I-Connect007

MAY 2019

PCB007 MAGAZINE

How Do Your Materials Stack Up?

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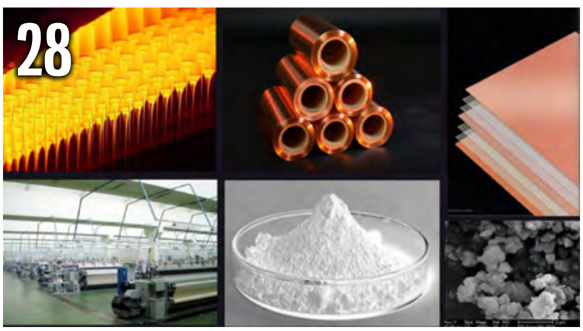
The Materials Issue

How do current materials stack up? We find out. First, we lay down some high-level perspective on materials, megatrends in materials, and economic forces at play in the market. Then, we layer in specifics with materials manufacturers in this our materials issue.



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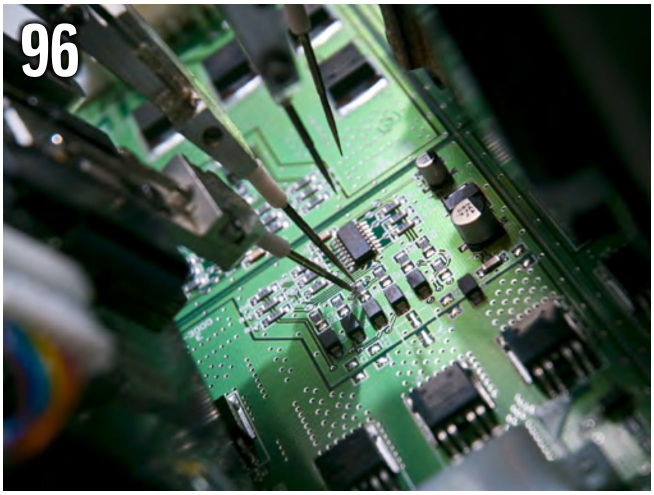


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How Do Current Materials Stack Up?

Nolan's Notes
by Nolan Johnson, I-CONNECT007

Bill Gates once noted that innovation "requires the ability to collaborate and share ideas with other people, and to sit down and talk with customers...get their feedback, and understand their needs."

One might say there are exceptions to Gates' perspective, but even some of the most protectionist of the famous inventors collaborated at some level—if only to build their innovations upon the prior work of others that was then shared. Dean Kamen's Segway product was an innovation kept under wraps during development, but the technology they used pulled heavily from existing capabilities. Thomas Edison, a famously secretive inventor, still had a staff of people throughout his career. I like to think of the famous feud between Edison and Tesla as one of the most dynamic public focus groups ever. The scientific community—and by extension, the engineering community—is built upon collaboration.

There's a lot of talk lately in the electronic hardware side of the industry about changing design constraints and the effect on material selection. OEMs are developing designs to meet new challenges in high-speed and low-loss applications and tolerance to environmental extremes. Designers are feeling that pressure to find solutions as well as fabricators and materials manufacturers, who are the focus of this issue. So, how does one keep up to date?

As Gates suggests, we talk. We see how materials stack up. We ask the experts about what's new, what we need to consider as we select a material for our current project, and who has what. We ask fabricators if they're familiar with the material we're considering. And we spoke with some of the key materials manufacturers—people in the know.

First, we lay down some high-level perspective on materials starting with Alun Morgan's take on the future of PCB materials. Next, columnist Tara Dunn writes about "New Materials or New to You?" Then, we have a conversation with Panasonic's Tony Senese on megatrends in materials. These three pieces deliver a panoramic primer on materials, opportunities, activity, and global economic forces at play in the market.

Next, our conversations get more specific, including discussions with John Andresakis and Jonathan Weldon from DuPont; Ken Parent from Insulectro; TUC America's Alan Cochrane; Sean Mirshafiei from Isola; and a second conversation specific to Panasonic materials with Tony Senese.

Interspersed, you'll find columns from Dr. John Mitchell on industry outlooks, Jan Pedersen on traceability and reliability, Steve Williams on training new employees, Todd Kolmodin on probers and testers, and Mark Ladle takes us on a brisk, poignant customer visit as a traveling engineer.

In addition, we're proud to bring you a tour of Microtek Labs' Chinese facility. Barry Matties and Edy Yu from the I-Connect007 China team spoke with Bob Neves about growing a business in China.

This makes for quite a stack of information on materials. What we learned—and hope you will take away as well—is that understanding the current trends in materials will require everyone from designers to material manufacturers and the entire manufacturing chain to talk, collaborate, and listen to each other to best master these new materials in the real world.

But, after all this seriousness, we should also remember what A.A. Milne had to say about talk. "It is more fun to talk with someone who doesn't use long, difficult words but rather short, easy words like 'What about lunch?'"

May this issue make for engaging lunchtime reading. **PCB007**

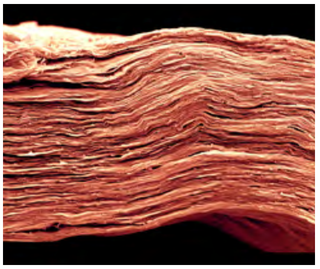
Nolan Johnson is managing editor of *PCB007 Magazine*. Nolan brings 30 years of career experience focused almost entirely on electronics design and manufacturing.

To contact Johnson, click here.

Right Electrolyte Doubles Material's Ability to Store Energy

Scientists at the Department of Energy's Oak Ridge National Laboratory, Drexel University, and their partners have discovered a way to improve the energy density of promising energy-storage materials with conductive, two-dimensional ceramics called MXenes. The findings are published in *Nature Energy*.

Today's batteries offer high energy-storage capacity, but slow charging speeds limit their application in consumer electronics and electric vehicles. Tomorrow's energy-storage mainstays may be supercapacitors, which store charge at the surface of their electrode material for fast charging and discharging. However, they currently lack the energy density of batteries.

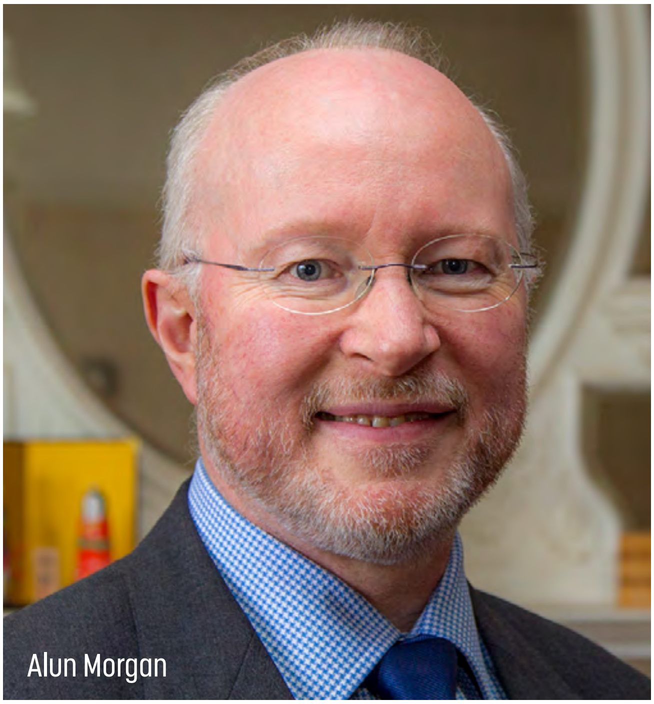


"The energy storage community is conservative, using the same few electrolyte solvents for all supercapacitors," said principal investigator Yury Gogotsi, a Drexel University professor who planned the study with his postdoctoral researcher Xuehang Wang. "New electrode materials like MXenes require electrolyte solvents that match their chemistry and properties."

The surfaces of different MXenes can be covered with diverse terminal groups, including oxygen, fluorine, or hydroxyl species, which interact strongly and specifically with different solvents and dissolved salts in the electrolyte. A good electrolyte solvent-electrode match may then increase charging speed or boost storage capacity.

"Our study showed that the energy density of supercapacitors based on two-dimensional MXene materials can be significantly increased by choosing the appropriate solvent for the electrolyte," added co-author Lukas Vlcek of the University of Tennessee who conducts research in UT and ORNL's Joint Institute for Computational Sciences. "By simply changing the solvent, we can double the charge storage."

(Source: Oak Ridge National Laboratory)


Alun Morgan

Alun Morgan on the Future of PCB Materials

Feature Interview by the I-Connect007 Editorial Team

The I-Connect007 editorial team asked Alun Morgan, technology ambassador for Ventec International Group, to discuss materials at a high level. Our conversation delivered a detailed overview of the current state of the electronics industry. Put industry experts like Alun Morgan, Happy Holden, Patty Goldman, Barry Matties, Andy Shaughnessy, and Nolan Johnson together on the topic of materials, and the results are enlightening, to say the least.

Barry Matties: Thanks for taking the time to speak with us, Alun. We always appreciate the conversation.

Nolan Johnson: Today's topic is materials, and as you know, there's a great deal of demand from automotive, IoT, and other new technologies. These sectors are pushing the limits for designers and materials. We want to investigate what's going on with the development of materials in the marketplace.

Matties: Also, there are so many choices out there. How do people navigate the options and make the proper choice?

Alun Morgan: That's always a challenge. People publish lots of data sheets on new products, so it is difficult sometimes. Right now, there are a few drivers. The last driver was reliability, and the last transition for the past 15–20 years has been to improve reliability. Also, 5G is very hot and an enabler to help us move on with IoT, autonomous driving, etc. Now, we're seeing a huge demand for products that will help enable the 5G rollout and revolution, which is coming towards the end of this year.

Further, 5G brings a lot of issues because of the data rates. An entire infrastructure will have to be built. It's probably the next big roll-out of infrastructure since the technology boom around the late '90s with the huge amount of infrastructure built into the network that we're still using today. There are two parts that concern PCB materials—the dielectric and conductor—and both have challenges with high speed.

Normally, in the digital space, people run 10–20 Gbps fairly routinely, and that can be managed. But once you reach higher speeds and data rates—as we've seen with radar products, for example—then the substrate itself becomes a bit of an issue because the substrate is a dielectric. It can be polarized by high-frequency signals, so if you think back to when they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showed you the north and south poles on magnets in school, north and south poles on magnets, you can align all of these by putting a magnet on the top. If you switch it around, all of the poles switch around the other way.

Alternating current does that all the time; it alternates up and down very quickly. All of these small, polarizable bits in the substrate flick back and forth all the time. Absorbing energy and generating heat is exactly the same way that a microwave oven works. In that case, it's a water molecule that's vibrating back and forth, generating heat. But overall, generating heat is bad in two ways. First, you have to get rid of it, so in big server farms, there's a lot of heat to get rid of because you've generated a lot of extra heat. Second, it saps the signal, so if you put 100 in, 20 will be used for heat and only 80 will be used for the signal. You end up with a loss of signal.

The property we talk about for that is called the dissipation factor, which is a number; it's dimensionless. The dissipation factor in a vacuum is zero, more or less, so you have no loss. And this number continues to rise depending on the kind of material you have and the frequency. There has been a big push to get that number lower and on the substrate side. About the lowest that we know of so far are PTFE materials, which are extremely difficult to polarize because the structure is pretty simple. It's a carbon backbone with fluorine atoms on either side. As fluorine is highly reactive the atoms get as far away from each other as they can, so they form a twisted helix and force themselves in position so that they can't vibrate, which is why PTFE has a very low loss. Materials like FR-4 are very polarizable; they contain moisture and all kinds of things that can be polarized. You end up with orders of magnitude difference in loss, so the drive has been towards that low side.

The other big problem is copper. It has a certain roughness on one side, particularly to stick it to the substrates, you don't want the copper falling off. Typically, in modern circuitry, the copper thickness is 17 microns or one-half ounce, sometimes even less. For a 17-micron foil, the treatment on the back of it can be five or even eight microns, even half of the total thickness can be treated, which is very rough; it's like hills and valleys or a mountain range.

The problem is as you reach higher and higher frequencies, the electrons travel in the outside of the conductor—not through the bulk of it. Even at relatively low frequencies, you find all of the electrons flowing to the outside of the conductor. One side is pretty smooth and flat while the other side is very mountainous and hilly. The electrons have to travel a further distance on the lower side and through a higher resistance path. That compromises signal integrity as well. As you reach a higher frequency, you must have lower profiles on the copper down to submicron level, which is a bit of a challenge on the copper side.

You must also consider the reinforcement in the substrate, which is formed from a resin and a reinforcement. PTFE will most likely be the lowest loss that we have because we normally use glass fibers. Glass fibers are used for reinforcement because they're very stable, hold everything in place, and stop things from moving around. They're pretty inert, so you can process them through wet chemistry and not have them dissolve or become damaged. The problem is that the electrical properties of the resin and glass fiber are quite different.

You might think of the dielectric constant of the resin, and it could be a value in the order of three. The dielectric constant of the glass is at least double that, so around six, and it has a capacitive effect. How much charge can the material carry and hold? Glass holds a lot more than the resin does. If you try to send signals down there with a pair of conductors—like a differential pair—and one of those conductors runs along a bit of laminate with a lot of glass underneath it and another part of the pair runs along a bit that's got a lot of resin underneath it, they see a very different dielectric property of the material. One of those conductors has a significantly slower signal speed compared to the other one, and you wind up with mismatches in the signal integrity.

