any sector could define their specific features on top of the common body
- If IPC-1752 or IPC-1754 are to be used broadly as data exchange standards, these standards must be available at no cost to solution providers. The IEC 62474 data exchange requirements are included in the IEC 62474 database, which is available online free of cost
- If IPC-1752 or IPC-1754 standards are to be used, IPC as an organization should commit to long-term support of standardization support activities, such as what is a core activity of the IEC central office

The governance model presented in Figure 14 would need to adapt to more sectors being represented and influence the standard development. The European Proactive Alliance (PA) that gathers dozens of sectors represented by their European trade associations is one exam-

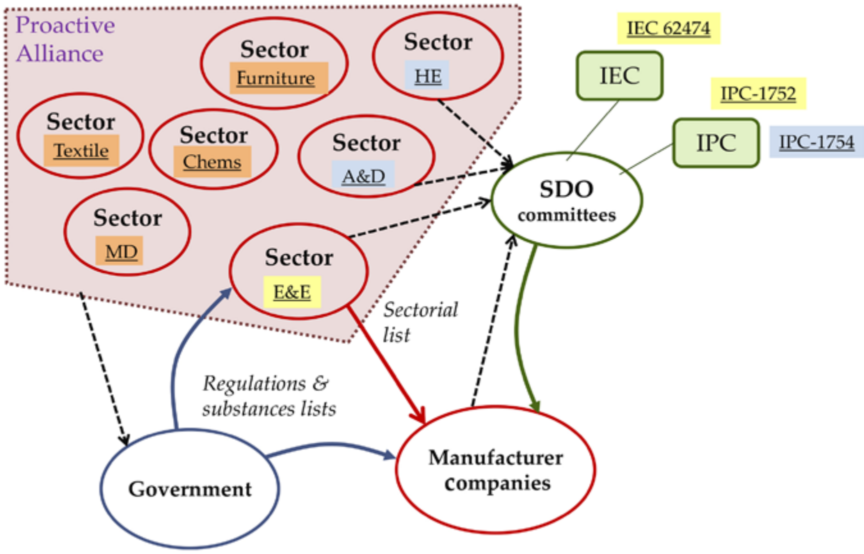


Figure 16: Possible future governance model for developing standards.

ple of such a trend for the coming future. PA would have to connect with standard development organizations (SDO) to push their intersectors requirements. PA would also have to influence the governments or their representatives (like ECHA) to provide more effective and efficient support to make regulations happen (Figure 16).

Conclusion With a Planned Proposal

The three stages described in this article could be implemented with a three-phase "ABC" strategic business plan (as named by the IEC procedure) as a proposal to align all stakeholders on the same objectives for an accurate, secure, and efficient reporting system globally for all sectors.

This strategic business plan would include:

- Clear objectives for each phase to be evaluated at the end of each phase
- A status-target-plan (STP, actions) with precise assignments: STP with who + what + when with the current situation and targets that have been proposed above with due dates

This strategic business plan would have to be built when the phasing and the scope of work will be established after a review of the sectors' needs, issues, and challenges; some priorities (high, medium, low) and implementation terms (short, medium, long) would be assigned to the business requirements and the standard requirements.

Figure 17 shows an example of what could be such a plan in terms of time phases or work packages (draft plan).

An initial agreement should be found to define the target for the common body (declaration and list) regarding the existing standards. This plan should also consider the dynamics of change by IPC and IEC committees:

- IPC-175x committees could amend a standard in one year or revise it in 2–3 years
- IEC 62474 edition 2 released end of 2018 will make it stable for several years before a new edition (edition 1 released in 2012, that means 6 years with edition 2)

Some resistance to change could be raised by organizations and authorities that have already adopted one standard, so this is important to

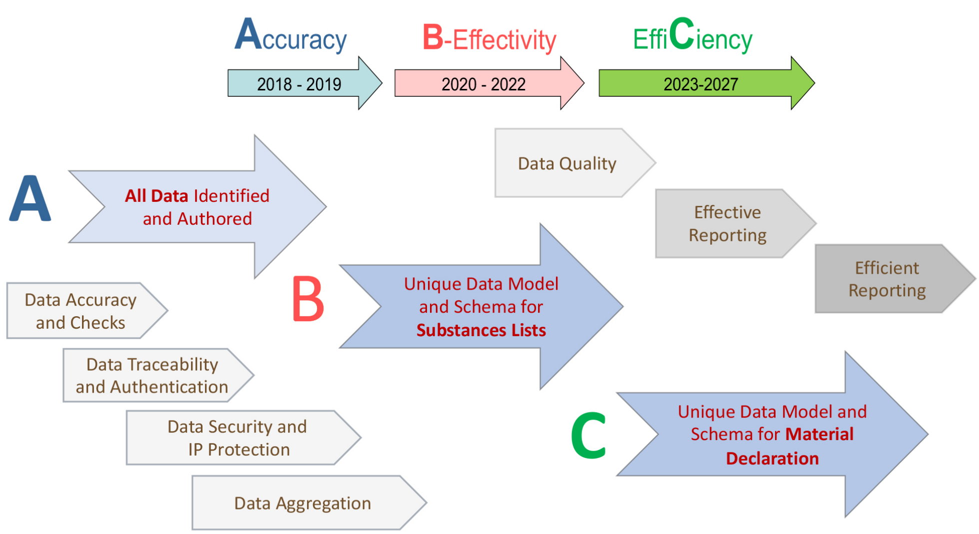


Figure 17: ABC strategic business plan.

highlight the benefits for all stakeholders to harmonize, converge on standards, and make operations the most in terms of performance so that it could be of benefit for all stakeholders. The stakes here are not a local business one like more money for my company; the real stake is a safer world for workers, consumers, families, children, friends, and future generations on Earth. This stake is well worth such an ambitious plan; let us start this long journey together.

Acknowledgments

My special thanks to Robert Friedman (Siemens Healthineers), Walter Jager (ECD Compliance), Koshi Kamigaki (Canon), Christophe Garnier (Schneider Electric), Will Martin (Granta Design), Aidan Turnbull (BOMcheck), and Rick Shanks (Pratt & Whitney) for their inputs and/or their review of this article. This article is established under the single responsibility of the author; the reviewers mentioned in this section may not agree with its content. **PCB007**

Glossary/References

1. JIG: Joint Industry Guide.

2. JGPSSI: The Japan Green Procurement Survey Standardization Initiative is a council established to standardize the list of substances targeted by surveys and survey response formats, thereby reducing the labor required for surveys undertaken to identify chemical substances in various parts and materials and improving the quality of responses received. (Source: acronyms.thefreedictionary)

3. RosettaNet: A non-profit consortium. (Source: wikipedia.org/wiki/RosettaNet)

4. PDF: Portable document format is an open standard maintained by the International Organization for Standardization (ISO). (Source: acrobat.adobe.com/us/en/acrobat/about-adobe-pdf)

5. SDDcomXML: A standard for the exchange of safety data sheets. (Source: esdscom.eu/english/sdscom-xml/)

6. chemSHERPA: The Chemical Information Sharing and Exchange Under Reporting Partnership in the Supply Chain is a distributed-for-free software authored by the Japan METI (Japanese Ministry of Industry). (Source: chemsherpa.net/chemSHERPA/english/)

7. Accuracy: Qualitative assessment of correctness or freedom from error. (Source: pascal.computer.org/sev_display/index.action)

8. Effectiveness: Accuracy and completeness with which users achieve specified goals. (Source: pascal.computer.org/sev_display/index.action)

9. Efficiency: The degree to which a system or component performs its designated functions with minimum consumption of resources. (Source: pascal.computer.org/sev_display/index.action)

10. CMMI: The Capability Maturity Model Integration is a maturity model for organization developed at Carnegie Mellon University (Pittsburgh, Pennsylvania) and administrated by the CMMI Institute. It is based on five maturity levels that the organization is assessed against and has been adapted for products and services development, like software, such as CMM-DEV. (Source: en.wikipedia.org/wiki/Capability_Maturity_Model_Integration)

11. SPICE: Software Process Improvement and Capability Determination, or ISO/IEC 15504, is a set of technical standards documents for the computer software development process and related business management functions. It is one of the joint International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) standards, which was developed by the ISO and IEC joint subcommittee, ISO/IEC JTC 1/SC 7. (Source: en.wikipedia.org/wiki/ISO/IEC_15504)

12. (Source: Aidan Turnbull)

This paper was first presented at the IPC APEX EXPO 2019 Technical Conference on and published in the 2019 Technical Conference Proceedings.

Jean-Pierre Théret is senior consultant and materials compliance and EcoDesign specialist with Dassault Systèmes.

PCB007 Supplier Highlights

Nano Dimension Details New DragonFly LDM ▶

Dan Feinberg talks with Nano Dimension CEO Amit Dror about the new DragonFly LDM 3D printer technology announced by the Israeli company on July 24, 2019, aimed at increasing machine uptime and moving forward from prototyping to higher production volumes.

Eternal Technologies Names IEC as Exclusive North American Distributor ▶

Eternal Technology Corp. has named International Electronic Components (IEC) as exclusive distributor for its dry film photoresist products.

Atotech Acquires J-KEM International ▶

Atotech has acquired J-KEM International, a global supplier of high-quality chemical products and processes for the PCB and general metal finishing industries.

Canadian Circuits Acquires Orbotech LDI System ▶

Canadian Circuits has acquired a new state-of-the-art Orbotech Paragon 9800 LDI system, which provides powerful performance for imaging of HDI, rigid, flex, and rigid-flex PCBs.

High-end CCL Demand from Huawei Ramping Up ▶

High-end copper clad laminate (CCL) demand from Huawei has been rising due to a major redesign of its 5G base station infrastructure, prompting Taiwan CCL makers to upgrade their CCL specs to meet the demand.

SAP Utilizing Very Uniform Ultrathin Copper ▶

As demand for miniaturization and higher density electronic products continues, the semiconductor miniaturization is bringing significant economic and technical benefits, and the semiconductor scale factor is becoming the master for the associated package and PCB design.

MKS Instruments Inks Multiple-system Order for Flex Laser Via Drilling Solution ▶

MKS Instruments Inc. has announced a multi-system order from one of China's leading flex PCB manufacturers for the recently released ESI CapStone laser drilling solution for flexible printed circuits (FPC).

CCL Makers Poised to Gain From AMD PCIe 4.0 Server CPU Launch ▶

As AMD has newly launched second-generation EPYC processors, dubbed Rome 7002 series, as the world's first 7 nm x 86 server CPUs that support PCIe 4.0, Taiwan-based CCL makers ITEQ and Elite Material (EMC) are poised to embrace new business opportunities arising from the new server transmission architecture of PCIe Gen 4.

Drill Bit Maker Topoint Optimistic About 3Q 2019 ▶

PCB drill bit maker Topoint Technology has seen orders for 5G base station equipment start generating revenues and expressed optimism about its performance in the third quarter of 2019.

Innovative Electroplating Processes for IC Substrates ▶

The decreasing chip scales and smaller line/spacing distances have created unique challenges for both the PCB industry and the semiconductor industry. This paper discusses innovative additive packages for direct-current copper electroplating specifically for IC substrates, which offer better trace profile and deliver via fill and through-hole plating.