Johnson: That means designers could have variations in the performance from board to board as they go to higher and higher frequencies simply based on what part of the weave, for example, is in the material underneath.

Morgan: Yes, and the reason for that is the bulk properties are uniform. If you take the average, everything is fine. But using today's very fine conductors, the microstructure underneath is very significant. We're talking about the weave of glass fibers—the actual scale of that weave. You may end up with a trace running in a good or bad area along the board. There are ways to mitigate that, but it is a fundamental problem. As long as there is reinforcement with different electrical properties, you will have this kind of issue. When you design the board, you don't know where the glass is going to lie underneath. When you build the board, you can make the boards one way, and they will be fine. Another day, you'll make them and they won't be fine.

I'll give you a very practical example of that. Some years ago, we had a customer in Ireland making transponders for automotive alarms. He suddenly said, "My boards stopped working. I can't get them to communicate with the car anymore." They thought that somebody had used the wrong material, so they specified the material but used a cheaper material that didn't work. I tested some samples, and the material was fine. But I did notice that the boards had been rotated 90 degrees on the design.

Instead of running against the warp direction of the glass fabric, they were running against the weft direction instead. The warp and the weft, by the way, are the X and the Y directions of the glass fabric, and they have a different density of the weave. That density of weave change was enough to cause the board to stop working. It sounds crazy, but that was enough. They were probably on the edge anyway, but that switch of warp and weft stopped the board from working.

Instead of running against the warp direction of the glass fabric, they were running against the weft direction instead.

Matties: If you're on the edge, what's the next step to break the barrier?

Morgan: Take out the glass. There are materials without glass—unreinforced materials—but the problem you have is that they're not reinforced so you could have stability problems. Polyimide films—flexible films—are done that way. Flexible materials also work that way; they don't have a glass weave in them. You can also attempt to mitigate this by using different kinds of glass.

Patty Goldman: Like flat glass?

Morgan: Yes, that's just a tweak of the edge. I mentioned before that the warp and the weft are very different densities of glass. You can do what's called a square weave and make them the same density. You can play around with that a bit and make it more uniform. You can also spread the fibers out more. The fibers are built in bundles like ropes. And the ropes have hundreds and hundreds of individual glass filaments. So, you end up with a very dense rope of glass with an area next to it of resin, then a dense area of glass again. Imagine those ropes being round. If you can make them flat, you can make them more oblong in shape or elliptical and can spread the fibers out and get a more uniform distribution of fibers, so that's another option.

The next thing you can do is change the properties of the glass. Most of what we use is E-glass—electrical-grade glass; it's the most widely used glass fiber in the world for everything, but it has a certain set of properties. If you change the formulation of the glass, you can tweak some properties and improve things that you want to improve. You can reduce the dielectric constant and loss.

The entire supply chain is making further tweaks, and they'll carry on doing so. The question is, "At what point will this not work anymore?" With copper foil, there are now treatments called ANP, which means "almost no profile," so it's almost no profile—submicron. And if you talk to companies like Circuit Foils, you'll see that they've been developing these for some years and are coming into the market now. We use lower-loss resin, low-loss glass, and flat copper. The so-called "copper crunch" was supposed to be upon us a few years ago, but we're still using copper.

We have to replace copper with something else, though; graphene has been mentioned. Maybe the glass has to come out, and we could have something else in there. The problem is the infrastructure and vested interests are all geared around making boards the way we make them today, so any change will be a gradual change. But it's a great testament to the FR-4 materials that we've been using for over 50 years.

Matties: When you mention the variation of direction on the laminate during board manufacturing, is this something that a designer would be mindful of and call out to ensure that they build in one direction versus another, or is this just random based on their optimal throughput?

Morgan: It's random. The designers have no idea at all. And that's why I love talking to designers and explaining to them that these things matter. Designers are aware of the issue and that there's a bigger problem now, but they don't tend to do much about it. The only solution that I've seen, which is a very poor one, is that they rotate the circuitry around 15 degrees on the panels. Instead of the risk of traces running vertically above or coincidentally with the glass fibers, they always run at an angle across them. You get an average distribution between the two traces of a differential pair. There's no potential for having a very high glass content or very low glass content, which is very wasteful. You waste a huge amount of the real estate on the laminate material because it's square.

Some OEMs will call up and specify glass fabrics that have directionality they can live with or square weave, etc. But many of the people designing boards don't have a clue about these things. The boards may come out fine one time, but they may not another time. My job for the last few years has been to try to explain to designers that these are things they need to be careful of that may impact their design. When they're building tolerances, they should make sure to allow for this as well.

Ventec International Group lab.

Andy Shaughnessy: I don't think a lot of designers worry about the glass weave for most designs. I don't hear them talking about that as often.

Morgan: Many designers don't even know there's glass inside the material; it's a green thing they put their components on. There are two groups: people who are new to design who don't know these things and we need to tell them, and people who have been designing for years who don't know about the latest developments and the things I've been talking about, such as low Dk glass or a spread weave. There's a need to continue the education for experienced designers as well.

Many designers don't even know there's glass inside the material; it's a green thing they put their components on.

Matties: For many years, it didn't matter. They could just build the board, and there weren't any consequences. But today, the demands are so high, and these critical variables are now coming into play.

Morgan: Right. You could get away with everything before. Now, people ask, "What's the best material to use?" There's no such thing as "the best material"; all materials are a compromise, and the ultimate compromise is cost. For years, the military has been using polyimide-based materials, which is a very high thermally performing material. All designs for the military use polyimide because you can go in the field, use a soldering iron to repair it, and it won't fall apart. And that's great, but there are lots of designs now where you're never going to do that. Many designs you can't repair in the field anymore, so the main reason for using polyimide is gone. But the military still specifies it and pays a huge premium for using a material that is way over-specified for their needs.

As Barry mentioned, the problem is that there's so much choice; it's a minefield. The right question to ask is, "You've shown me 100 different products. Which ones do you really sell and are used in the market?" Once you know that, then you can home in on those and start to be sensible about it. Right now, we're discussing another materials evaluation with the High-Density Packaging User Group (HDPUG). We have a list of materials to test, and there are loads of them. OEMs are trying to decide which ones are interesting and they want to have a look at, and they don't know. They're just given names and some kind of basic properties. They don't know whether these are variations on old themes or if they're brand new, or what the chemistry is.

As a designer, I would hate to be in the position of having to choose. I once heard someone say, "Just use the IPC slash sheets," and that is complete nonsense. The IPC slash sheets define a material based on its chemistry, but that has nothing to do with its performance in the modern context. Anybody trying to design purely based on IPC slash sheets is going to fail from the beginning because it doesn't have any relationship to the final properties of the material, which is a huge challenge. When they were designed in the first place, there were three resin systems—phenolic, epoxy, and polyimide—and they were all very different.

If you say epoxy, there is no epoxy in the final material. Epoxy is just a chemical structure—the C-O-C three-atom ring structure—that was present when you formed it. It all reacts, so you end up with a single molecule comprising many component parts that has little to do with epoxy at all. And let's not forget that it's also full of ceramic fillers, flame-retardants, other fillers, etc. Trying to define a material based purely on chemistry just doesn't work anymore, which has made life more difficult for everybody. Now, the industry is crying out for a performance-based or sector-based classification.

For example, automotive people are saying, "I have a requirement for in-cabin for my automobile. Please give me a list of materials and properties that would fit that kind of application," or, "I have a hostile environment. What can I use?" Meanwhile, someone else in aerospace says, "I'm going to send a satellite up into low orbit. Please let me know what kind of materials work for that."

Matties: That makes a strong case for application-specific status sheets or specifications. What will drive that?

Morgan: Groups are doing it now, such as HDPUG, which I mentioned earlier. They're largely a group of OEMs in the data communications space. They've been doing this for years and are up to phase six now. I ran the last two projects for them. They asked each other, "What do we need for the next generation of our products and in terms of material properties?" Then, they put a list down and said, "We need this kind of property, etc." Next, they approach the manufacturer and ask, "We have these requirements. Do you have any products that would fit that requirement? Is there something new coming along?" The manufacturers give them a list of products and respond, "Yes, we have this product we're just developing. Would you like to look at it?"

HDPUG then narrows that list down to between 10–20 products and goes through a rigorous testing regime on a test board. It's called the MRT-6 board, which is developed by Nokia—a very challenging board with many difficult structures for reliability and signal integrity. We put all of the boards through this test vehicle in the same process with the same board shop and then analyze the results. They produce a table for their members of how the materials perform. Then, you can use this data and say, "I see all of these products, and that one matches what I want," and that gives you a shortlist. There are companies that will not use any product unless it has already been through the HDPUG screening process.

You really can't trust all the data on the data sheet of the manufacturers because some of these might be desirable properties, but they don't even reach final production. Many of

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these products that we talk about are newly released, so this is part of the development process. You can't be sure, and you need to test them. I've been trying for years to try to get some commonality, but they have their own test methods and coupons, and they don't use any material until it has passed all of their tests; they don't rely on standards like IPC's, but that's not very efficient for the industry. That's something that some companies might like to do, but it would be far better if the sector said, "We're in automotive and would like to have a set of standards that work for our sector." That's how I would like to see things going, and the same for data communications and hand-held mobile devices, but I don't know how we get there.

Matties: Well, it's the high end that you have to pay attention to.

Morgan: Yes, but the same problem exists elsewhere as well. The high end is driven by performance, and the low end is driven far more by cost, which is also important. I'm most interested in high-end performance, so that's where I'm always working.

Johnson: You laid out a nice list of resources for practical information about materials. How would you recommend that a design team get acclimated as they move into these high-performance materials? Where should they start?

Morgan: What usually happens is a designer goes to their favorite board shop and says, "I want to build this board. What do you recommend?" The board shop decides what material to propose, and they typically propose things they're used to that work with other OEMs. The board shop recommends it because the designer doesn't know. Thus, the board shops carry most of that information, and they're who people go to for specifying materials. That's how it works.

The designer knows them and is going to buy boards from them, so there's a customer-supplier relationship there. The board shop is going to help them out if they can, but they tend to recommend the materials they know best or have used most. However, they may be missing out on some other area, or they don't have a relationship with a supplier who has generated a load of great, new products.

Johnson: So, there is an added responsibility now for the designers to have a better understanding of the materials their designs will be built upon.

Morgan: I think so. And all that I can do is try to help them. The recent AltiumLive 2019 PCB Design Summit was great with all of the designers in there, but designers need to understand that the material interacts massively with their design, and the properties of the material impact the final performance. Many didn't understand that until now. Again, it didn't really matter as much in the past, but people are perhaps waking up to this issue now.

Many of the PCB design software tools now contain material libraries from the suppliers, so you can pull down the loss characteristics, etc., and get that data in there and then design on it, which is fine. The only question is, "Is it really true?" The properties that people publish and the ones that work in designs are not necessarily the same; you have to test them.

Let me give you an example of how these things work. I mentioned before about glass fabric and resins. Resins typically have quite high loss, and glass fabrics have a lower loss. Of the two components, the resin has the highest loss. So, when you specify a value for loss, you put a number down, such as 0.010. We supply a range of material, so if I'm supplying X material to somebody, I can supply that having a resin content around 45%, for example. And I could go as high as 75% resin content on that material.

If I'm quoting loss figures, I test it on 45% resin content because that gives me the best value. And I will get a value of 0.01 at 45% resin content. If I take a board and build that material, for high-end circuitry, it will be probably around 70% resin content. My loss of those materials might be 0.015 ,so 50% higher loss than the tested value. I still call the loss at the lower value because I'm allowed to as the specification sheets say quote the value in the resin content range between 40% and X%.

People choose the material to write the data sheets based on what gives them the best result. Classically, for rigid material, it's 0.5 mm. It has a fixed resin content—50%. You're never going to use that in a final design—that's out of the question—but that's the data sheet values that you're going to find. It's not really cheating because the values are correct, but they're not necessarily the values of the product you're going to receive from the supplier.

Also, there are different ways of measuring these things. Entire projects run on comparing different values. You can measure the loss in three or four different ways and get different numbers, for instance. You can measure different Dk values and frequencies as well; it's not like a melting point of 10. Instead, it's a broad range of numbers, and it depends on how you measure. Therefore, you can't rely on the data

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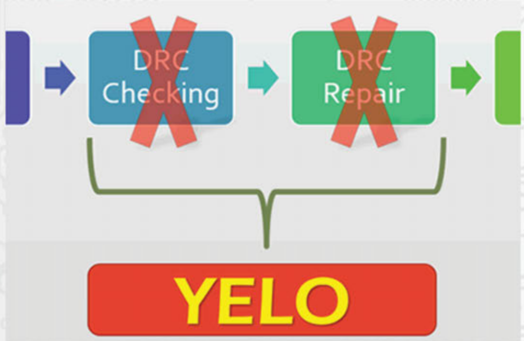

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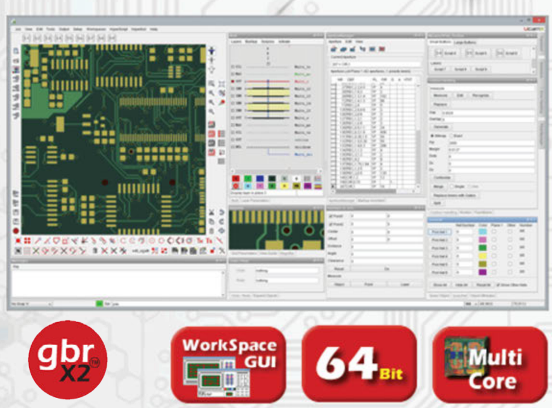

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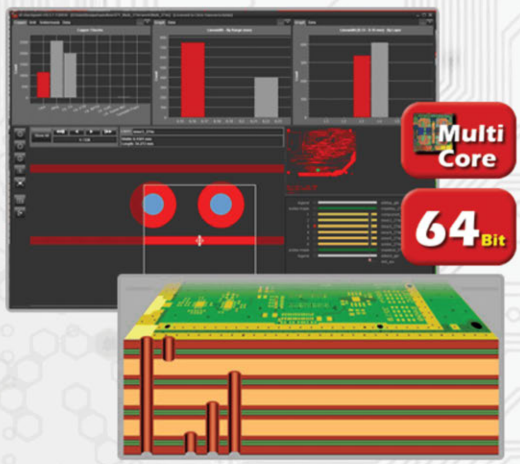

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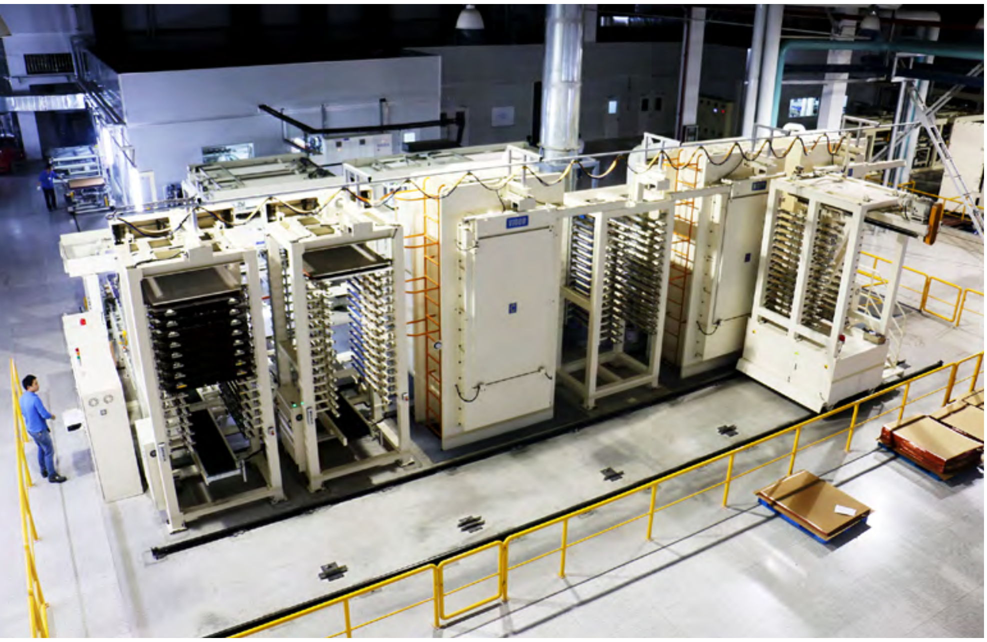

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sheet values; you have to do it in your context and also in a comparative way. That's where the HDPUG work goes. We test everything using the same methodology. We don't care what they tell us; we ignore all of that and test based on our standardized test methods.

Matties: When we look at the way that designers are specifying material, often, they're over-materializing. You made that point earlier, and it drives a lot of extra cost into a product.

Morgan: Absolutely, and it can be enough to destroy the product from the beginning. That can be a massive problem. But people do it because that's how they've been used to doing things. Usually, you will find specific materials on drawings on the design. The designer writes, "Use X material from this supplier," because they know that has worked in a previous project. They carry on doing that without reviewing that decision ever until they can't get hold of that material anymore. Then, they think about it. But once it's on the drawing on the design, it's very hard to remove.

The military sector is a classic case. Polyimide is a big issue I've been discussing with aerospace companies for some years now. They're fully aware that their habit of using polyimide for all of their products is costing them money and doesn't work for the new designs because it's too lossy. They need something that has a better property in terms of loss. Now, they know that many materials from the epoxy family, for example, have the same performance in terms of high-temperature soldering that polyimide had in the past. These things are difficult to address because when you've been using a particular product for years, it's very hard to change that mindset.

Matties: In the world of Industry 4.0, could it be that a piece of material will be X-rayed before being put into a process so that the work can be oriented in the most optimal fashion based on the construction of that base material?

Morgan: Well, that's possible, but not practical. It's very hard to X-ray the glass fabric because you don't get much contrast. You do that for stability, and when you have copper traces, that's entirely possible. But I highly doubt we'll get to that. I think we'll use other tweaks, such as lower Dk and Df glass, spread fibers, etc. In theory, Industry 4.0 allows you to customize the process for every single panel. In terms of where to put the design, it's an idea. That would probably be a stretch too far. I'm not sure technology exists today to do that.

It's possible that may be the last optimization; it might be the last thing that we do to stretch it out a bit further, but that's quite a move. We're aware that AI can do a lot of things, including solving issues like this but it would be tricky. There is scope to optimize the designs though. At the EIPC conference two weeks ago, Robrecht Belis of Elsyca showed software for optimizing plating on panels. He typifies your system, characterizes how your plating works, takes your solution as well as your arrangement of the anodes and everything, analyzes it, and can predict from the design where the copper is going to be fine and where it's not on the board.

He can say, "You're going to overplate it here and underplate it here." Then, he can move the circuit around or mix jobs together to get a better overall balance and predict where the copper is going to be. The same kind of process could be applied, but it's more difficult when it comes to organic materials because if you try to X-ray the glass fabric, it's really hard to see it; it's not contrasting like copper. There might be a way of analyzing it with an MRI scanner or something, but it would be tough.

Happy Holden: One thing my group at Hewlett-Packard was responsible for was characterizing our laminates. We would characterize all of the prepreg and cores out to 22 GHz, but we would also do it at different temperatures and humidities. Most electrical engineers didn't seem to realize that these dielectic properties change with temperature and humidity. Thermal simulation at one temperature doesn't tell the whole story because the electrical properties change with temperature, which means we at least need a minimum and maximum temperature. Especially in RF and high frequency for 5G, the higher the humidity and temperature, the more the properties degrade.

Morgan: It's absolutely critical. There are a couple of angles. One thing is moisture absorption. Moisture is very lossy and is highly polarizable, so there's a very high dissipation factor. If you get moisture in the board, you have high losses right away. Moisture inside these products completely kills them. Many of the products have low moisture absorption, but others absorb a lot of moisture, so you must stop that. If you allow it to absorb moisture, you have a different set of properties loss-wise and temperature-wise than you had when they were dry, which is a massive problem. Some products go through phase changes, such as PTFE, between room temperature and operating temperature. And that changes properties as well. Thus, what you measure at 20°C and what you measure at 120°C can be very different.

The other big issue is oxidation of materials. Some materials oxidize in use, so they're fine when you start. But over time, the properties of the material change because the material oxidizes and you get higher loss. One of the HDPUG tests, for example, is that we take the materials, characterize the loss on the materials, go through six simulated reflow cycles, and measure it again. We try to find out whether it's changed or not.

Holden: Because of 5G, is there a future for a material that's made from handmade fibers?

Morgan: Potentially, and it has been done before, but it disappeared from the market. There's not much sign of it being resurrected, but there might be a way. Screening conductors onto material rather than using photosensitive, screening conducts might be a way forward. We may end up replacing copper with conductive materials, which could be graphene, silver, etc.

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Holden: A material that we do have is the Ajinomoto film, which other people are thinking about creating. This material doesn't have copper on it for semi-additive, but a film material can be packed and laminated for conventional multilayers, not just semiconductor packaging. The Ajinomoto film uses permanganate, a different concentration, to treat the adhesion profile for the semi-additive process. It has only a six-minute lamination cycle, so it's a conveyorized lamination and doesn't have to sit in a press for two hours.

Morgan: That could have a place now because if you're using permanganate to texture the substrate, you could do that in a very fine profile—certainly submicron—which is what we want. Yes, that may work. But how do you go from small scale to big-volume, high-reliability thermal cycling requirements that are required?

Matties: It sounds like base material is on the path of evolution, and not revolution.

Morgan: It has been all through its life, but everyone is waiting for the revolution to come one day.

Matties: As you're saying, though, it will take years to bring it to market in any mass scale.

Morgan: Right, that works in mobile communications and handsets; there has been a complete revolution there, but to bring that across the whole industry will be difficult. The automotive sector requires zero defects and a 10-year life if not more. And it has very severe testing regimes to make that happen, so you have to bear that in mind always. And if we're talking about 5G IoT, the vehicle becomes a server on wheels. It has to have all of the attributes of a server with data integrity but on wheels. Some days, it's going to be in Finland at -30°C; other times, it's going to be in the Arizona desert at +50°C.

The automotive sector requires zero defects and a 10-year life if not more.

Matties: I remember chatting with Mark Goodwin from Ventec International Group about the R&D that a laminator needs to go through. To plan a product for the future, you have to be thinking five or six years out because it's such a slow process.

Morgan: I'm sure a revolution will come eventually. There are many ideas out there, but these novel technologies tend to find one application area where they work, and then they don't go anywhere else. Today, our mainstream volume is still the old technologies. There's nothing revolutionary at all; it has been an evolution. I'm sure that there will be something one day that tips the balance, but the market is not there yet by a long shot. There have also been a lot of investments around the world in treating glass fabrics with resins and applying copper foil to them. To break out of that is going to be very hard. We're not talking a few million dollars; we're talking tens and hundreds of millions of dollars, so that's not something you do lightly.

Matties: What piece of advice would you give to designers?

Morgan: Talk to me or someone in the laminate business. Some people know this field, but there aren't too many as it is a very narrow discipline. We're giving seminars and trying to build up training sessions on this topic with Altium. I'm going to do some more with them as well. My paper at the ICT seminar is what I delivered to Altium to bring designers up to speed with where we are, explaining how materials are developed and what things matter. My advice would be to take a materials course. Honestly, they could learn all of the information that they need to know to find their bearings in a half-day or one-day course. That's all it takes. Otherwise, they could spend a lifetime not understanding it.

Johnson: Very good, Alun. Thank you for your time.

Morgan: Any time, Nolan. It's my pleasure.

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New Materials or New to You?

Flex Talk

Feature Column by Tara Dunn, OMNI PCB

I think the phrase, "There is something new for everyone," absolutely applies to the PCB industry. Our industry offers a wide range of materials just on the fabrication side, and I feel like we are consistently exposed to materials that are new to us. Reflecting back on just the last couple of weeks, I have learned about copper coins, which is something new to me, and also had a request for ENIP, which is a surface finish I am not yet familiar with. I have also introduced a couple of different groups to a palladium-based ALD-type ink that is enabling an additive process capable of very high-density interconnect as well as MINA, a surface treatment for aluminum. Other questions I have answered revolve around rigid-flex materials for someone starting one of their first rigid-flex designs and different coverlay options for a flexible circuit application.

This leads me to the thought that our industry is growing quickly with new processes and materials being introduced on a regular basis. Even if you have been in the industry for your full career, I would place a wager that there is something new for you or something new to you.

When you have questions, who do you go to for answers? Have you built a strong network to reach out to? If not, what could you do to help expand that network? Personally, as a manufacturer's representative serving the PCB industry, I try my best to help my customers learn about new materials, processes, and technologies, and at the same time, I am intentional about attending industry events and being sure that I am learning about all three as well. I am very interested in how others approach the issue of keeping up to date with new things in our industry and welcome suggestions for events to attend.

Regularly, I am asked to help answer questions regarding flexible circuit materials, so I wanted to put together a brief explanation of materials available and things to be aware of when creating a stackup. First, for flexible circuits, specifically polyimide-copper laminates, there are a wide variety of options available. Polyimide is available in both adhesive-based

and adhesiveless options from 0.5–5 mils, and copper is available from 0.25–2 oz. Other thicknesses are available, but these are the most widely used. From there, it is important to research what you preferred fabricator regularly stocks. Each fabricator stocks a group of materials based on existing customer demand and preferred materials. If you can create a stackup around those materials, it will save time and project costs.

Each fabricator stocks a group of materials based on existing customer demand and preferred materials. If you can create a stackup around those materials, it will save time and project costs.