The Past 15 Years:

Changes to MIL-PRF-31032 Certification, Part 2

From the Hill

Feature Column by Mike Hill, MIL-Q-CONSULTING LLC

In Part 1 of this column series, I introduced background information and data from changes in military certification to MIL-PRF-31032 from 2003 to 2018. In this column, I will provide an overview of six of the possible related factors to what could have caused the reduction in certified companies, including:

1. A decline in the total military market
2. The cost of certification
3. The number of military boards now built to industry standards (IPC-6012 & 6018)
4. A reduction of profit margin on military specification boards
5. Consolidation of the PWB industry
6. The general loss of US PWB manufacturing sites.

An in-depth analysis of these factors will be left to an expert in each market segment.

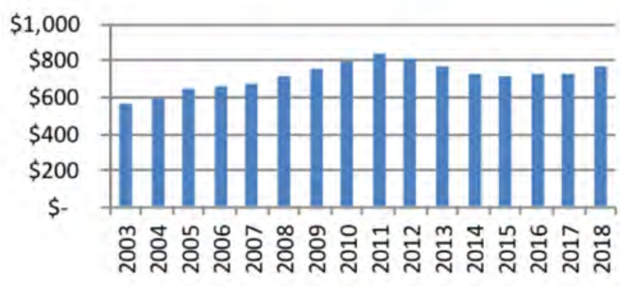


Figure 1: Annual military budget of the U.S. (2003-December 2018, Billion$). (Source: Wikipedia)

1. Effect of the U.S. Military Spending and Associated PWB Market

U.S. military spending drives the total related PWB demand year to year. Furthermore, as the use of electronics grows in military hardware as it has done in automotive and everything else in our lives, the percent of that spending for PWBs rises even faster.

The military spending for the last 15 years (2003–2018) is shown in Figure 1. In those 15 years, it has increased by 36% from $563 billion to $766 billion. Obviously, this positive spending increase logically should have driven an increase in military-certified companies and not less.

How does this U.S. defense spending increase translate to the total PWB market? On

U.S. Marine Corps photo by Sgt. Timothy Smithers

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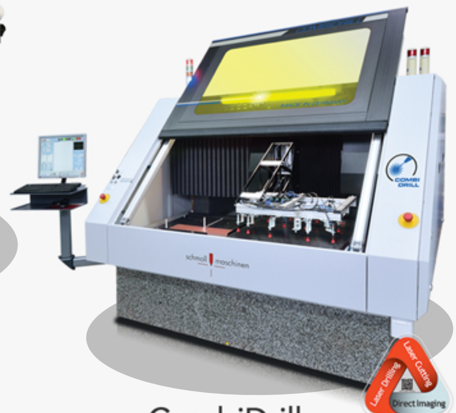

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- User-friendly visualization system
- Affordable initial investment

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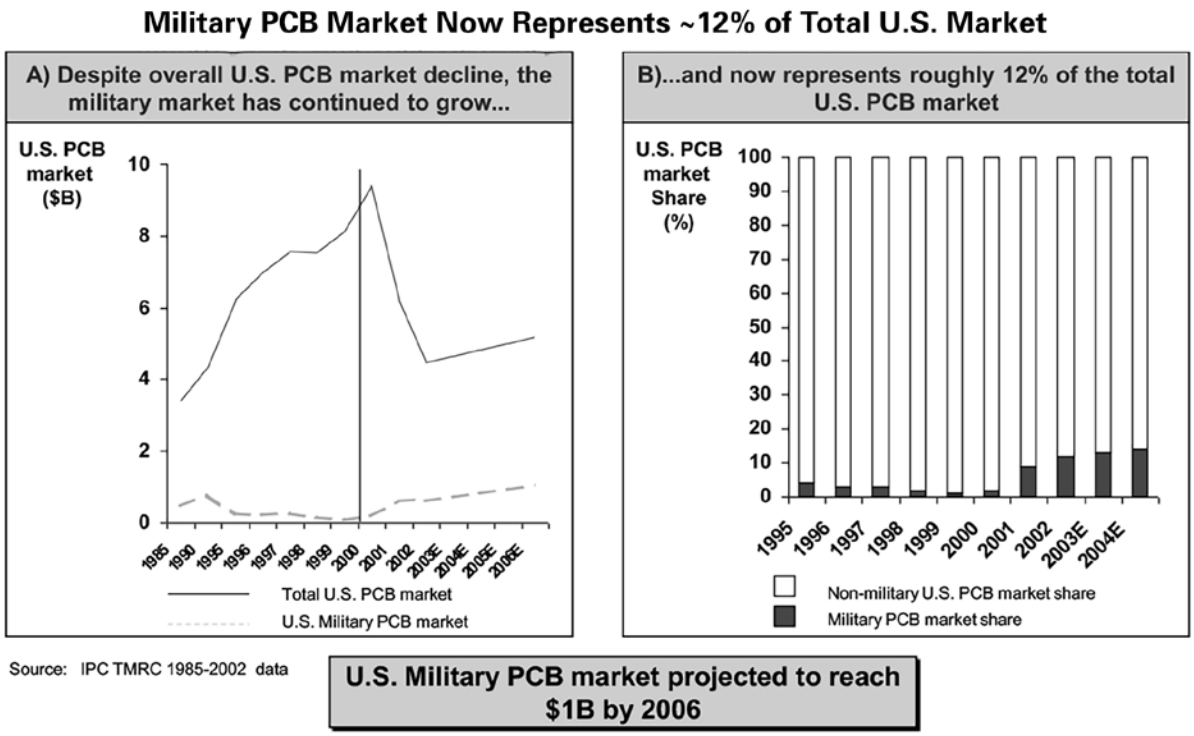


Figure 2: While the overall PCB market has declined dramatically, the military market has continued to grow.

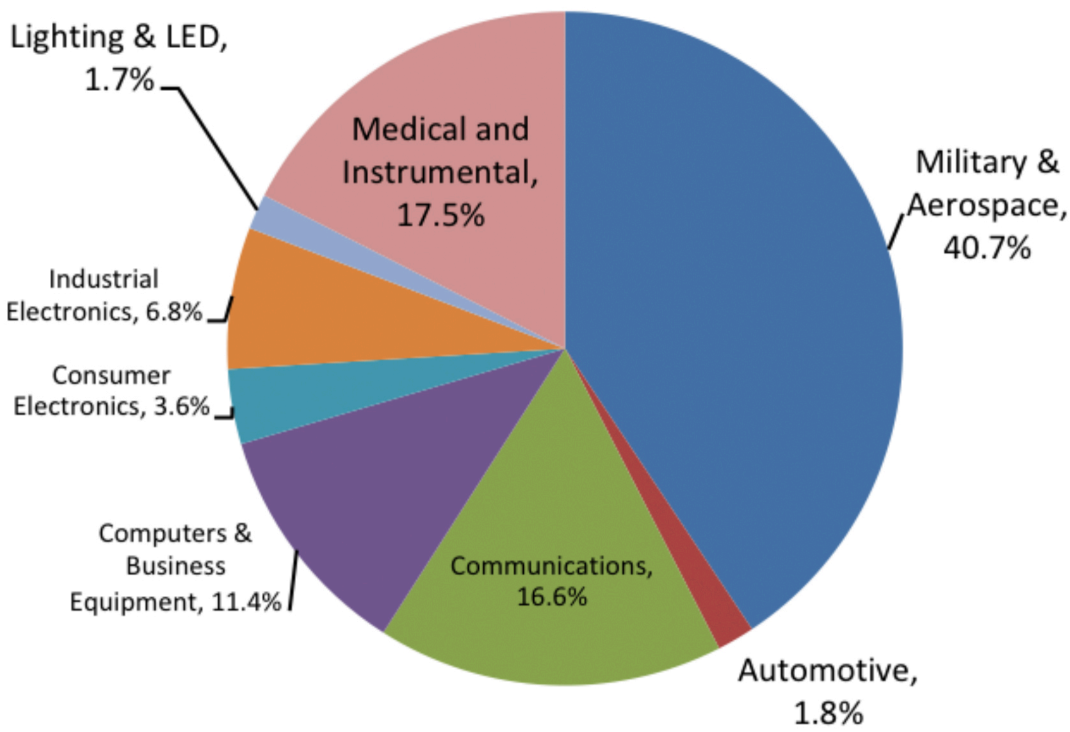


Figure 3: U.S. vertical PCB markets by reporting companies 2017. (Source: IPC)

an annual basis, IPC collects and generates the past and present military-aerospace percent of the U.S. PWB market. Figure 2 represents this IPC data in 2003, and Figure 3 shows the same for 2017. In the 15 years since 2003, the percentage of the U.S. PWB market has increased from 12% (Figure 2) to 40% (Figure 3). The part of this 40% milaero market share that requires certification to MIL-PRF-31032, obviously, is a sector that is worth investigating if you are not already certified today.

2. Effects of the Costs of Military Certification

What resources are required to be certified to MIL-PRF-31032? High costs could play a role in retaining certification or initiating this activity.

Having completed the initial certification for three different companies, I have a good understanding of the initial investment. This initial work consists of writing documentation (quality management plan), third-party testing, self-auditing, DLA site audit, and the resulting DLA corrective actions. This will require approximately six man-months using a resource with an experienced background in quality.

Third-party testing test costs depend on how many material types you are trying to certify. Most sites start with their two main types. Costs run to about $1,700 for each material type. The site self-audit, DLA audit, and audit corrective actions add another man-month. Assuming $5,000 per month, the total initial certification expense would be as follows: 7MM x $5,000/month + 2X $1,700 = $35,000 + $3400 = $38,400.

Ongoing certification consists of third-party audits and DLA required reporting. This takes one-half the time of a full-time quality professional. Therefore, six months x $5,000/month represents an ongoing cost of $30,000 per year. Ongoing third-party testing for two materials is approximately $12,000 per year. The total ongoing cost of $42,000 per year ($30,000 + $12,000) is obviously something to consider, especially for a smaller company where it could prohibit initial and/or ongoing certification. Overall, since these entry and ongoing costs have not changed since 2003, they realistically did not affect the number of PWB companies certified to MIL-PRF-31032.

3. Effect of Military Product Requirements (Military Specifications or IPC Industry Standards)

When they think of PWBs built for the military, many people associate them all with military specifications. This is not a conclusion that should be assumed. Certainly, we have many military PWBs that require MIL-PRF-31032, MIL-PRF-55110, or MIL-PRF-50884; however, based on data collected over many years, many of them are built to IPC/industry standards.

With the magnitude and the ever-changing military contracts, it would be quite a challenge to determine what percentage require military specification requirements. From experience, the more the contract supports strategic U.S. defense, the more likely the fabrication requirements are pure military. Such contracts often require 100% of the boards to meet military specifications. The extent of boards that require MIL-PRF-31032, MIL-PRF-55110, or MIL-PRF-50884 is a critical factor of the analysis of certification investment, potential market share, and associated payback.