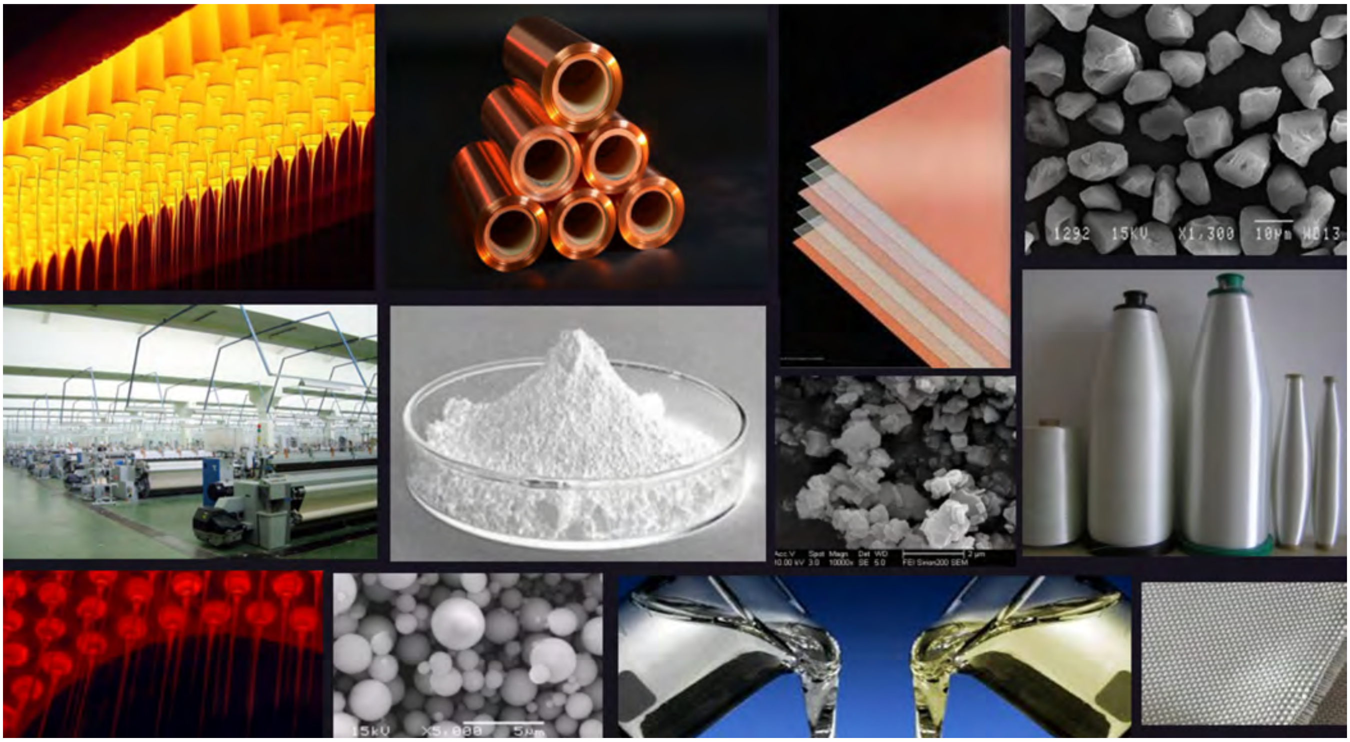
Flexible coverlay options are also something that is asked about frequently. There are two primary options. First, and most common, is polyimide film-based coverlay. This option is highly recommended for dynamically flexing applications and rigid-flex. It is important to specify the adhesive thickness in accordance with the copper height on the base laminate to ensure full encapsulation. Another option for flexible cover coat is flexible photoimageable coverlay. This option provides a better resolution for dense SMT component areas and produces crisp, square SMT pad openings. But while this material is flexible, it is not intended for dynamically flexing applications. If you need dense SMT pad openings on flex, laser-skived, polyimide-based coverlay is an excellent solution. It is a bit more expense than drilled or routed coverlay, but it is a viable option when those things are critical.

I am also frequently asked about ALD ink supporting the semi-additive process (SAP) domestically. This process has been proven with prototypes and is on the cusp of transitioning to production in North America. This is an exciting new chemistry that enables line width and space at 0.001″ and below. Numerous application areas are investigating how to incorporate this technology, and fabricators are exploring how to bring this process on-line to meet those needs best. Over time, this will be quite the game changer for the PCB industry by reducing layer count and lamination cycle requirements as well as supporting the technology needed for increasing complex pinouts.

The previous technologies are areas that I am familiar with. But, as I mentioned in the introduction, I am also consistently asked about processes and materials that are new to me. Copper coin technology is not something that I have been familiar with. After seeing an application that was built with this technology, I did a little research and learned that it is used to dissipate heat when thermal vias or metal core materials are not sufficient. The concept is based on getting a copper coin press-fit into a premade cut-out in the board directly under the area that is a hot spot. Interesting!

What an exciting time to be in this industry. There are so many new processes and materials in the PCB segment that it can be a challenge to keep up with all the new developments. It is fun to start chasing the next new thing, but I also think it is important to keep in mind that even materials and processes that have been around for a while are still new to someone. Not everyone has used flex materials or copper coin technology, and only a select few have used additive processes for PCB fabrication. Thank goodness our industry is supported by strong technical publications and industry events to help us all learn about technology that is new to us and help us build a strong network of people to reach out to with questions. **PCB007**

Tara Dunn is the president of Omni PCB, a manufacturer's rep firm specializing in the PCB industry. To read past columns or contact Dunn, click here.



Making Materials Succeed: Past, Present, and Future Trends

Feature Interview by Nolan Johnson
I-CONNECT007

Tony Senese—manager, business development group, Panasonic EMBD—gives Nolan Johnson an overview of materials and components as well as changing business models and methods to make materials succeed and how to stay profitable.

Nolan Johnson: Can you describe the changes you've seen in the cost and structure of materials?

Tony Senese: It's a lot easier for people to talk about cost than it is price because the price is considered to be negotiable. Forget inflation. Everybody wants to talk about all of the technical integration that's required, but nobody understands the structural changes that we've gone through in the last 30–40 years.

I'll start with a global overview of what materials existed in terms of what people were using, what materials exist now, and the changes. In 1980, about 90% of all materials used to make circuit boards were some form of FR-4. By now, about 60% of materials are some form of FR-4, meaning that the basic constituent is epoxy resin, E-glass fiberglass, and copper. There are differences that we could debate about, but the cost drivers are the same.

The materials that everybody likes to talk about are 40% of everything else. Fabricators, OEMs, and material suppliers like to talk about those because of the value that they offer to each, and they are all different. Laminators have been making low margins for so long that they've forgotten what it was like to make FR-4 in 1980, for example. Back then, FR-4 was a very profitable business. Gross margins without overhead were in the neighborhood of 70%.

The three basic materials that we use are resin, glass, and copper and are still the primary cost drivers in the materials business. But the big difference then and now is we were able

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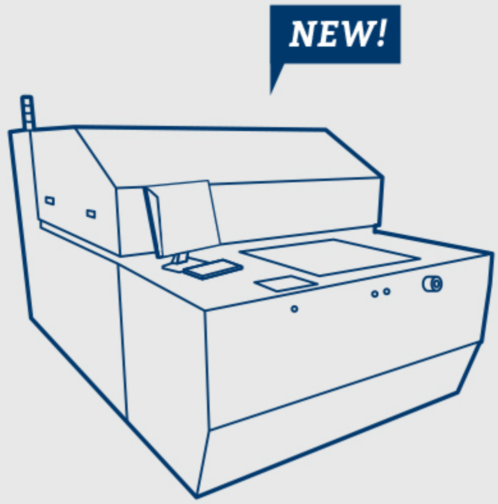

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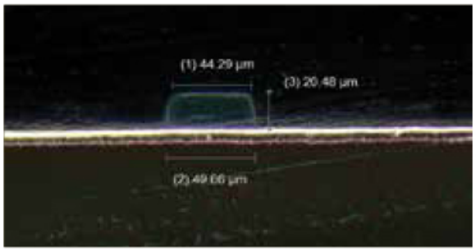
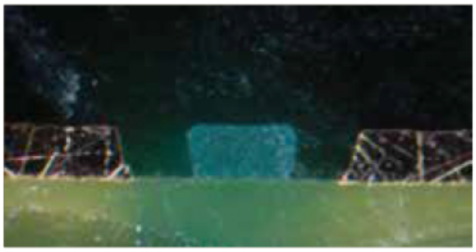


50µm solder dam, 20µm thickness on Cu



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Panasonic factory.

to leverage those three materials, which were completely commodity materials at the time. All of us that were in the business thought about them as technical materials because we were doing a lot of research on how we made things better.

The most basic two-part epoxy resin, which is the same kind you would buy in a glue today, was almost all of what Panasonic made. It cost about $1 per pound and was available from 10 different resin suppliers in North America as well as 2–3 in Europe where it was being made. In some cases, Asia was just starting to get into the business, but it was such an easy product to make that the first people in the business there made their own. These products were a commodity and very cheap. They are still extremely high-quality adhesives and resins to use in a composite as we do.

Fiberglass has also been around for quite a while. Most of the glass styles that we used in 1980 had been available for industrial use for other products for a while. That glass would sell for $1–2 per square meter, and that price hasn't changed much today. Further, electroplated copper was only used in our business. The applications that we have today, including batteries, didn't exist in any volume. Copper price was dictated by the commodity price of copper and the conversion cost, which is electricity and capital. Copper cost about 30 cents per square foot in 1980.

When you added up those three to a 0.059 material, which was still a large part of the business and sold for around $2.50 per square foot with 70% gross margin. But that margin seems like a distant memory. Most people would argue with me about whether or not that was the real gross margin because our net profits were in low, double-digit numbers, but there was a lot of money being spent on many other things. All of these large companies that were in the business at the time were quite profitable. Price negotiations were really a question of your position in the market and supply and demand; it didn't have as much to do with cost.

Today, overall prices for standard FR-4 material haven't changed very much. In 40 years of inflation, no matter what you count as inflation, the cost of those materials has decreased by 30–40% in relative dollars. The margins, however, have decreased by at least an order of magnitude to the point where the net profit of making those FR-4 materials is in the low single digits unless you're making a couple of billion dollars' worth of that material in a very high volume environment. Many people would say that's not making money.

Johnson: These margins are down in the grocery store range.

Senese: Yes, if you're good. And if you're bad, you're going to go out of business; it's one of the drivers for laminators to look for materials that offer other value and try to change it up. That's driven us into specialization. The raw material suppliers for resin, glass, and copper have changed even more. Epoxy resin for our business in the United States is only available from one supplier, and it's not inexpensive. In China, Japan, and Taiwan, a lot of the volume of that epoxy resin is made in-house. For them to make a profit, they've had to vertically integrate downward to survive; they can make their own resin as cheaply in that volume as anybody can sell it.

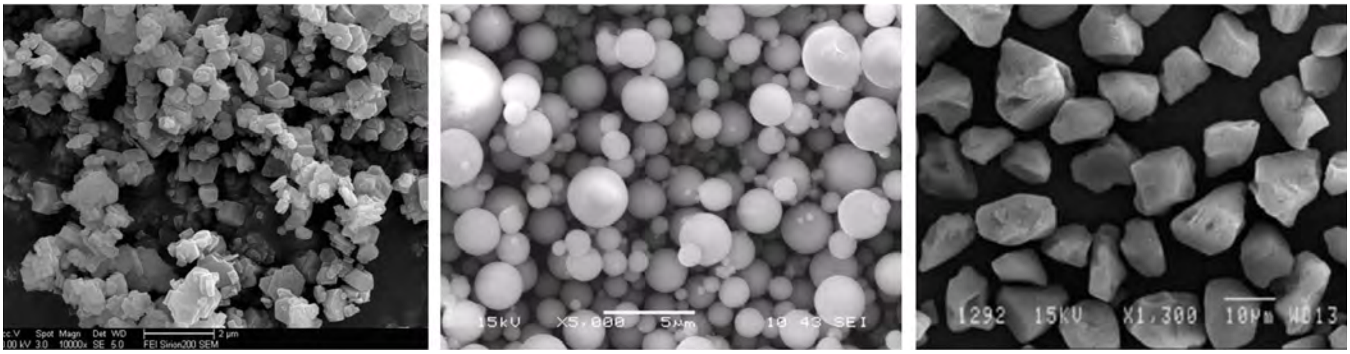
The specialty resins that constitute the other 40% are still extremely expensive. Compared to that $1 per pound price, they're anywhere from 10–20 times more expensive. Copper foil is in the same price range that it was then, and it depends a lot on demand. It's hard to find new vendors for copper foil. Capacity that was dedicated to electronic circuit boards has gone to battery production. Some dedicated suppliers have gone out of business, and there has been some consolidation. It is a very low-margin business as well; all the copper foil suppliers are competing on the foil that's going into high-end products because they can eke out a bit more profit there.

The glass business is a similar story to copper. The price of glass hasn't changed very much. In fact, it has gone down over the years for style-to-style comparisons, which has allowed most of us to keep our per square foot price of FR-4 down. But a lot of the companies, in this business, have chosen to not develop products on the low end because there's no profit in it. No matter what the glass cost is, it's unprofitable. And the new innovations in glass cloth are much more expensive. For instance, quartz glass, which is the lowest loss glass fabric you can buy, is over 10 times as much as E-glass; everything else falls somewhere in between.

We have gone from a commodity-based raw materials supply to suppliers that are trying to survive by making specialty materials. Whether the resins are PPO, cyanate ester, polybutadiene, polybenzoxazine, etc., all of those are very low-volume engineering thermosets that have been adopted to our business. In most cases, we're not the biggest part of their customer base, but we're still a significant part of those suppliers' customer base that they can afford to develop new products. That means that we are all using a supply chain that is not set up for huge volumes of inventory and instant access to a never-ending flow of material. This has created a very crowded space at the top of that technology pyramid.