Data collected over the last 7–8 years for general military boards from various contracts indicates the percent that requires fabrication to military specifications varies between 5% and 12%. I see no downward trend in such percentages, and therefore, do not consider it a major factor in the reduction of military PWB suppliers over the last 15 years. An in-depth study of these percentages would be welcome.

Therefore, if you consider initial certification or re-certification to MIL-PRF-31032, you must complete a detailed analysis of each potential military part number you might build and determine if its fabrication and test specification is commercial or military.

4. Effects of Profit Margins

Only accountant experts could detail the ongoing profit margins in the last 15 years for military PWBs; however, in general, they tend to be higher than commercial products since there is limited capacity to build them. With military demand increasing from 2003 to 2018, it is reasonable to assume the profit margins are acceptable and is not a negative factor in the number of companies certified to military specifications.

5. Effects of PWB Company Consolidations

Has the change of PWB fabrication sites to multi-company ownership had an effect on the number of locations certified to build military products? If such consolidations closed sites, it may have. However, in general, such consolidation changed the site names and ownership but did not result in any significant number of closures. Note: Viasystems closures happened before 2003.

6. Effects of the Closed PWB Manufacturing Sites

A review of the U.S. PCB suppliers from 2003 to 2018 shows a decline from 567 to 226 companies (Figure 4). This 60% decline is higher than the 49% drop in MIL-PRF-31032 certified facilities in this same 15 year period. Losing these 341 U.S. bare board suppliers is the main factor for the decline in military-certified companies. It's almost certain that of the 226 remaining U.S. PWB fabricators in 2018, a dozen or more are still in business because they were military-certified.

If this loss of U.S. PWB fabricators was random and truly the root cause of reduced certified sites, we should expect the percentage of all U.S. PWB manufacturers military-certified to be about the same in 2003 and 2018. In 2013, that percentage was 18% (102/577). In 2018, that percentage increases to 25% (57/226) but nearly the same. Note: The actual number of companies to make 2018 the same percentage as 2003 would be the removal of 16 certified from 2018 (Figure 5). Perhaps military certification saved all 16 from closing.

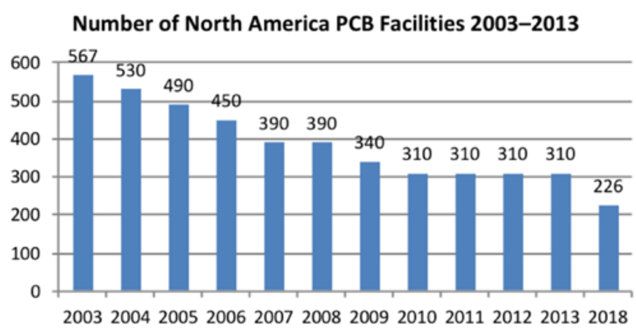


Figure 4: Decline in North American PCB facilities, 2003-2013. (Source: Electronics 360, Semiconductor Supply Chain, James Carbone, IPC 2018)

Summary

Hence, with the growth in the U.S. Military spending up 36%, no change in the cost of certification, the increased percentage of the U.S. Military/aerospace PWB market to over 40%, a 40–50% reduction in the in number of certified PWB manufacturing sites, and continued increasing use of electronics for warfare, the remaining certified fabricators now share in a bigger and bigger total military market. All of this has made the opportunity for new PWB fabrication sites to be military-certified extremely positive and better than it has ever been.

Policy Implications and Future Considerations

Here are three questions for the remaining 226 U.S. PCB fabricators:

1. Is the reduction in certified suppliers a problem for DLA, or is it a benefit because of more stable profitable remaining players and more efficient management of their resources?
2. DLA has never pushed to certify anyone. Should they change and push to certify more? Perhaps if the present capacity is hampering the DoD's ability? Is it even possible? Are there enough fabrication sites out there to matter? Are there any non-military certified suppliers today that need/want a new market segment?
3. Do defense contractors desire more certified sources? Perhaps for more competition or perhaps not for the added cost of supplier management?

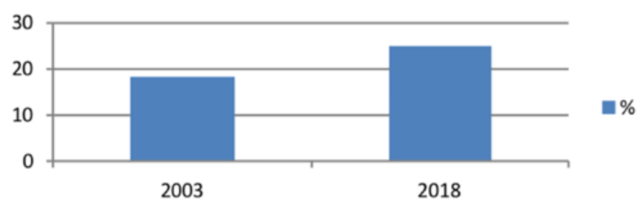


Figure 5: PWB military certification 15-year overall summary (2003-2018).

DLA's response to the previous three questions is as follows:

"The number of certified PWB suppliers today is basically adequate for the demand, but we continue to certify new suppliers as requested for basic items or specialty products. PWB sites certified to MIL-PRF-31032 require a lot more DLA management resources as compared to the historical MIL-PRF-55110 and MIL-PRF-50884. However, today, DLA has these resources."

In fact, as of April 2019, two additional PWB suppliers were added to the DLA list of MIL-PRF-31032 certified sites. **PCB007**

Mike Hill is president of MIL-Q-Consulting LLC. He has been in the PWB fabrication industry for over 40 years. During that time, he participated in specification writing for both IPC and the military. Past employers include ViaSystems, Colonial Circuits, and DDi. To read past columns or contact Hill, click here.

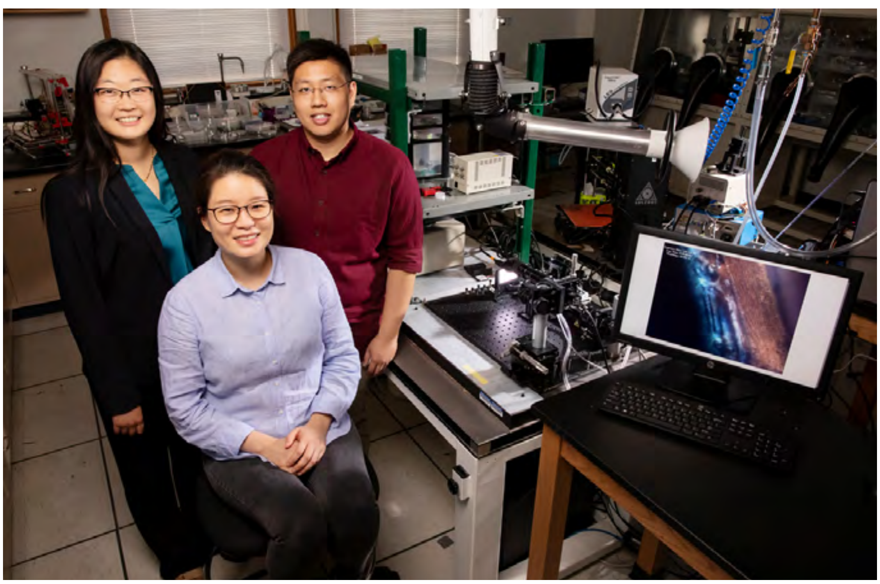
Printing Flattens Polymers, Improving Electrical and Optical Properties

A research team led by chemical and biomolecular engineers from the University of Illinois at Urbana-Champaign (UIUC) have found a way to use polymer printing to stretch and flatten twisted molecules so that they conduct electricity better. The findings are published in *Science Advances*.

Conjugated polymers are formed by the union of electron-rich molecules along a backbone of alternating single and double chemical bonds. The conjunction allows electricity to travel very quickly through a polymer, making it highly desirable for use in electrical and optical applications. This mode of transporting charges works so well that conjugated polymers are now poised to compete with silicon materials, the researchers said. However, these polymers tend to contort into twisted spirals when they join, severely impeding charge transport.

It is possible to flatten conjugated polymers by applying an enormous amount of pressure or by manipulating their molecular structure, but both techniques are very labor-intensive, said chemical and biomolecular engineering professor Ying Diao, who led the study. "There really is no easy way to do this."

Postdoctoral researcher Kyung Sun Park and graduate student Justin Kwok noticed something while running printing experiments and flow simulations in Diao's lab. Polymers go through two distinct phases of flow during printing. The first phase occurs when capillary action pulls on the polymer ink as it begins to evaporate, and the second phase is the result of the forces imposed by the printing blades and substrate.



They also discovered a third phase, which occurs in between the two already-defined phases, and shows the polymers being stretched into planar shapes. The polymers stretched and flattened in this third phase, but they also remain that way after precipitating out of solution, making it possible to fine-tune printer settings to produce conjugated polymers for use in new, faster biomedical devices and flexible electronics.

(Source: UIUC)

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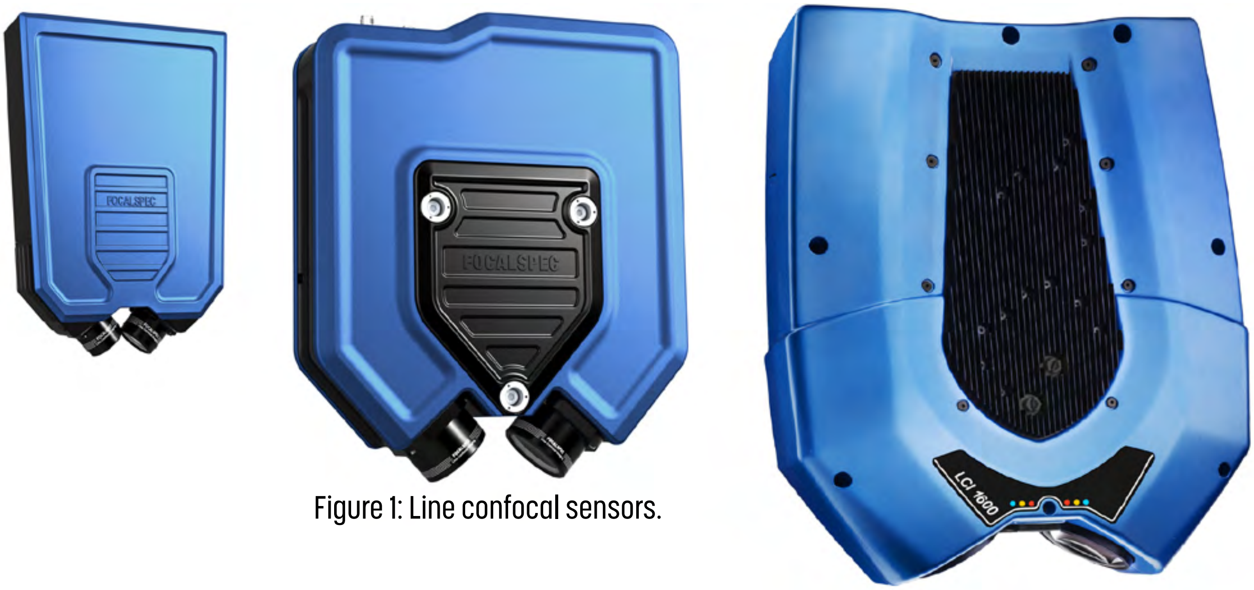


Figure 1: Line confocal sensors.

New High-speed 3D Surface Imaging Technology in Electronics Manufacturing Applications

Article by Juha Saily
FOCALSPEC INC.

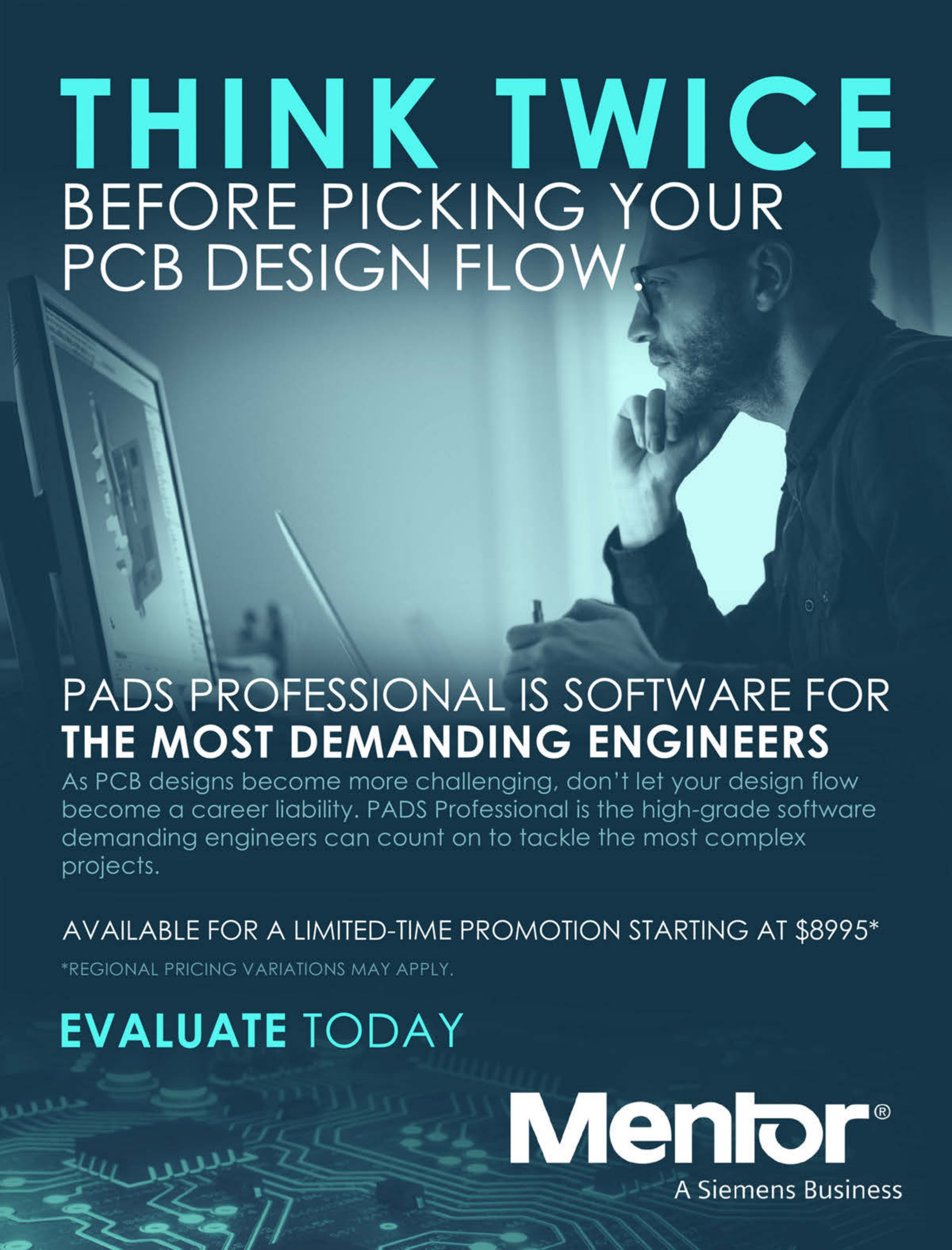
Introduction

Line confocal sensors—and scanners based on them—are used in the imaging of surfaces, transparent materials, and multi-layered structures in various metrology and inspection applications on discrete parts, assemblies, webs, and other continuous products. Examples of well-suited applications for line confocal technology include glossy, mirror-like, transparent and multi-layered surfaces made of metals (connector pins, conductor traces, solder bumps, etc.), polymers (adhesives, enclosures, coatings, etc.), ceramics (components, substrates, etc.) and glass (display panels, etc.). Line confocal sensors operate at high speed and can be used to scan fast-moving surfaces in real-time as well as stationary product samples in the laboratory.

Imaging results can be used to characterize a product's dimensions, form, surface topography, surface roughness, flatness, thickness, and 3D volume. The line confocal method also has a tomographic functionality, which enables the capture of 3D structures under transparent layers, as well as the simultaneous acquisition of 2D gray-scale (intensity) images from single or multiple surfaces with a large depth of focus covering the sensor's entire Z range (up to 5.50 mm).

Line Confocal Method

Figure 1 shows the line confocal sensor models that are currently in production. Each sensor has two front lenses—one for its transmitter and another for the receiver.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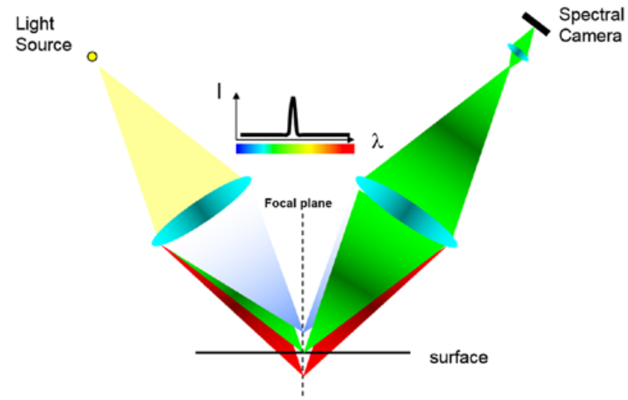


Figure 2: Line confocal method principle.

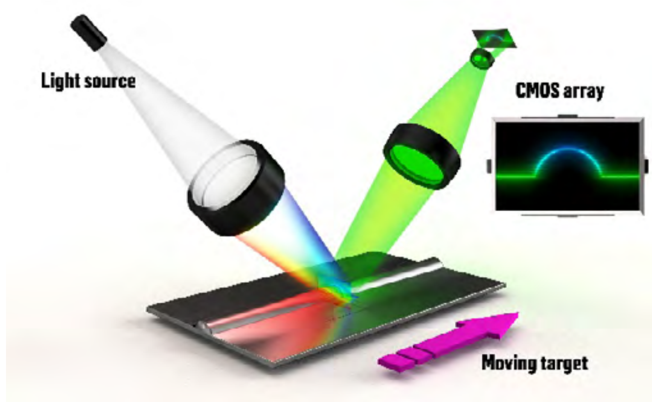


Figure 4: Line confocal method principle.

Figure 2 depicts the sensor's operating principle. The transmitter has a light source that emits white light containing all visible wavelengths. An optical assembly separates the light into wavelengths and focuses each color at a different distance from the sensor, forming a focal plane (Figure 3).

Depending on the vertical position of the imaged surface within the plane, corresponding wavelengths from 2,048 lateral points are reflected back to the sensor's receiver. The receiver's spectral camera captures wavelength and intensity information from each point to form related height and gray-scale profile lines. When the surface is moved in front of the sensor (Figure 4), a 3D point cloud and 2D gray-scale image are generated from the scanned area line by line. The resulting data can be processed, analyzed, and reported with various 3D surface analysis and image processing software packages.

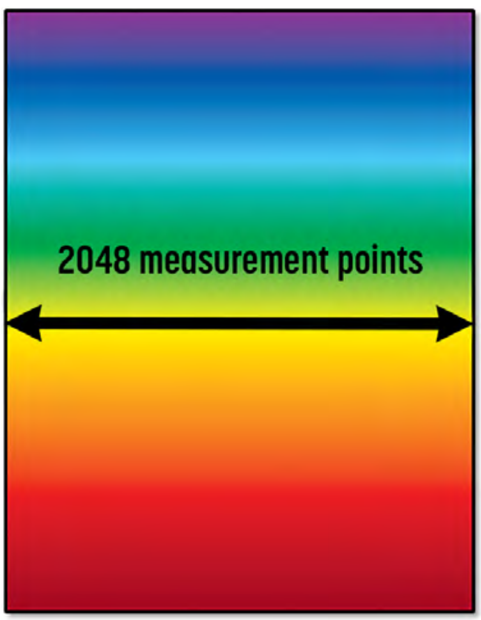


Figure 3: Focal plane.

Line Confocal Method Imaging Capabilities

The line confocal sensors and systems work well in applications that require high-speed imaging of challenging materials at sub-micron resolution. Scanning an area that would require minutes or hours for traditional 3D imaging methods, such as point confocal or interferometric technologies, can be completed within a few seconds.

Transparent materials and products with highly reflective or mirror-like surfaces are ideal for the line confocal method. The sensors' large numerical aperture and high tolerance for surface angle allow for imaging of steep slopes and glossy curved surfaces. This method does not suffer from speckle noise; this enables surface imaging at a much higher resolution than laser triangulation sensors.

The quality of the raw image data produced by the line confocal sensors is good and rarely needs filtering or other manipulation of any kind. Since the sensors capture 2,048 measurement points simultaneously, the vibration of the imaged surface or the sensor itself seldom causes issues; relative point height positions within the measurement profile line remain unaffected.

Example 1: 3D Imaging of PCBs

In this imaging example, a section of rigid PCB with fine lines at the top (Figure 5) was scanned to characterize the width, height, cross-sectional area, and surface roughness of conductor traces (Figures 6 through 16). The scan was performed with a table-top scanner. A line confocal sensor mounted on the production line can capture similar 3D profiles from a moving surface for automated real-time analysis.

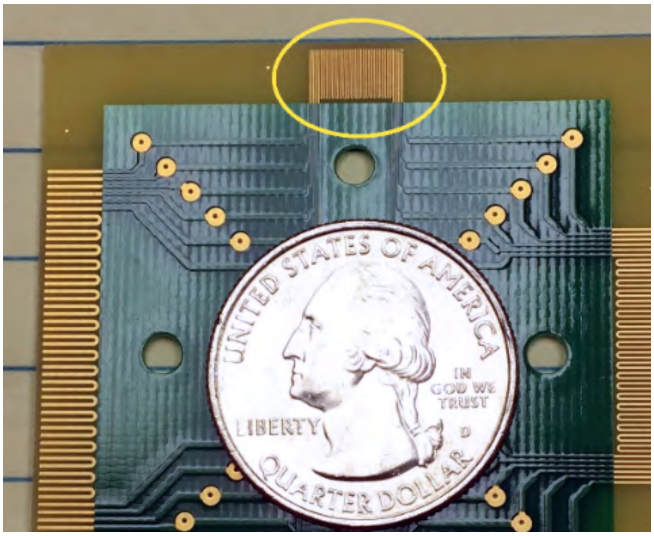


Figure 5: Scanned area with fine lines.