This is one of the things that drives the fact that we need to know the end users and their customers as well as the markets that drive change. Are they telling us the true story? And not because our customers and their customers are lying to us, but because these things are all projected based on assumptions that sometimes are true but sometimes not. When you go to a glass supplier, the question is, "We love your E-glass and use it for our FR-4. It's perfect, and we can count on it. We also like the low Dk glass that you developed 10–15 years ago. We started using it about two years ago, but we need something a little better. What can you do for us?"

These people trying to report to their boss what they're going to do look at you like you're from another planet because they don't even want to ask the question, "How much are you going to buy and when?" They know we don't have a good answer (laughs). It's a waste of time to ask us that question. They go straight to the end users now. Laminators are talking to end users, but so are raw material suppliers because they're trying to get a handle on how much time they have to do this, and when they get it to the market, when are you going to buy some. Our challenge is driven by cost and the supply chain. We are no longer in a commodity zone. Everyone in the supply chain, because of what has happened in terms of transferring to lower cost areas of the world, is hugely risk-averse. They are looking for the next thing that's going to disrupt the status quo.



Highly magnified images of various types of solid compounds used in the production of epoxy resins.

One of the issues we have to solve when we go from one generation of material to the next is how does a material supplier convince a glass copper or resin supplier that this really is the next big thing? I've had that question posed to me by my customers and their customers—the end users—several times, and there's no easy answer. The real change comes when the structure changes and money starts being spent. Until there are actual designs that go to some level of production, then you can start talking about cost because the cost reduction is completely driven by volume. It doesn't have to be the same volume of production as the FR-4 type materials, but it has to be a significant production for at least a couple of suppliers in the supply chain. The raw materials that are being used to make the resin, glass, or copper are commodities, for the most part. The chemicals are in the resin and the way the glass is formulated drives down into a small production volume. That small production volume drives the margins all along the supply chain. Our challenge with advancing technology is to figure out when and how much.

That small production volume drives the margins all along the supply chain.

Companies in the PCB business that have survived are surviving for a reason. Within our business, one of the reasons we've survived is because we adopted a more conservative business model than in the late '70s and early '80s. They were very bold risk takers. It paid off often enough that it worked for the industry at the time. Those people have had a tough time supplying our business without a significant amount of risk.

I'll give you an example. In the '80s, one of the largest problems we had in the circuit board business was the reduction in the size of the features, the spacing, and the thickness of the dielectrics. We were going to controlled impedance. The boards were getting thicker, the cores were getting thinner, and the space requirements and true position tolerances were getting tighter and tighter all the time. The circuit board business hadn't figured out how to compensate artwork to make up for that.

Then, a company came along that made what seemed like a common-sense effort to make a unidirectional prepreg. This prepreg basically had zero movement along the axis of the glass because it was not woven. If you put one ply one direction and turned another ply the other direction and made a symmetrical construction, you could achieve almost zero movement on a standard FR-4 composite. But it had some limitations and problems that I'm sure Ed Kelley at Isola could tell about you every one because he was involved, but this product worked. Everybody I ever heard of that tested this product had amazing registration far beyond what they needed. The product was a significant threat to FR-4. If it had become commercially successful, it would've been very disruptive. Unfortunately, it was a low-volume manufacturer. They never signed up a big enough customer to transition over into mass production, and they failed.

In the meantime, PCB businesses, which never sit still for long, had been investing in their front-end engineering and equipment. They decided to cover this problem through artwork compensation. By doing artwork compensation and dialing it in, they got where they needed to be technically. That solution, which was best for them, was the worst for this particular supplier, and they just disappeared. Those are the kind of things that happen in our business. You're often given a choice of one or the other solution, and the technology that's not chosen usually doesn't survive. This is pretty well-known among people in my business (laughs). We've been watching it happen for a long time.

Johnson: You could take a risk on something years back because you had the margins to support that; now, you don't.

Senese: Right, and that's exactly where we sit. One particular high-visibility change over the last few years is the use of low Dk glass to reduce the Dk and loss in high-end materials. You can only get so much out of the resin. This is a fairly easy change to make for the laminators. It's expensive because the glass costs more than E-glass. But when designs go from 6 Gb to 12, 25, and 100 over the next 10–15 years, the loss has to go down. Right now, most of the low-loss material in the market is E-glass like MEGTRON 6. The next generation is moving to a low Dk glass, which would've been the same that was used by NELCO-13SI 20 years ago. That glass has existed in some volume for a long time, and it's only now beginning to be needed for certain speeds.

It's still a difficult glass to get; It's only about 1–2% of the glass made for our business. Certain types of equipment in the server and switch business needed to have that extra 20–30% lower loss, so they've started building it. We build it every day: our MEGTRON 7N uses a low Dk glass that has not yet transitioned to mass production like E-glass. Even for us–who make quite a bit of low-loss material–it's still nowhere close to the volume of MEGTRON 6, and it won't be for some time.

We have two partners that we buy that material from. Until very recently, we didn't have supply issues. Last year for the first time, because several other OEMs adopted this at pretty much the same time without doing much research into the supply chain, there was a shortage of this glass. The shortage affected everyone differently, but during that time, I heard all kinds of stories from people. Most of them were made up, but some of them are true. People make promises based on what you say minus some guesstimate. As a supplier, if I believed what every end user or fabricator tells me, I would predict hundreds of points per year of expansion in a particular market, but we know that doesn't happen.

You have to plan your business around something that makes sense, so you're a little more conservative. Sometimes, that conservatism is wrong. As a group, we haven't learned to manage the risk of developing technologies in the supply chain very well. We are working very hard with suppliers, as opposed to 10 years ago, to give them up-to-the-minute and up-to-the-month information about where things are going. What's happening right now is that the second generation of low Dk glass is being developed by two different sources. However, it's being looked at by anybody who makes glass for the same reason that we're looking at making higher volumes of low-loss material and lower volumes of FR-4—because it's how you survive and make money in the box that we've ped ourselves into.

Johnson: Tony, how do you see the industry getting out of this box?

Senese: The industry may not need to eliminate this box, but the industry has to work together to do a better job communicating needs at a very basic level– monthly, daily, and weekly forecasting from the whole supply chain as well as a more honest and rigorous discussion of megatrends. One of those is the advent of 5G. There are devices within this realm requiring low-loss material and maybe even high-frequency materials like PTFE, but there will be a constant pressure to drive down the cost.

In the past, that has created opportunities for companies that can make materials and boards that have a low-cost constituent in the digital portion—a hybrid circuit board with FR-4 and PTFE, for instance. Or in the case of high-speed circuits, for a long time, hybrids with FR-4 in the ground power pairs have been designed in to eliminate the cost there because the Dk and Df of the ground power plane doesn't matter. These are techniques that some OEMs are leveraging, but others aren't. That's something Panasonic always talks about when we manufacture a new material. We want to make sure that we have an alternative in the high-speed digital place for customers when they don't need low loss.

Johnson: That seems pretty thoughtful.

Senese: It is helpful. It is one way of eliminating the cost without just talking about price. This is turning into a list of 100 things you have to do to make a material successful. One more thing is that the material has to be compatible with a lower cost material in the stackup so that you can save money where it electrically works.

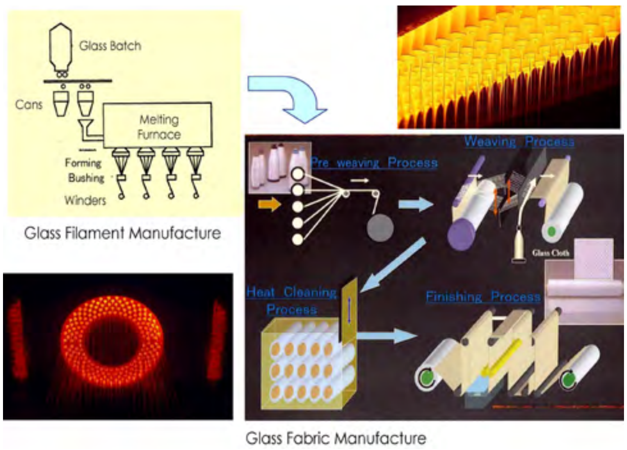
Johnson: With all of these megatrends going on in applications as well as changes in the business model over time, it seems you're putting forth that some very accurate, realistic forecasting needs to happen so that the right kinds of materials can be manufactured in time. What do we change about the forecasting model?

Senese: If I had the answer to that, I would be the president of Panasonic, but I don't, and I'm not (laughs). We do things differently than we did 10 years ago because people realize that when you talk to material suppliers, you can't just put a gun to their heads and say, "You will do it." All of the design community needs to be aware, and they're becoming more aware because of pains they've gone through, that when they make changes to base materials, there's an impact on the business model. That has to be factored in. Anybody that's a project manager of any sort understands that you have to give things realistic dates, and you have to scale them.

The first thing that we do when we start talking to an OEM about a project is ask a lot of questions about timing. Often, that means involving a different person or a group early on. The most aggressive OEMs put those people in front of the supply chain early enough that they can get what they need when they need it, asking those questions ahead of time before there's a problem.

After the tsunami in Japan in 2011, glass manufacturers in the area had to shut down a couple of their low Dk glass furnaces. That didn't cause much of a problem for Panasonic's business, but it had a significant impact on one of our competitors. That was an issue of single-sourcing that customers remember. We always have a backup if something happens to one product someplace else. That's something OEMs need to think about when they start talking about material supply. Quality is very good almost everywhere. But instant, high-volume availability with new, raw materials, is not. Thus, OEMs must that take that into consideration when they start scaling up projects. They have to have a contingency plan.

The supply chain needs to have a greater awareness of these raw materials in as well as a backup plan. If you pick the wrong supplier, they may not be physically capable of having a backup plan. Even if they can get the raw material, you may not get the material if there's a problem. This is something that's new for OEMs because they're used to buying things that are commodities. Even in the electronics business, with the exception of the specialty low-volume chips, the things they buy from large suppliers have millions and millions of units on the shelf at all times.



Johnson: Earlier, we touched on trends like batteries. Automotive is a big driver in battery technology right now, creating an immense appetite for copper. Batteries offer a higher potential for a profit margin for copper producers than foil does. At the same time, those same automotive producers are trying to put a whole bunch of electronics in the car, which is driving the demand for electronics.

Senese: Copper foil has been the most volatile thing that we buy over the last five years. Because we are not as big as the largest suppliers in terms of square feet, especially the low-end kind of material, our challenge has been to drive our products toward thinner coppers. You can do that by picking the type of device that your customers make and trying to supply them.

For example, almost all of the iPhones (8, 9, and 10) use a buildup process with 3-micron copper, which comes on a 2-mil sacrificial copper. That's how it's shipped out. However, we do not sell copper. All of the people that have to buy 3-micron copper for everything but the inner two layers of an iPhone are buying it from a copper supplier. Essentially, they're buying three ounces of copper to use a few tenths for this modified semi-additive process. The copper that they sacrifice all goes right back to the copper supplier and is recycled and used again.

That dynamic has driven cost down in something as high-volume as mobile phones. It has the added advantage of being easier to use for a buildup process that has very fine line spacing. However, when they buy that copper, it's 10 times more expensive than one-half-ounce copper. Swallowing that pill and knowing that it's going to pay off later is not the way our supply chain has been trained. This is a value proposition that has to be sold from the start when the designers are building something. In the cellphone business, it's easy to do because it's a one-year cycle. If you make a mistake for one year, you can fix it the next year. In IT and automotive businesses, you don't get a chance to make a mistake like that.

Johnson: No, it would have to have a much longer life than that.

Senese: Yes. You have a long development cycle, and then you have a longer business adoption cycle since everybody is more risk-averse; they don't get to reset every year. This creates an issue for us. We could easily try to sell people on the idea, "If you want to save some money on copper, which is the most volatile thing, start adopting a semi-additive process." That's great if you're doing a buildup or an "any layer via" kind of thing, but if you're doing a traditional one or two lamination multilayer, it doesn't work. For example, most of the IT business is looking at HDI for some of their outer layers of the line cards and backplanes.

It's a possibility, and it certainly will happen at some point in time on some level of technology. It's going to be part of what drives the cost of 5G devices. But we still have to have the backbone of the network built out on traditional servers, routers, and switches. They can't take advantage of that technology from a fine-line spacing or cost standpoint right away, but they're all learning about this at the same time. There will be some movement over the next 10 years toward not being so highly leveraged on a subtractive process where most of the copper is going into waste treatment.

Johnson: There are a lot of decisions being made there, and those designers have a surprisingly large influence on everything that happens downstream. What can a designer or design team do to help with this?

Senese: It used to be, "You have to talk to us." Now, it's, "We have to hear what you have to say. We need to know what you want." Our supply chain has that one down, but our audience needs to listen, work with that, and be aware of the trade-offs you're making. In other words, communicate.

Johnson: Where do you see distributors in this conversation?

Senese: Distributors are becoming a larger part of the communication, especially in import where most of the communication can be done by someone who doesn't ever touch the product. They need to know how to talk to both their fabricator's customers and the OEMs to get that information. The distributors have had to become smarter, more aggressive, and they cover more ground than ever before. There was a time when all you needed to be a distributor was a warehouse, some shelving, and a big truck or a good contract with a local trucking company. While that still exists, now you have to have a higher level of interaction with all the customers. That's because the bandwidth of each of these manufacturers is different. Even Panasonic, who has put a lot of money into encouraging people to have these conversations, still runs out of bandwidth when things get really big.