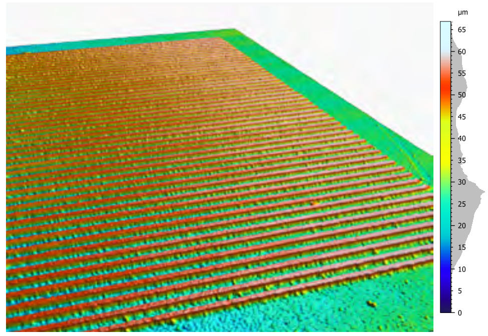


Figure 7: 3D view of the surface.

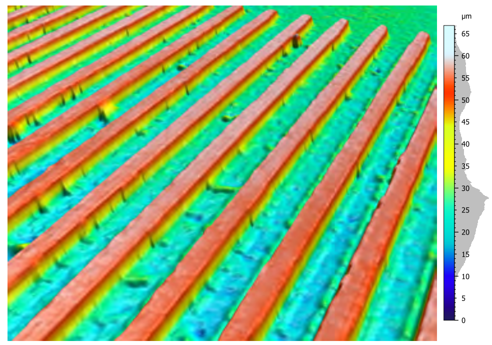


Figure 8: Zoomed-in 3D view of the surface.

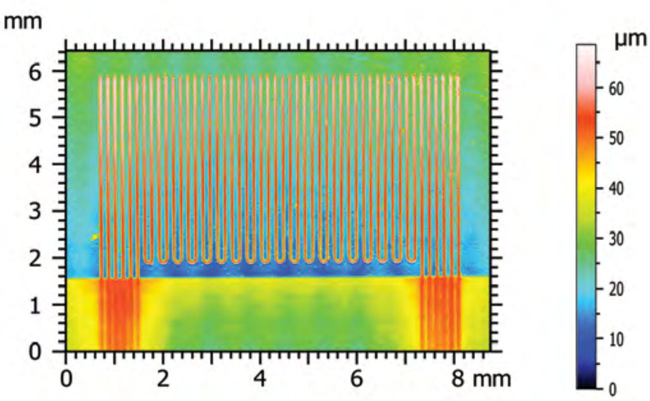


Figure 6: 2D pseudo-color view of the scanned area.

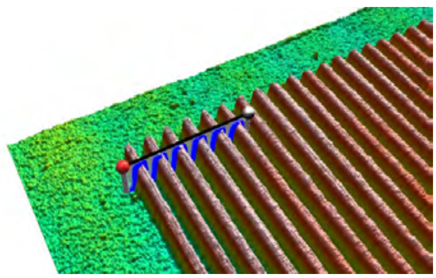
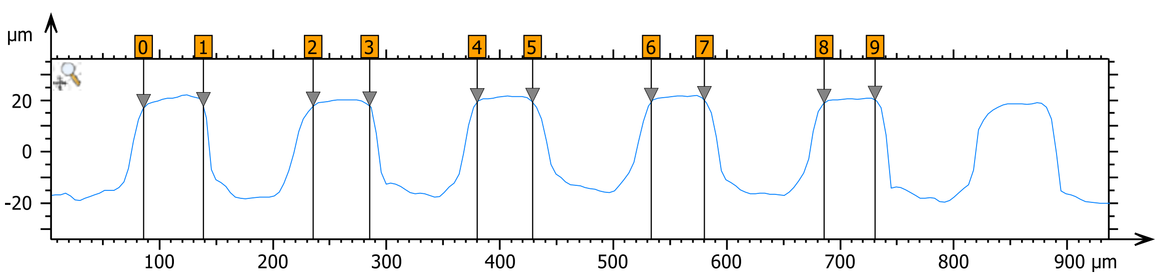
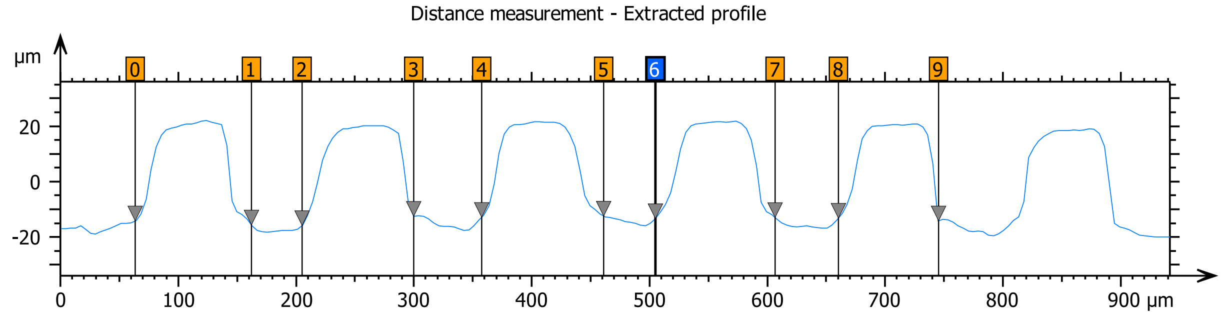


Figure 9: Extracting a cross-sectional profile.



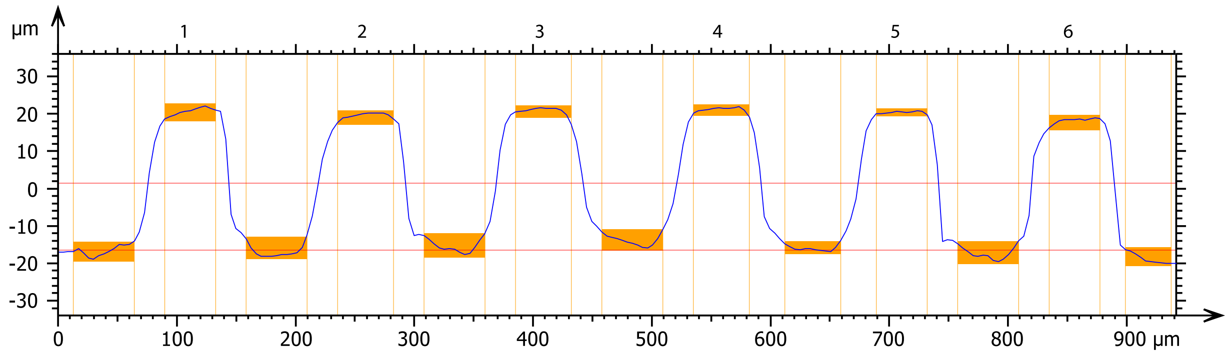
Parameters	Unit	0-1	2-3	4-5	6-7	8-9
Horizontal distance	µm	52.8	49.8	48.8	46.9	44.9
Height difference	µm	0.774	0.0722	0.102	0.700	1.20

Figure 10: Trace width measurement at the top from the extracted profile.



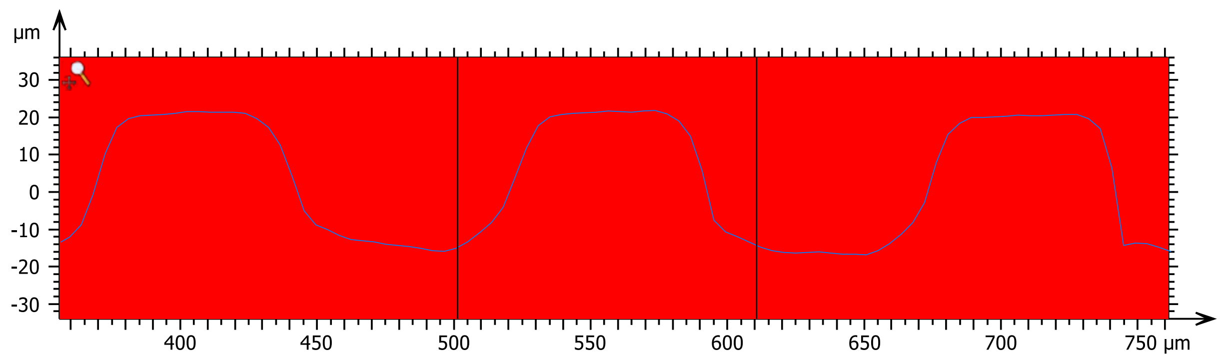
Parameters	Unit	0-1	2-3	4-5	6-7	8-9
Horizontal distance	µm	98.7	94.8	104	102	85.0
Height difference	µm	-1.46	3.33	0.435	0.418	-0.991

Figure 11: Trace width measurement at the foot.



Parameters	Unit	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Width	µm	42.8	47.1	47.1	47.1	42.8	42.8
Maximum height	µm	38.6	36.7	38.1	38.4	37.2	35.5
Mean height	µm	37.1	36.1	37.5	37.7	36.9	34.7

Figure 12: Trace height measurement.



Parameters	Value	Unit
Maximum height	36.8	µm
Area of the peak	2572	µm²

Figure 13: Measurement of a trace's cross-sectional area.

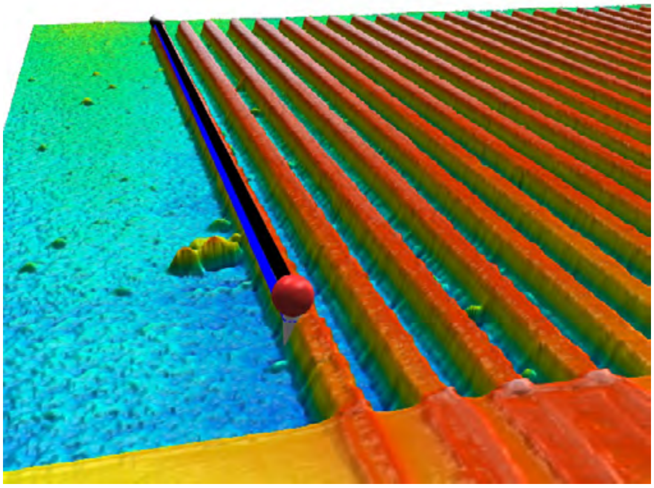
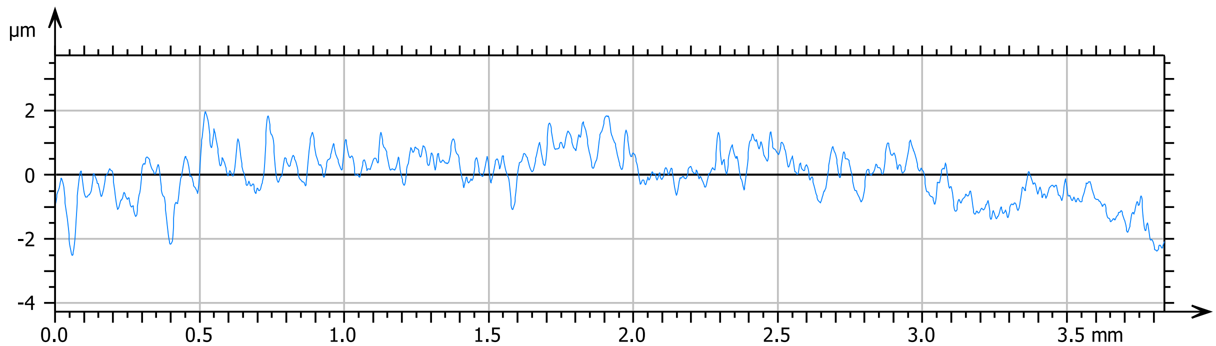


Figure 14: Extracting copper surface profile from a single trace.