Johnson: It would seem like the distributors could be in a place to be a reliable source of forecasting information.

Senese: True. We do forecasting in two different ways. One is forward-looking, long-term materials-related forecasting. The other one is related to what we're going to sell next month. The best distributors have incorporated some form of an ERP/MRP closed-loop system where the customers are either ordering online or with knowledge of what's sitting in the warehouse when they order it. That step up from old-fashioned verbal customer service allows distributors to see what's happening in the markets every month or week and report it to their principals because it's so dynamic.

Every year, and over a period of many years, they can predict what they think is happening, at least for their geography. Things disrupt that all the time. Customers don't always survive, and you have to adjust for what's going to happen, but those big things aren't as hard to deal with as fluctuations in the yearly/monthly trends. For them to survive and make money, they have to manage that well.

Johnson: I'm sure you can guess what I'm going to ask next. What is the fabricator's role in this?

Senese: The fabricator has the hardest job of any of us logistically and otherwise. They end up holding a lot of financial responsibility. Successful fabricators have to do what I would think of as faux vertical integration. They treat their suppliers and customers as if they're part of their company. In other words, they have constant interaction and contact, ask a lot of questions, and provide a lot of information so that people are not in an adversarial situation when something happens. As a material supplier, what I want is open communication and to work on making things better instead of the traditional reactive firefighting. We've done pretty well with that with our biggest customers; in Tier 2 and 3 shops, we're all still learning the hard way.

Johnson: Tony, do you have any closing thoughts to wrap up our conversation on materials trends?

Senese: Materials will continue to change, improve, and grow, but keep in mind that they're just materials—not miracles. Everybody in the electronics supply chain has to work together to get to where we need to be. Material suppliers are working in the direction we need to, but we need help from everybody else in terms of making this a business that works, which has to do with communication.

Johnson: Tony, thanks so much.

Senese: Thank you. **PCB007**

DuPont on Materials Challenges and New Opportunities

John Andresakis

Feature Interview

John Andresakis, senior marketing technologist in the Interconnect Solutions (ICS) Group of DuPont, and Jonathan Weldon, RF applications engineer also in ICS at DuPont, spoke with the I-Connect007 editorial team about trends the company is seeing, what challenges their customers are facing with materials today, and future opportunities with new technologies, including 5G, electric cars, IoT, etc.

Andy Shaughnessy: Starting with John Andresakis, could you talk about materials from a higher level, and then we'll go to Jon to hear about some of your work with 5G in more detail?

Patty Goldman: Also, can you tell us a little bit about your division at DuPont? I'm interested in that and your perspective regarding flex circuits.

John Andresakis: Dow and DuPont merged August 31, 2017; now, we're doing the spinoff into three different companies. In April, Dow split off and became their own company. In June, DuPont and Corteva—which is the agricultural business—will split off, which will complete the transition to three separate companies.

We are going to be part of the new DuPont, which has several different divisions. Our division is Electronics and Imaging, and within that, we are part of Interconnect Solutions (ICS), which includes Pyralux® laminates for flex materials and Kapton® films. It also includes the Riston® photoresist and the combined chemistry of Dow and DuPont for plating, final transitions, etc.—overall, the chemical processing for making PCBs.

Jonathan Weldon: In addition to the plating, we handle final finish, so for the most part, ICS contains everything for making a flex PCB from the ground up from Pyralux® flexible copper-clad laminate through the final finish of the board.

Goldman: Okay, so what's coming down the pike with new materials?

Andresakis: Everybody is looking for lower loss materials; that has been the major focus, especially in the rigid market. Customers are looking at what they can do to keep driving the losses lower to the point where they're getting materials that are thermostats with properties getting close to Teflon-based (PTFE) materials. There has been a lot of work on resin chemistries. And when you get into this type of performance, the number of choices you have

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is somewhat limited. Now, it's starting to get harder and harder to have an incremental improvement in the loss due to resins.

Weldon: We're seeing an increase in the number of issues in high-speed digital. As they go to higher data rates, skew, signal levels, and SNR are becoming more of a problem, which goes back to what John was mentioning with low-loss materials. Glass-free materials have also started to become a hot topic as skew is no longer manageable by adjusting the glass weave or using traditional techniques. Even homogenous materials, such as polyimides, are becoming interesting to the high-speed digital community.

From the traditional RF, high-frequency side of things, we're seeing an increase in the frequencies of interest. Traditional 4G LTE and consumer electronics applications were relatively low in frequency between 1–6 GHz. They're still operating there today, but now we're looking at the 28–39 GHz bands for 5G, which is changing the game.

From the traditional RF, high-frequency side of things, we're seeing an increase in the frequencies of interest.

It used to be that dielectric loss wasn't the primary player while constant and conductor loss would have been fairly dominant, especially in thin constructions and flex. But with those higher frequencies now, dielectric loss itself starts to rear its ugly head, and traditional materials that might have been relatively lossy from a dissipation factor standpoint may not be sufficient for all applications. There is a definite need for improved materials.

Further, we're seeing some interesting things in terms of design space where people are starting to increase package densities. There have been a lot of changes in substrate height requirements for certain designs that may have been very thick before but are trying to get thinner as well as things that have been thin that people are trying to make thicker to improve performance. Overall, we're seeing changes in how people are approaching design challenges due to these higher frequencies.

Feinberg: What is the most used thickness of dry-film resist right now? Back in the day, it was 0.5 mil, 1 mil, or 1.3 mils.

Andresakis: Not much has changed as far as thickness; the range you mentioned is still very common. We still sell a lot of traditional Riston® products because the lines and spaces for servers and routers haven't changed appreciably either. I think it switches over when you go to the consumer world with modified semi-additive processes, etc. They're using the thinner resists and switching from subtractive to additive processing. doing a plate up versus an etching. However, more people are using laser direct imaging for regular products because of the benefits you have removing the photo tool. Almost every board shop now has some degree of laser direct imaging, even if it is just for quick turns and prototypes.

Feinberg: We used to look at 10-mil lines and spaces being very, very fine line with 15–20-mil lines and spaces being more typical. Is that still the same for both the standard circuit boards as well as the ones where you're trying to shrink all of the circuitry down? Because the average person wants more space in their phone for a battery than they do for a circuit board, but yet still want all of the functions. What kind of resolutions do you see now, and what are your customers asking for?

Andresakis: I haven't checked in that space in a while. But when it comes to traditional high layer count, servers and routers, they've been doing 3-mil lines and spaces for a long time with traditional photoresist, so that's not an issue. When it gets to the consumer, the big switch is that the resolutions have improved so you can do the subtractive process down to a finer point than before. But below a certain point (maybe 20–25 microns), the subtractive product starts to have issues. It has been reported that companies like Apple and their iPhones are using the modified semi-additive process. There's more of a switch from a subtractive world to an additive or semi-additive world to get that next level of resolution. And the photoresists are capable of doing that; it's just a matter of the overall process. As we start getting into those fine lines and spaces, everything becomes an issue. The materials, processes, environment, and pretty much everything must be under tight control. It has been reported that the initial yields have not been very good, but they are getting better.

As seen at CES 2019, the Royole FlexPai foldable smartphone and tablet in one.

Matties: I'm seeing a lot of roll-to-roll applications being represented at the FLEXCon Show. What materials do people need to be aware of in that arena?

Andresakis: Considering that our business is flex materials, that's something that we hope catches on with people because our material can be supplied in roll form. It lends itself very well to this process since polyimide is a robust substrate. For certain electronics that don't have to deal with any temperature extremes or harsh environments, you might use the cheapest film available, such as PET. But if you want a high-performing material, then our polyimides lend themselves very well. The other area where our polyimides are coming into play is that we make a clear polyimide, which can be used for flexible displays.

Feinberg: Flex materials could be seeing a huge increase in interest and use, especially with the new foldable, portable devices. Suddenly, we're going to have a 7-inch computer that you can fold in half and use as a phone or for a terminal. It's interesting that you mentioned it because I think foldable and stretchable things are going to be a big factor and pose some huge demands from designers.

Andresakis: Royole was the first one to announce a folding phone, and now Samsung has released one. They were at CES, so flexible displays and foldable phones are definitely here. LG had a roll-up TV that might have been on the Willow Glass from Corning with a plastic overlay, but the big substrate was glass. There's also going to be a boost in cellphone sales once 5G hits, but the foldable ones are the next thing to get people to upgrade their technology. However, I think most people are going to wait and see about their reliability. Even though they can guarantee so many folds, early adopters are going to check out that technology and see how robust it really is.

Matties: What's amazing is the number of materials that are on the market. What advice would you give to designers and OEMs so that they can keep up with all the latest materials?

Andresakis: Often, they rely on their supply chain. But every OEM should spend time going directly to the material suppliers and working closely with them, especially on new developments, because then they will see what people are working on and can learn about the latest and greatest materials. Also, attending conferences and seminars helps you keep up to date on the materials world because there's a lot going on. And it's our job as material suppliers to spread the word on what we're working on. OEMs have to seek it out, but material suppliers need to ensure that the information is available for them.

We're trying to get people to realize that things that have been introduced in the flex world could maybe be used in the rigid world, which Jon mentioned earlier. We have examples of people using our flexible materials inside of circuit boards for reducing the thickness or other electrical improvements. Companies are using more like mixed constructions; it's not a pure package anymore. Instead of all layers being one material, it could utilize multiple material sets to try to accomplish everything at the right cost performance.

Matties: When an OEM comes to you, what advantages are they looking for in materials in addition to cost?

Andresakis: Each OEM has their own hot button. In the infrastructure world—telecommunications and internet—they want to reduce loss and skew because that's becoming a much bigger issue at the higher data rates. With everything being done at the package level for making things denser, they still need to have more layers on the circuit boards. Some of these boards have gone out of control with thickness. That's where materials that are film-based, like what we make, have an advantage because we can make very reliable layers. It's hard for fiberglass to get below two mils reliably, and we can do that day in and day out.

Happy Holden: I'd like to hear your thoughts on five materials, and the first one is liquid crystal polymer (LCP), which has been turned into material but can also be made into a film. Especially for 5G, what's your opinion on the LCP?

Weldon: LCP is an excellent material if converted to a film properly. As a standalone material, LCP has some isotropy concerns, meaning its

Copper foil rolls.

dielectric properties are variable in certain dimensions. If converted to a proper film, which I think most manufacturers available now are producing a film that's relatively isotropic, LCP does perform well. It has a relatively low loss tangent around 0.001–0.002, a dielectric constant around 3–3.1, and an extremely low moisture uptake. It's almost hermetic in its properties, but it does pose some challenges and has some process issues. If you try to use it as a self-bonding method (i.e., using LCP to bond to other LCPs), you hit the melting point of the material to do the bonding. Making a multilayer circuit, which most flex circuits would be, it creates a swimming trace problem that we've seen in past type materials as well, which is pretty classic of a thermoplastic.

Then, there are some adhesion issues of very smooth coppers to the base substrate. As I mentioned earlier, conductor losses and roughness can play as much or more of a role in the dielectric loss, especially in thin flex laminates. You may end up losing some of the benefits of having a low-loss material by using a non- or un-optimized copper type. So, LCP is great, depending on how you're using it and where you're using it, but it's certainly not the only material out there that will meet the needs for 5G and other sorts of high-frequency flex.

Holden: Second, is there any chance that something like THERMOUNT® can come back as a low-loss material?

Andresakis: THERMOUNT® was more of a reinforcement than a resin system. It was a kind

of nonwoven paper. We make similar products to that today, such as our Nomex® brand of papers that have very good temperature stability and are nonflammable. They are used in a lot of different applications, so the technology is out there to make it. The issue with THERMOUNT® when it was first made was it was designed for CTE control, so it had a good CTE, but the electrical properties were just okay. And again, THERMOUNT® was discontinued well over a decade ago. Something like THERMOUNT® as a reinforcement is definitely of interest because if we could make a reinforcement that has properties closer to the resin system, that would mitigate the majority if not all of the skew issue. There are some thoughts about whether a modern version of THERMOUNT® would have its place in the market.

There are some thoughts about whether a modern version of THERMOUNT® would have its place in the market.

Holden: But what about the use of a non-reinforced material that was a dielectric with or without being photosensitive since we can laser drill that?

Andresakis: Those types of material are normally used in chip packaging. We have a product here called Cyclotene™, and it has very high TG, very low CTE, and very good dielectric constant and very low loss. But it's a spun-on dielectric and is available as both photo-definable and non-photo-definable, but they're typically very thin layers. Again, they're mostly for redistribution layers on chip packaging or semiconductor wafer-level packaging. The only thing I could say that's similar is Mitsui was making a product for a while they called Multifoil®. It was a resin-coated copper, so there was no reinforcement whatsoever, and it was used to make cellphones as well as some chip packages. The problem is you still have to start with some structural integrity in the package, so you have to be careful about how you do that.

Holden: You mentioned the iPhone X, but that brings up SLP, which is kind of a new area between chip packaging and traditional HDI that is thin.

Andresakis: If you're looking at just dielectrics for consumer products and the really thin stuff, there's a place for certain materials there. But at some point, you need someplace to start. So, you may start with a core and just build up from there using these type of materials.

Holden: By the same token, my forward theory is regarding Ajinomoto film. Do you have a product in that space?

Andresakis: Right now, the products we offer in that space are the liquid version. Ajinomoto has enjoyed a majority of the market share in that space for a while, and others are looking at developing similar materials. They're not resting on their laurels, though. They are working on new and improved versions.

Holden: What do you think of the possibility of graphene as a dielectric?

Andresakis: I think of graphene as being used more in the conductor space. It typically has very good thermal and electrical conductivities.

Holden: One of the universities reported graphene that serves a conductor as good as copper and an insulator as good as Teflon. The same material can have two totally different states.

Andresakis: Yes, modifications could be done to graphene to change its conductivity.

Weldon: It will be some time, which isn't surprising. There's carbon that makes diamonds, and carbon that makes conductive carbon black. Modifying carbon to do multiple things is not revolutionary. I think it will be some time from graphene in these novel, single-layer, crystalline constructions of being conductive or insulating and transitioning that to a mass production scale. I haven't seen anybody making that jump yet. If it doesn't compete conductively with copper, it shouldn't have a whole lot of time there because copper is king, and it will stay that way for some time. As an insulator, if it's not as good as PTFE, what are the major benefits to me? There are still some challenges to work out technically before it becomes any real adoption.

Andresakis: And if it does get adopted, it's going to be mostly in sensor technology or displays—things where they need the very thin layers of these materials—so it's going to be very application specific when it comes around. I don't see it in traditional circuit boards.

Weldon: I agree.

Holden: I won't mention my chicken feather laminate (laughs). That's a real product and enormously low loss because it uses air as the dielectric thanks to the unique structure of chicken feathers.

Matties: To that end, bringing new products to the market is a rather lengthy process. First, how do we shorten the process? And second, how do you look ahead to develop a product for the future when it can take a couple of years to bring a new product to market?

Weldon: Going back to Happy's comment on chicken feathers, the biggest challenge isn't that we're not working on materials as an industry to fit the needs of the OEM; it's that there's a big gap between what that material property is, what we can make, and how it is processed into a final product. The biggest gap to adoption or even fielding to the middle ground between the supplier of the material and the company that turns that material into a product to meet an OEM's specification is for

Jonathan Weldon

something that has a lot of void space and performs extremely well electrically but can't perform mechanically or survive processing. And until we start correcting that process step to make it more in line with novel materials that will increase performance, it's going to take some very special development of materials to get through all of that and meet the OEM need at the same time.

Andresakis: That's a good point, Jon. Again, we're at the front end. We're material suppliers, but we have to make them work through the whole supply chain to ensure that what we come up with can be processed through the board shops, assembled, and gives the customer what they want. We're not the only ones doing it, but most of the material suppliers now have a pretty significant OEM marketing group that listens to customers, attends trade shows, and tries to help them develop the roadmap. Sometimes, customers don't know everything that they need right away, but we have to try to anticipate based on our knowledge what they need and work on the right products at the right time. It's a long process, which is why we have to be vigilant in monitoring the needs of the industry and make sure we're working on the right things. And having a good relationship with the fabricators is also important

because they have to live with the material. We just can't throw it over the wall and say, "Figure out how to make something with it."

Shaughnessy: Most design engineers say that when new materials come out, they have to test them. They're used to doing it, and it takes so long to release a new material. Is it even possible to do all of the testing and simulations?

Weldon: I would say it's nearly impossible. If you asked me to give you a perfect dataset or set of information for all of the processing and use conditions for an older product—such as a Pyralux® LF or even AP, for instance, which has been around for almost 30 years—then the answer would be no. Every day, we receive questions that we don't have answers to, and we have to develop methods and test procedures to collect that data. There's a minimum threshold that we try to meet to make sure we can get a viable product to the customer. From there, it's going to be a lifetime of test and iteration to gather more comprehensive information.

Andresakis: As material suppliers, we'll do all of the initial testing. We'll measure all of the electrical properties as well as the relevant IPC testing. This forms the basis to determine if it looks like it could be used in our industry. Then, we'll go ahead and work with a fabricator. OEMs and fabricators come up with some test vehicles, such as a CAF test vehicle to check for reliability. Certain test vehicles have to be run before a material will even be considered a viable alternative. Besides CAF, we'll also run signal integrity test vehicles. We will use this data to compare against existing materials and make sure we meet the minimum requirements.

And to Jon's point, we can't cover every possible combination, especially if these are going to be used in hybrid constructions where we don't know what the other material might be used in the stackup. There might be some sort of interactions that occurs, but we try to do the best that we can and stay on top of it. That's why when we introduce a new product into the field, you want to control where it goes. It's not wise to just shotgun the market with a brand new material. We want to have a more controlled rollout, so if something does develop, we can try to work on it and correct it before it becomes a major issue.

Shaughnessy: That's interesting. I think they look forward to it. For example, Lee Ritchey looks forward to when a new material comes out because he can start generating some numbers on it.

Andresakis: The other thing that's important is material suppliers have to work together. During my years at Oak-Mitsui, we always complained to the laminate suppliers, saying, "You come up with this new resin system, and then at the end, you try and stick copper to it?'" Then, they come back to us and ask, "Can you come up with a copper that works?" It would have been nice if we had talked about it sooner since there are three major components—the resin, reinforcement, and copper; all of them should be working in conjunction with each other.

Nolan Johnson: What should the industry do to create a more efficient development process that's faster than what you're doing now but not reckless?

Andresakis: We try to hire people with experience in the industry, so we have a lot of good polymer chemists and chemists in general who have been in the field for a while. We need to have a solid pipeline and we want to have a good front end for ideas. Then, we have to go through a process, look through that list of ideas, and say, "Which are the ones that need to continue?" We use a version of the stage-gate process where we do an upfront evaluation of the total available market and market trends to figure out if it plays in our area of expertise.

We try to screen things ahead of time with a committee and look at what are the right projects to be investing our resources. Next, we go through a series of every increasing detailed steps. We regularly check on the progress. It's always easy to start a project. One of the hardest things is to kill a project, so you also have to be diligent. If something is going to down the right way, you have to decide if something has to change or if you do something new. It's a balancing act because you want to be very creative and dynamic with the marketplace, but you still have to have a procedure to make sure you're covering all the bases.

Weldon: If you look at a materials supplier, a fabricator, and then an OEM, they all do a pretty good job independently. The question is, more or less, how do we get those three to work together to streamline the process of pulling through a requirement down to material development and up through fielding? And some of that is because everybody comes to the dance, but nobody wants to pick a partner; they're all trying to determine if it's worthwhile to undertake that activity. For example, does a designer who might be an entry-level engineer or an early designer on a project need a new material to solve the problem? Do they need to take that back to a material supplier like a DuPont and make that request? That's a big jump for a 23-year-old, entry-level engineer. At the same time, a company like DuPont doesn't want to then talk to another company at the OEM level, and based on information they receive, say, "I'm going to undertake material development independently without having that guaranteed pull through."

The constant tension between buying and making is always there. However clever I may or may not be, I don't have an answer for that problem. That specific component of the market interaction is what limits that cycle time. Until there's a real demand with an absolute dollar figure that everybody else can look at and say, "I have to fill that need, and I can make money," I don't think anybody is going to speed up. Unless you have a clever way to break that cycle, we're going to see in the design cycle the way it is.

The constant tension between buying and making is always there.

Feinberg: One of the things that we've heard from some of the designers is that they're beginning to think that it might be a good idea to talk to some of the material suppliers as they're designing new types of circuitry and devices. Nolan and I asked a couple of them if they were seeing any of that activity, and if any of the designers were reaching out to suppliers. They're designing things that may or may not be possible with the materials that are currently available. Maybe, if they would talk with some of the suppliers on what they want, it might help speed things up.

Weldon: We have a steady flow, and more communication is always better. I'll take any question they have, even if they seem trivial. I'd rather have it be asked and answered than to go under speculation. We do see an increase in the questions on circuit boards materials.

Usually, the breakdown voltage for any of our insulating materials has been where we're not asked the right questions early enough because people assume that a data sheet says 7,000 volts per mil for polyimide. They can run it at 6,900 volts continuously, so they try that for about 30 seconds, and it blows up. That's a classic example where I wish they would have called. I would encourage everybody to interact more with your supplier. We have seen an increase in phone or email traffic, and we look forward to responding.

EDA and design automation tools out there are great, but they're not always updated in time to catch up with the speed of development and release of products at a supplier level. At the OEM level, I suggest that you work with your fabricator. Find out the available materials, and then call those suppliers and ask. Do that over and over again until everything has been answered.

At the OEM level, I suggest that you work with your fabricator. Find out the available materials, and then call those suppliers and ask. Do that over and over again until everything has been answered.

Feinberg: That's a very good comment. There may be some designers out there that don't realize how important that could be for them.

Matties: Is there any smart material technology that is entering into the marketplace? And how do you define smart materials?

Weldon: If I were to go back to our smart materials team and ask them, they would say their mission is to view the world as a circuit. It's a matter of what you were talking about earlier with 3D printing, additive manufacturing, and adding electronics to the housings of the physical device itself rather than have it be a traditional PCB mounted with standoffs and a set of Allen screws.

Andresakis: Again, it's about enabling the connectivity and capability into the materials other than just being the structural element.

Matties: This seems like a booming market,

Weldon: Absolutely, and we have a few examples in the Sunnyvale site. For example, outside of one of our meeting rooms, there was a telecommunications box with a bunch of wires, etc. They integrated all of those peripherals, including wireless charging and speakers and everything else, into the conference room table itself. The table is the circuit, and the device is on top of that. So, it's not just a table, and that's the vision: How do we integrate these things into something more streamlined? Because that's certainly where the world is going.

Andresakis: Yes, and it's the same thing with our Corian® material for your kitchen countertops.

Matties: Right, it has hand warmers built in. You can set your hand or a plate on the table and warm it right up. When you think of a circuit manufacturer, though, it's changing the definition of what a circuit manufacturer is and does because of the materials. And there's a whole new level of design in this "smart world."

Goldman: What's going on with copper foils, availability, etc.? What's happening in the supply chain?

Andresakis: From a technical standpoint, for electrodeposited (ED) copper, major manufacturers have moved to very smooth copper foil. They can make the finished product relatively smooth even with nodular treatment for adhesion. They are now using micronodules. Now, these ultra-low profile copper foils are more commonplace. They're not quite as low as rolled annealed (RA) copper, but it's hard to go to DesignCon lately without a paper on copper foil roughness because it is a concern. We've seen it ourselves, and our product has been testing with various coppers up to very high frequencies. Companies are continuing to look at the possibility of making copper even better than it is now. And if so, what can be done? Companies are also considering oxide treatments because we can make a beautiful copper foil, but it could be ruined by the oxide process needed for the multilayer lamination process.

Tesla battery pack with a protective plastic cover over it (the shiny black hard cover has either been removed or not yet installed). You can see some of the internal structure with large blocks of lithium cells. (Source: Windell H. Oskay, evilmadscientist.com)

And as far as availability goes, I haven't heard about any shortages in the electronics industry lately. However, if business started booming again suddenly in electronics, there would be a possibility of another shortage. This shortage may be more about the impact the lithium-ion battery market is having on the global copper supply. I know that in the U.S., more copper foil is being sold for battery purposes with demand continuing to grow. There's more copper processed in Tesla's Gigafactory than there is in all of the electronics made in the U.S. Thus, battery production and the battery market has taken up a lot of the capacity for copper foil. Major copper manufacturers are looking at bringing on additional capacity, but with the types of plating drums they require, there are only so many companies that can make them.

Goldman: The whole lithium battery thing just keeps getting bigger and bigger, but there's only so much capacity out there, and it cannot increase very rapidly.

Andresakis: Correct.

Goldman: I'm guessing that all of your laminate and materials teams are trying to get their hands on as much copper as possible.

Andresakis: Most of the major laminate suppliers have a good relationship with the copper suppliers, so everyone is working on it. The only good thing is the copper weights used for batteries are usually a lot lighter than for circuit boards. They can crank out more area for battery foil with the same drum. They often use just 7–9-micron copper thicknesses, but sometimes go up to 18 microns. Most PCBs use 18–70-micron copper.

Matties: This has been great. Thank you so much for all of the information.

Andresakis: You are welcome. We appreciate the opportunity. We would also like to invite those interested in seeing examples of our materials in action to come to our new Innovation Center located at our Silicon Valley Technology Center in Sunnyvale, California.

Weldon: Thank you for your interest and your time. **PCB007**

IPC Pulse Survey Shows Positive Industry Outlook Continues but Varies by Region

One World, One Industry

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

First-quarter 2019 results from IPC's "Pulse of the Electronics Industry" global data service shows an electronics industry that is still riding the crest of the current growth cycle despite cooling enthusiasm in some regions and industry segments. The 167 participating companies worldwide reported an average quarterly sales growth of 8.4% in the fourth quarter of 2018. Their average forecast for first-quarter 2019 sales growth was a bullish 9.8% worldwide.

The industry's outlook on the current direction of the business environment worldwide rebounded in the first quarter of 2019 after scores edged downward in the last three quarters of 2018, although they remained positive all year. Most participating companies reported the current direction for sales, orders, order backlogs, and profit margins as moving in a positive direction. Increasing labor and materials costs and recruiting challenges were the main factors negatively affecting the current-state score.