ISO 4287			
Amplitude parameters - Roughness profile			
Rp	1.34	µm	*Gaussian filter, 0.8 mm*
Rv	1.54	µm	*Gaussian filter, 0.8 mm*
Rz	2.88	µm	*Gaussian filter, 0.8 mm*
Rc	1.23	µm	*Gaussian filter, 0.8 mm, ISO 4287 w/o ame...*
Rt	3.89	µm	*Gaussian filter, 0.8 mm*
Ra	0.402	µm	*Gaussian filter, 0.8 mm*
Rq	0.514	µm	*Gaussian filter, 0.8 mm*
Rsk	0.000311		*Gaussian filter, 0.8 mm*
Rku	3.40		*Gaussian filter, 0.8 mm*
Material Ratio parameters - Roughness profile			
Rmr	4.93	%	*c = 1 µm under the highest peak, Gaussian...*
Rdc	0.831	µm	*p = 20%, q = 80%, Gaussian filter, 0.8 mm*

Figure 16: Roughness measurements from the extracted profile.



Parameters	Value	Unit
Length	3.84	mm

Figure 15: Extracted surface profile.

Example 2: 3D Imaging of Printed Features and Substrates in Printed and Flexible Electronics Applications

The line confocal method works well in characterizing multi-material high-contrast surfaces that are typical in printed electronics products. The system's capability to image clear, highly reflective substrates with non-transparent and often matte conductive inks with the same parameter settings in a single pass speeds up scanning and analysis of the entire product.

Figures 17–25 show a sequence to measure ink height (thickness) and width, gap width between traces, substrate radius, and thick-

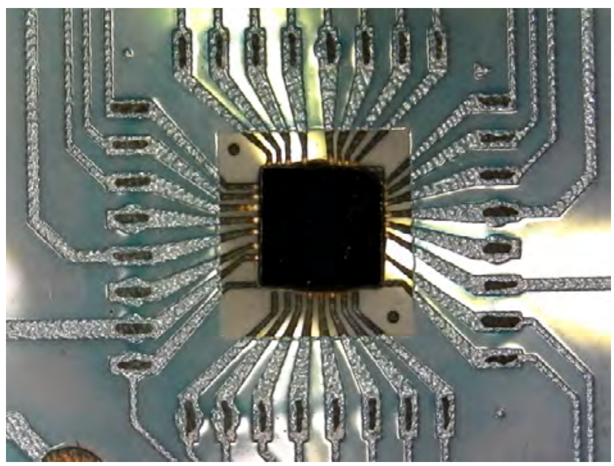


Figure 17: Digital microscope photo of the scanned area (note the tinted dielectric coating and reflections that are often a challenge for camera-based inspection systems).

ness/height of the dielectric coating in a flexible hybrid electronics circuit with a die. Silver traces are shown on a clear, glossy substrate. A 2D gray-scale image from the scanned surface and additional 3D scans show 0.004" silver lines and printed pads for a 0402-size component are included as well.

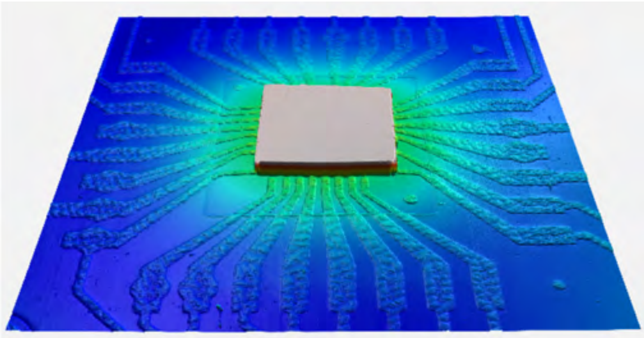


Figure 18: 3D view of the scanned area.

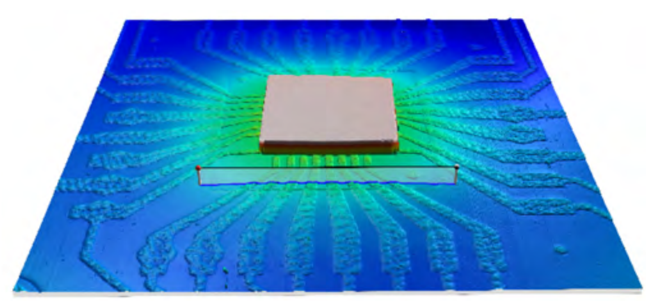
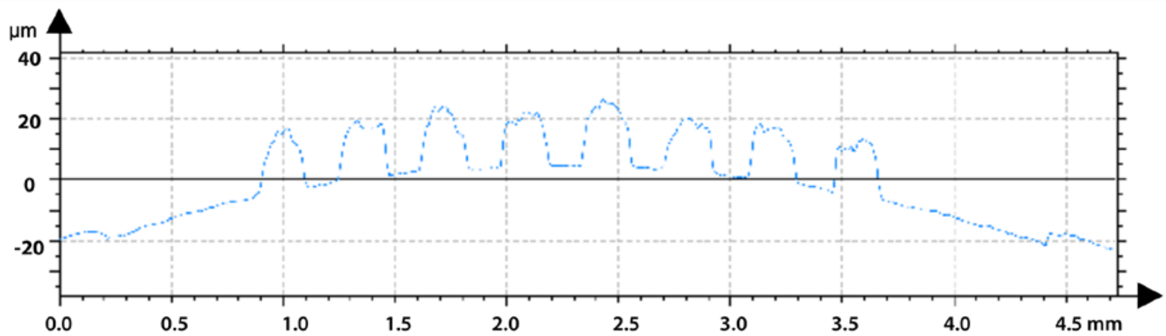


Figure 19: Extracting a cross-sectional surface profile.



Parameters	Value	Unit
Length	4./3	mm

Figure 20: Profile that can be used to determine trace height, width, and shape; gap width; radius of the substrate; and height of dielectric coating at the edges of the profile.

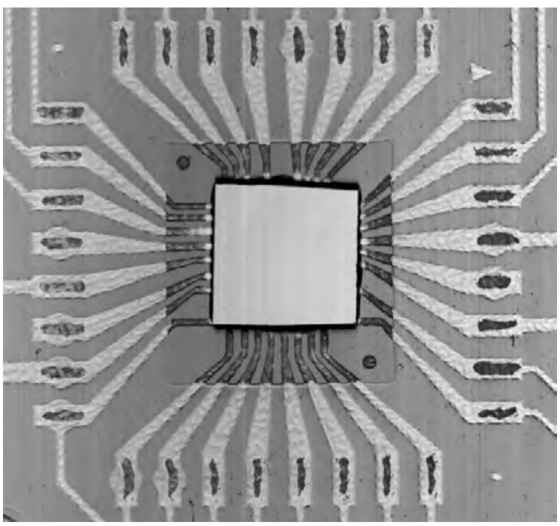


Figure 21: Line confocal method sensors simultaneously capture 2D gray-scale image from the scanned area with a large depth of focus and without unwanted reflections.

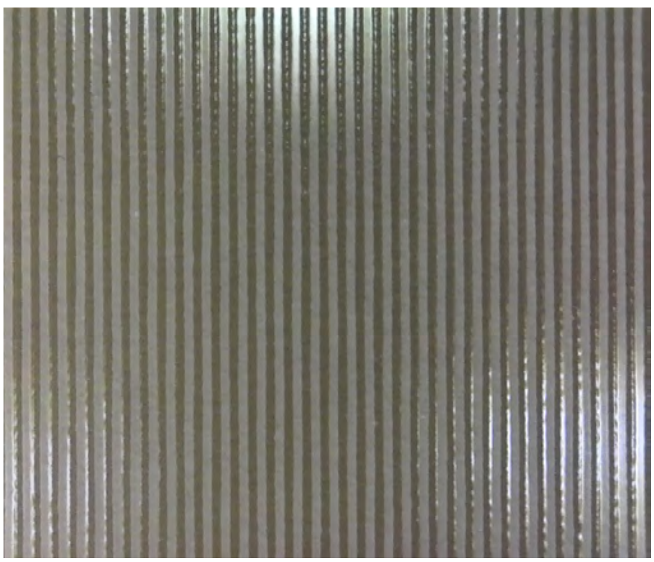


Figure 22: Microscope photo of 0.004" printed silver lines with 0.006" spacing.

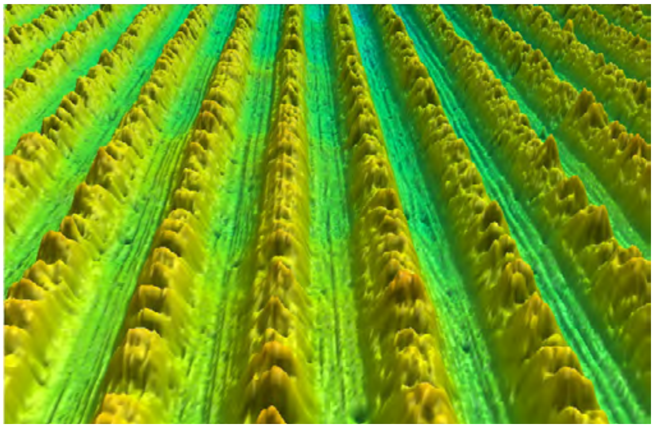


Figure 23: Zoomed-in 3D view of the lines.

Figure 25: 3D view of the pads.

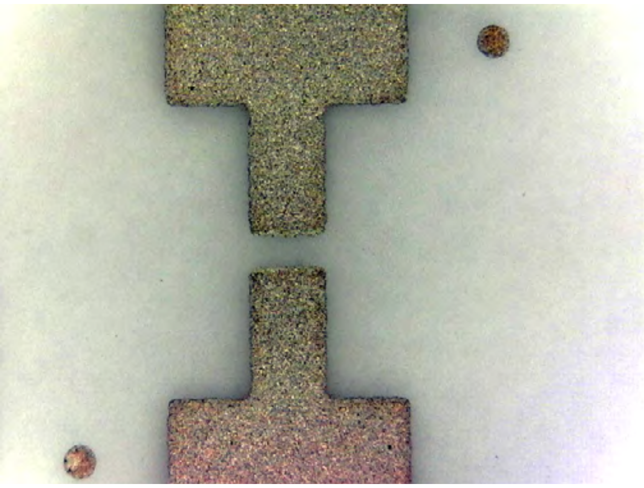


Figure 24: Microscope photo of landing pads for a 0402-size component.

Example 3: 3D Imaging of Adhesives and Other Dispensed Materials

The line confocal method can be used to image transparent, translucent, and opaque structural and pressure-sensitive adhesives in liquid, paste, and solid forms. Shape, size, cross-sectional area, height, width, volume, surface roughness, and position of glue dots and lines can be measured with the system's sensors. The technology works equally well on sealants and other dispensed materials. Materials can be characterized by the system's sensors both in laboratory and production conditions in real time.

The technology works well in challenging applications, such as imaging transparent glue dots on transparent or mirror-like surfaces. Figure 26 shows a 3D view of an approximately 85-µm high bead of transparent cyanoacrylate glue on a glossy transparent glass substrate. The bead was scanned with a line confocal sensor. Figure 27 depicts a 2D top view of the same bead with its automatically calculated volume and height values.

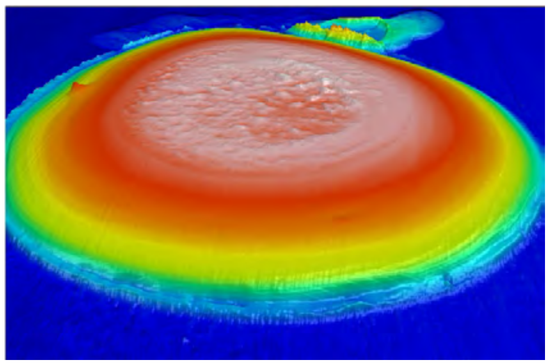
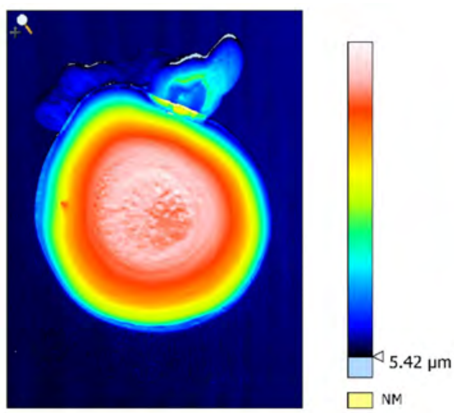


Figure 26: A bead of cyanoacrylate glue on a glass surface.



Parameters	Stat.	Value	Unit
Volume	Max	451483066	µm³
Max height	Max	85.8	µm

Figure 27: Volume and height of a glue bead.

Conclusion

This article introduced line confocal technology that was recently developed to characterize 3D features of various surface types at sub-micron resolution. This technology enables automatic microtopographic 3D imaging of challenging products and materials that are difficult or impossible to scan with traditional methods, such as machine vision or laser triangulation. Examples of suitable applications for line confocal imaging include highly reflective, mirror-like, transparent, and high-contrast parts, assemblies, and continuous products. The operational principle of the line confocal method and its strengths and limitations were discussed, and three metrology applications for the technology in electronics product manufacturing were examined.

Several line confocal sensor models are currently in production and commercially available for use in real-time metrology and inspection applications that require different resolution and field of view. A new bench-top tool that can be equipped with a desired line confocal sensor model is also available. PCB007

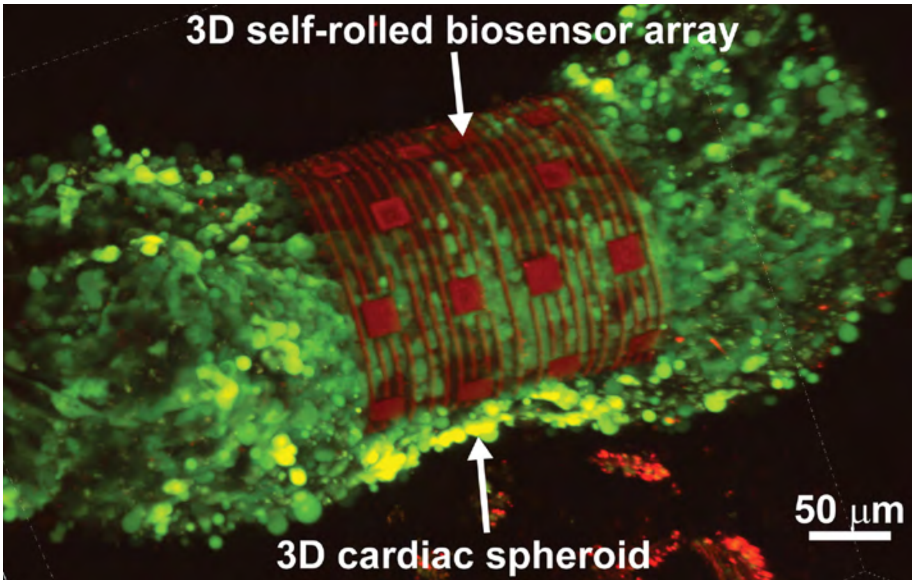
This paper was first presented at the IPC APEX EXPO 2019 Technical Conference and published in the 2019 Technical Conference Proceedings.

Juha Saily is sales manager at FocalSpec Inc. in Santa Clara, California, USA.

Self-rolling Sensors Take Heart Cell Readings in 3D

Researchers from Carnegie Mellon University (CMU) and Nanyang Technological University (NTU) in Singapore have developed an organ-on-an-electronic-chip platform, which uses bioelectrical sensors to measure the electrophysiology of the heart cells in three dimensions. These 3D, self-rolling biosensor arrays coil up over heart cell spheroid tissues to form an "organ-on-an-electronic-chip," thus enabling the researchers to study how cells communicate with each other in multicellular systems, such as the heart.

The organ-on-e-chip approach will help develop and assess the efficacy of drugs for disease treatment—perhaps even enabling researchers to screen for drugs and toxins directly on a human-like tissue rather than testing on animal tissue. The platform will be used to shed light on the connection between the heart's electrical signals and disease, such as arrhythmias. The research, published in *Science Advances*, allows the researchers to investigate processes in cultured cells that currently are not accessible, such as tissue development and cell maturation.



The researchers tested the platform on cardiac spheroids, or elongated organoids, made of heart cells. These 3D heart spheroids are about the width of two to three human hairs. Coiling the platform over the spheroid allows the researchers to collect electrical signal readings with high precision. Through collaboration with the labs of Adam Feinberg and Jimmy Hsia, the researchers were able to design a proof of concept and test them on 3D micro-mold formed cardiomyocyte spheroids.

(Source: CMU)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Working With Flexible Circuits

Trouble in Your Tank

by Michael Carano, RBP CHEMICAL TECHNOLOGY

Introduction

Flexible circuits were first introduced as a replacement for wire harnesses. The earliest versions date back to World War II. Today, flex and rigid-flex circuits are filling an important role across multiple industries, including applications in the medical, automotive, and telecommunications fields.

Even though they are a smaller part of the circuit board industry, flex and rigid-flex circuits have been growing in popularity over the last decade, and for good reasons. These circuits are made to be thin, flexible, and durable. However, in addition to the opportunities that come with flex and rigid-flex circuits, there are also challenges. Generally, these occur with the processing part of the technology.

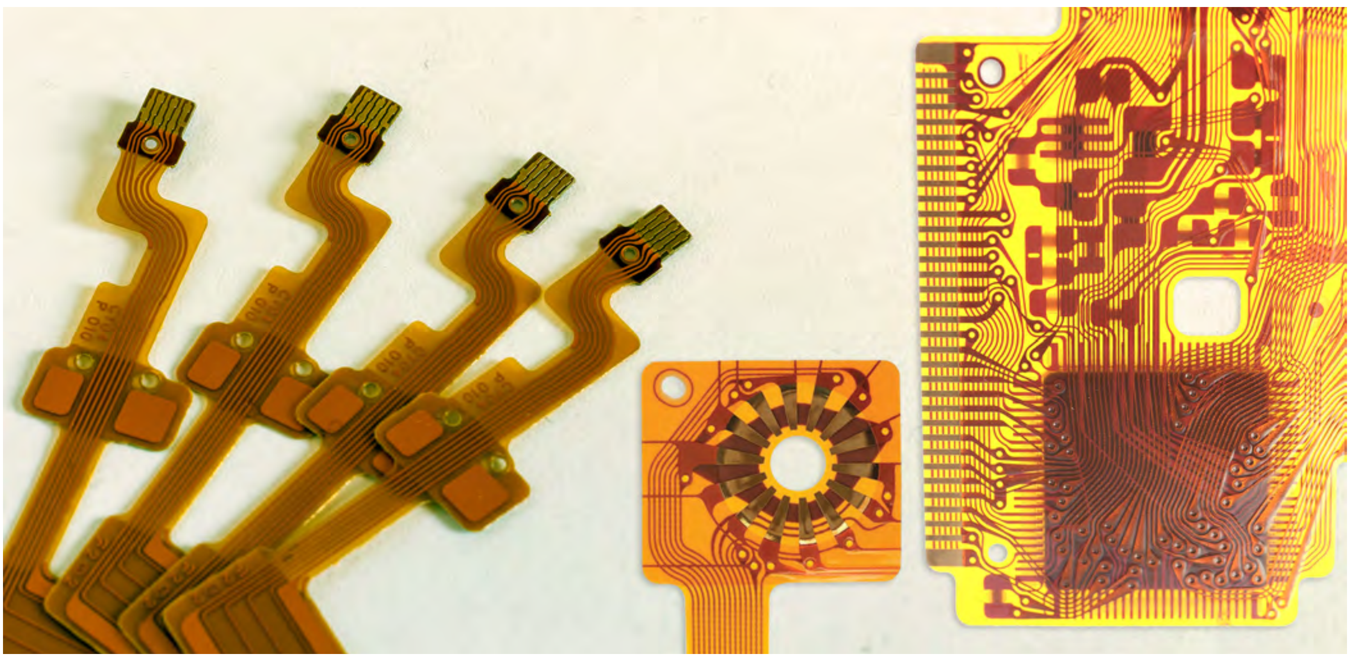
Characteristics of Flex and Rigid-flex Circuits

Flex and rigid-flex circuits have become a go-to solution for a variety of applications because they offer capabilities that simply aren't available from alternatives. They can be manufactured to very thin specifications, and they will survive bending and folding without error. These circuits can be run over long distances to make a connection. For example, some users have designed 14–18-foot flexible cables.

Some of the most sought-after features of flex and rigid-flex circuits include the following:

- Thin-core capability
- Improved dielectric constant
- Low dielectric constant (Dk) and dissipation factor (Df) critical concerns
- Ultra-fine line capable (L/S decreasing to less than 15 microns)
- Shorter interconnect distances

Flexible circuits have the same capabilities of their rigid counterparts, including repeatability, reliability, and high density. In addition, they have characteristics that make them more versatile than rigid circuits. For example,



they are flexible, of course, and can resist vibration more effectively. One of the most popular features of flexible circuits is that they can be designed into three-dimensional configurations.

Rigid-flex circuits combine the best features of flexible and rigid circuits to meet a variety of needs. The rigid areas make it possible to mount stationary components while the flexible areas can be custom configured and serve as protection against vibration.

Despite the fact that flex boards can be extremely thin, they are remarkably durable. These circuits are capable of repeating the same bends through millions of cycles without interruption. This is a critical point when it comes to applications that face intense vibration and/or acceleration.

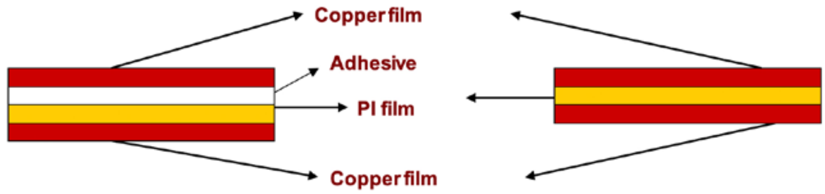


Figure 1: Schematic of a double-sided flexible circuit with adhesive.

Challenges With Flex and Rigid-flex Circuits

The conductors on flex boards are covered with polyimide. This solution offers more complete protection for the circuit than a solder mask. One of the first challenges you are likely to face is the fact that polyimide films are difficult to activate, as they are inert materials. This creates seeding issues with the palladium catalyst. Though they are extremely reliable, getting metallization to adhere and cover polyimide is an issue that must be overcome.

An excellent way to overcome these issues is to either employ a low deposition rate electroless copper or one of the direct metalization systems that are commercially available. Carbon-based systems have been user-friendly and production-proven for difficult to metalize substrates, including flexible circuitry. In particular, graphite-based metalization will easily coat and adhere to a variety of substrate materials. This enables the direct electrodeposition of copper to the conductive pathway provided the very conductive graphite layer. Further, this eliminates adhesion barriers created by electroless copper catalyst (palladium/tin) and the electroless copper deposit itself.

Another challenge you may face is the need to adjust your chemical practices if you are relying on an adhesive base flex. A schematic of a double-sided flex board is shown in Figure 1.

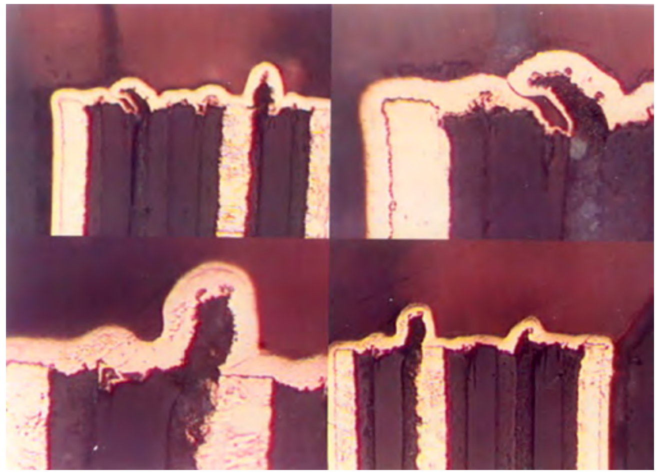


Figure 2: Highly alkaline conditions, causing swelling of the acrylic adhesive.

It is common for adhesives—particularly acrylic adhesives—to falter or completely succumb to attacks when exposed to highly alkaline solutions. If your adhesive flex application is impacted by this issue, you may choose to rely on plasma alone instead of alkaline permanganate. A good example of an attack of the adhesive by strongly alkaline solutions is shown in Figure 2.

In a future column, I will present additional process modifications to ensure the optimum metalization for flexible circuitry. Don't let the challenges of flex and rigid-flex circuits prevent you from enjoying the benefits of this technology. **PCB007**

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

Editor Picks from PCB007

1 Trouble in Your Tank: Moving Into Microvias, Part 4 ▶

In this installment of the column series, Mike Carano talks about the metallization for HDI blind via processing.


Mike Carano

2 EPTE Newsletter: JPCA Show 2019, Part 4 ▶

Many vendors and manufacturers featured test equipment for flexible circuits. It was worthwhile for Dominique Numakura to take a long look at this equipment that evaluates new functional, flexible circuits.


Dominique Numakura

3 The PCB Norsemen: Avoid Failures in PCB Production With Compliance Control ▶

Failures and reliability in the printed circuit industry are usually considered in the context of quality claims and non-conformity. This is a logical approach; however, there is a new context where these aspects are under close scrutiny, namely compliance—especially in the defense industry.


Didrik Bech

4 Testing Todd: What Do You Mean 'Passed' Isn't Enough? ▶

From a reliability standpoint, we need to quickly assess what risk we may have uncovered when faults are detected during electrical test (ET). "Passed" is not always passed. We must be diligent to scrutinize the failures found during routine ET as a high yield may not indicate high reliability.


Todd Kolmodin

5 It's Only Common Sense: Hiring the Best ▶

Here are five tips, including suggested interview questions, to ensure that you hire the best salespeople for your company.


Dan Beaulieu

6 Ladle on Manufacturing: Sunday Afternoon in Dongguan ▶

Every time Marc Ladle comes to China, there is always something new to see. But even with a reasonable amount of prior experience, he has been a little surprised by what he has seen in Dongguan.


Marc Ladle

7 Automotive PCB Market Global Outlook ▶

The global automotive PCB market is expected to reach more than $14 billion during 2018–2024, mainly driven by the rising applicability of rigid-flex PCBs, the penetration of in-vehicle infotainment systems, the arrival of new energy vehicles, and the increased potential of ADAS.

8 Better to Light a Candle: Chapter Four—Next Steps for Developing the Future Workforce ▶

This fourth installment of Marc Carter's column series will give the prospects and status of repeat (perhaps even expanded) classes at Michigan Tech, and report on developing contacts at other prospective university, industry, and government nodes for similar efforts to ensure basic printed circuit technology familiarity of college graduates over the next few years.


Marc Carter

9 TTM Technologies Unveils Executive Transition ▶

Catherine Gridley has joined TTM Technologies Inc.'s executive team as senior vice president and president of the aerospace and defense/specialty (A&D) business unit (BU). She will formally assume the A&D leadership role on January 1, 2020.


Catherine Gridley

10 Punching Out! Mid-2019 M&A Round-up ▶

There have been quite a few deals in North America in the PCB and EMS spaces over the past 12 months. What's remarkable is that so many of these deals involve private equity.


Tom Kastner

Career Opportunities

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- Manage our internal/external CA/PA system
- Manage the RMA process
- Manage the ISO Quality System, including the Internal Audit System
- Manage the IPC, military, Bellcore and customer specs
- Measure quality performance
- Employee training, certification, and performance reviews
- Plan & coordinate audits to ensure controls are in place and maintained to continuously improve product yield
- Set QA compliance objectives
- Other duties as assigned

REQUIREMENTS:

- 5 years managerial experience in PCB operation
- Technical degree or equivalent experience
- In-depth understanding of IPC specifications, military specifications and Bellcore requirements
- SPC, SQC and DOE training/experience
- Able to analyze non-conformance of product
- Effective verbal and written skills
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Career Opportunities

Analyst Programmer, Hong Kong

We believe in caring about our people because they are our greatest asset. CML works with multicultural stakeholders daily to achieve more and bring them the best solutions. That's why we continuously invest in optimizing our culture and focus on providing our team with opportunities to develop their skills (e.g., through professional coaching to achieve their highest potential).

The analyst programmer will assist the IT and ERP manager in Hong Kong to support the company's BI systems, ERP systems, and other related IT-landscape applications.

In addition, this post will participate in system development projects and provide support including, but not limited to, user requirement collection and analysis, user training, system documentation, system support and maintenance, enhancement, and programming.

- Develop and enhance related IT systems and applications
- Prepare functional specifications
- Transfer the relevant business and interface processes into IT systems and other applications to get a maximum automation degree and prepare all required business reports
- Conduct function testing and prepare documentation
- Manage help desk/hotline service

CML is a leading provider of printed circuit boards. We develop tailor-made sourcing and manufacturing solutions for our customers worldwide with strong partnerships and reliable connections.

apply now

APCT, Printed Circuit Board Solutions: Opportunities Await

APCT, a leading manufacturer of printed circuit boards, has experienced rapid growth over the past year and has multiple opportunities for highly skilled individuals looking to join a progressive and growing company. APCT is always eager to speak with professionals who understand the value of hard work, quality craftsmanship, and being part of a culture that not only serves the customer but one another.

APCT currently has opportunities in Santa Clara, CA; Orange County, CA; Anaheim, CA; Wallingford, CT; and Austin, TX. Positions available range from manufacturing to quality control, sales, and finance.

We invite you to read about APCT at APCT.com and encourage you to understand our core values of passion, commitment, and trust. If you can embrace these principles and what they entail, then you may be a great match to join our team! Peruse the opportunities by clicking the link below.

Thank you, and we look forward to hearing from you soon.

apply now

Career Opportunities

Career Opportunities

THERMAL SYSTEMS

Service Engineer Reflow Soldering Systems (m/f)

To strengthen our service team at Rehm Thermal Systems LLC. in Roswell, Georgia, we are seeking candidates to fill the position of Service Engineer—Reflow Soldering Systems.

Your area of responsibility:

- Installation of Rehm reflow soldering systems at the customers' site
- Maintenance and repair work as well as technical service for our customers in the USA and Mexico
- Execution of machine training

Your profile:

- Completed education studies as an engineer in the field of electrical engineering/mechatronics or comparable education (m/f)
- Basic and specialist knowledge in the field of electronics and electrical engineering/ mechatronics
- High willingness to travel and have flexible employment
- Service-oriented and like to work independently

We offer:

- Performance-oriented, attractive compensation
- Comprehensive training
- A safe workplace in one successful group of companies
- Self-responsibility and leeway

Please send application documents online to Natalie Werner at n.werner@rehm-group.com.

apply now

Manncorp™

SMT Field Technician
Huntingdon Valley, 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

Career Opportunities

Events Calendar

EIPC PCB Pavilion @ WNIE Exhibition ▶
September 18–19, 2019
Warwickshire, U.K.

SMTA International 2019 ▶
September 22–26, 2019
Rosemont, Illinois, USA

electronica India 2019 ▶
September 25–27, 2019
Delhi NCR, India

52nd International Symposium on Microelectronics ▶
September 29–October 3, 2019
Boston, Massachusetts, USA

AltiumLive 2019: Annual PCB Design Summit ▶
October 9–11, 2019
San Diego, California, USA

Additive Electronics Conference: PCB Scale to IC Scale ▶
October 24, 2019
San Jose, California 95110

IPC Electronics Materials Forum ▶
November 5–7, 2019
Minneapolis, Minnesota, USA

productronica 2019 ▶
November 12–15, 2019
Munich, Germany

2019 International Electronics Circuit Exhibition (Shenzhen) ▶
December 4–6, 2019
Shenzhen, China

IPC APEX EXPO 2020 ▶
February 1–6, 2020
San Diego, California, USA

Additional Event Calendars

Coming Soon to *PCB007 Magazine:*

OCTOBER: Landscape of the Industry
We examine the current landscape of the electronics industry and how it is changing from design tools to AI, manufacturing, and markets.

NOVEMBER: From My Point of View
Sometimes, the best view into an industry or a community is through individual voices. In this issue, we talk to members of our business community, gathering and sharing their voices and perspectives.

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

SALES MANAGER: **BARB HOCKADAY**
(916) 608-0660; barb@iconnect007.com

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

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

MANAGING EDITOR: **NOLAN JOHNSON**
(503) 597-8037; nolan@iconnect007.com

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

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

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

ASSOCIATE EDITOR: **KIERSTEN ROHDE**
kiersten@iconnect007.com

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

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

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