The companies' outlook for the next six months also strengthened in the first quarter of 2019. Growth in sales, production, number of full-time employees, markets, capital investment, and exports contributed to the strong six-month outlook. The 12-month business outlook also strengthened in the first quarter, with 88% of responding companies indicating a positive outlook (Figure 1).

The strong current-state outlook was driven by results from companies in the Americas and global businesses. The current state score was sharply negative in the Asia Pacific region and mildly negative in Europe. Strength in sales and orders were the main positive drivers of the current-state scores, but these factors were neutral for Asia in the first quarter. In all regions, recruiting difficulties and rising labor and material costs continued to affect these scores negatively. All regions gave positive scores on the expected direction of the industry in the next six months, but those of companies in the Ameri-

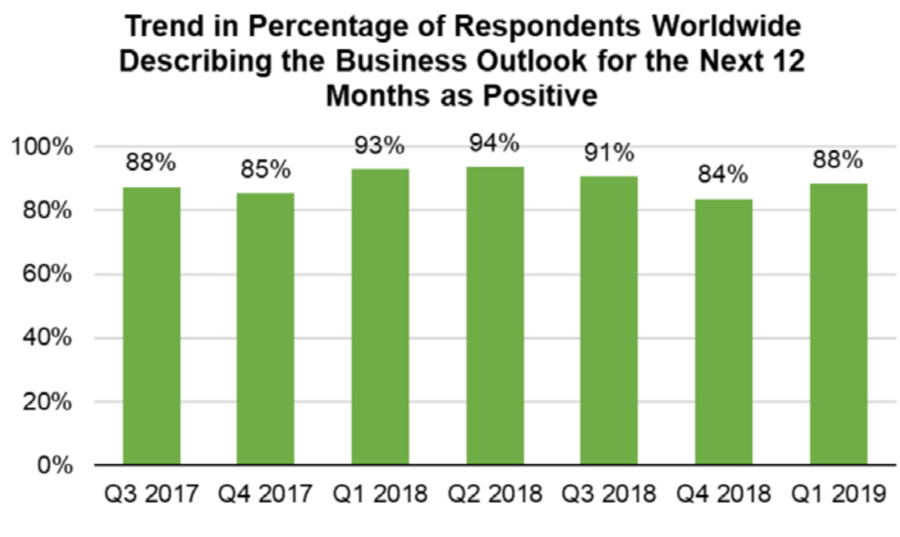


Figure 1.

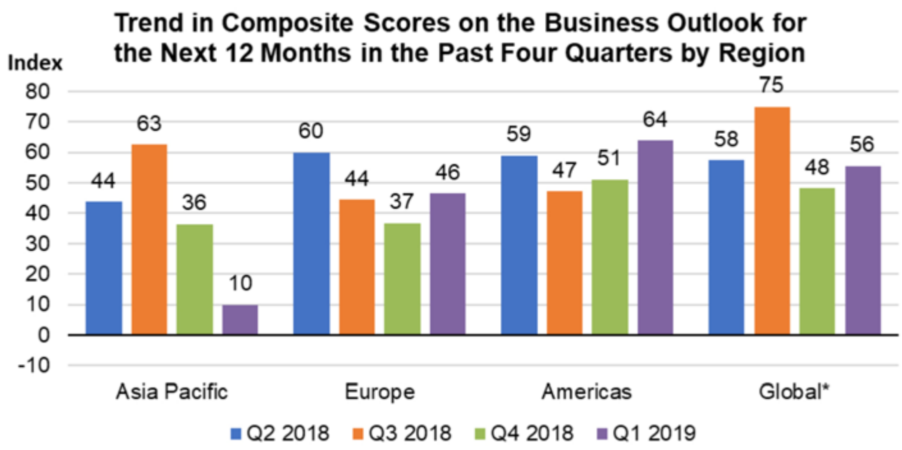


Figure 2.

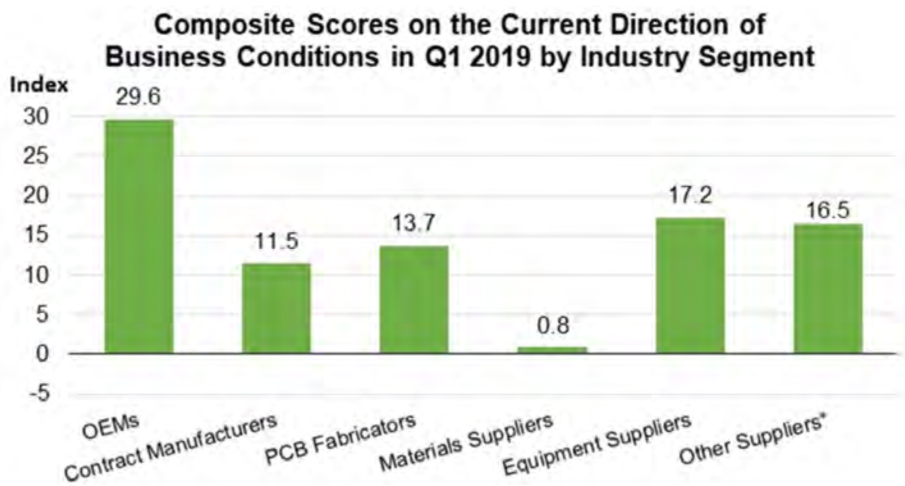


Figure 3.

cas and global businesses were substantially higher. The same regional differences held true for the respondents' 12-month business outlook (Figure 2).

Among the industry segments, the current-state score was strongest for original equipment manufacturers (OEMs) and weakest for materials suppliers, although all industry segments indicated positive current-state scores in the first quarter of 2019 (Figure 3). The same pattern was seen in the industry segments' composite scores on the six-month and 12-month business outlook. Sales and order growth were the main positive factors in the current-state scores, and higher labor and materials costs and recruiting difficulties were the main negative drivers. All industry segments averaged positive net scores on the current direction of profit margins except for contract electronics manufacturing services (EMS) companies. In the six-month outlook, OEMs indicated the strongest outlooks for capital investment.

Segmenting the results by company size tiers, companies with more than $100 million in annual sales produced the highest scores for the current direction of the industry and six-month business outlook, but companies in the $10–100 million annual sales range had the most bullish outlook for the next 12 months.

Respondents comment every quarter on the trends or conditions that are driving or limiting their business growth. The comments reveal that component shortages have begun to ease while there is growing concern about the shortage of qualified workers as the major factor limiting growth. Workforce issues now appear to be the biggest concern in all regions and segments of the industry followed by tariffs and trade disruptions.

For more information on IPC's first-quarter 2019 results from the "Pulse of the Electronics Industry" data service, please contact the market research department at marketresearch@ipc.org. **PCB007**

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

Insulectro's OEM Program: Time to ACT!

Feature Interview

Ken Parent, Insulectro VP of sales and product management, discusses the current dynamics in the materials marketplace and how Insulectro is developing educational resources to help design teams and fabricators better understand the capabilities and features for the emerging laminate materials.

Nolan Johnson: Ken, let's start with a quick introduction of you and Insulectro.

Ken Parent: Insulectro is an electronic materials distribution company. We have been doing business in the PCB world for 50+ years. We provide materials that our fabricator customers use to build PCBs. In the last decade, Insulectro has also expanded into the printed electronics world, which brings some interesting perspectives to electronic material requirements. And we are focusing on how materials get specified in design as we continue to work through our OEM ACT! program—Accomplish Change Together!—which educates OEMs and designers by partnering with our fabricator customers.

Johnson: What are the dynamics in the market right now, and how do you see it changing?

Parent: Material selection right now is very dynamic especially with the two major laminate suppliers we represent. On the rigid laminate side, Isola has brought out at least seven new materials in the last 10 years, including products like Tachyon® 100G, I-Tera® MT40, I-Speed®, Astra MT77, and materials that they've just started to release as well. Many new materials are coming to the market, and they all have a very special performance attribute that is needed in the market.

On the flex side, we're also seeing new materials addressing high temperatures, for example. And there's a renewed interest in materials that have been around for decades but now seem to be hitting their stride, such as DuPont's Interra™ HK 04 buried capacitance material. There are great opportunities for new materials, but it also creates a lot of work and demand for educating the designers and fabricator customers on how to best use them. A lot of work is being done on laminates as well with copper foil enabling higher performance materials for electronic products and using

smoother copper for better signal integrity performance.

Johnson: And the trade-offs in soldering and adhesion that go along with that.

Parent: Everything has its trade-offs, but in our case, Oak-Mitsui is working with the laminators, and they have some very good proprietary processes to make sure that those trade-offs are meeting the expectations of IPC and OEMs. But even with help from IPC and UL, it's a lot to keep up with, but we have resources to help; that's one of the key things that distinguishes Insulectro from the pack. For those looking for materials choices, we can match up Isola laminates together with DuPont Pyralux® laminates along with copper foils to create the best solution to a particular demand in the marketplace. We're very fortunate to get the ear of designers and people that are challenged for the next level of performance in their material choices.

We're very fortunate to get the ear of designers and people that are challenged for the next level of performance in their material choices.

Johnson: It seems to be time for designers to start thinking about the substrate as an active, performing part of the design. And you really need to think about the board as if it is an active component in your overall assembly.

Parent: Yes, that's true in a lot of ways. There's electrical and thermal performance to consider as well as other requirements like flexibility, fitting into a particular box, or building a 32-layer board with minimal thickness. There are all sorts of mechanical, electrical, and thermal criteria required by these boards today. Evolving technology in electronics is stretching the limits of some of process capabilities.

I am amazed at what PCB shops are able to do today, including the small holes they're drilling, the number of layers they're doing, how well they're registering them, and the fact that now 3-mil lines and spaces are a daily occurrence in many shops. OEMs are requiring sub-50-micron lines and spaces on certain high-density jobs. All of those examples are challenging our fabricator customers, and therefore, our materials.

Johnson: With all of this new work going on in materials, there's a spectrum of materials appropriate for a particular design. Historically, it was standard FR-4m and you would go to some sort of high-end material; those were your two choices. But now, there is a range of products in the middle, and the ultimate specifier for materials is the design. How do we educate designers to make better decisions so that they're not under-specifying nor over-specifying their substrate?

Parent: That's a great question. It's an ongoing challenge, and we're looking for ways to become a better solution provider on that front as well. We're a little premature to talk about it today, but we are about to announce that Insulectro is going to be getting a lot closer to the PCBs design houses by providing design services to our fabricator customers that don't currently have that as an offering. We've recently promoted one of our top Field Application Engineers, Megan Teta, to be product manager for these new design services.

There are a few circuit board shops that have a relationship with design houses today, and they do get involved with early design choices, including material selection, layer count, lines and spaces, hole sizes, etc. We have hired another resource who will be starting in May to drive our design services program to a significantly higher level within our business. We are anticipating having a relationship with as many as 100+ designers in the next 3–5 years do a better design of circuit boards. It's a very young program that we've been talking about and investing time in over the last few months, and we're about to take one giant step forward on that front soon.

Johnson: That's great.

Parent: About your question on how to educate the design community, there are very good PCB design chapters across the country. And with Megan and our new hire, we expect to spend a lot more time on that front, learning about what designers need and providing tools to those designers that we know are available through the relationships that we already have. Again, we are going to increase the level of relationships with those design houses.

Johnson: Interesting. Are you doing some chapter-by-chapter work with IPC Designers Councils or other similar organizations?

Parent: Yes. We think that's a good use of our time. It has been one of the more exciting things that I've had to work on over the past few months. Over the next 24 months, you'll hear about the next steps we're taking in offering those design services. Our intention is not to have designers on our staff, but to connect designers and OEM programs that need design work earlier netting fewer revisions through the prototype build stages.

Johnson: That makes a lot of sense. Earlier, you mentioned the ACT! Program. Is that the same program you've been talking about?

Parent: No, but we learned through our ACT! Program that this was a missing opportunity for us. ACT! started because of the new materials coming to market. But the PCB fabricators didn't want to use the materials until an OEM specified them. And the OEMs didn't know how to specify them because they didn't know enough about their properties or which qualified PCB shops could process the materials. ACT! is an opportunity for Insulectro to connect our fabricators and OEM contacts.

Our goal with ACT! is to always work through our fabricators. We know our PCB fabricator customers, their sales teams, and what's going on with their OEM targeted customers. They know the programs coming out of that OEM and need circuit boards for them, so they're getting involved early on with some prototype builds. We work with our customers' sales teams and field application engineers as much as possible to educate OEMs on new materials that are available and may provide a solution—electrical, mechanical, thermal, cost, delivery, etc. There are all sorts of opportunities, and sometimes, more often than not, it's a combination of multiple attributes that an OEM is working to improve upon.

There are all sorts of opportunities, and sometimes, more often than not, it's a combination of multiple attributes that an OEM is working to improve upon.

We're taking our message of what materials are coming to the market that can solve challenges to the OEM through our fabricator customer. And we're building better relationships with them and their sales teams, so that they know that the material we're bringing to them is something that their circuit board shop has approved. We want them to have enough process knowledge to get through their shop with the fewest problems possible. It's all about getting the circuit board shop qualified on the material, and then having their sales team be confident enough to talk about those new materials to their customers. We want to build that trust.

Johnson: That's good because it seems that engineers and design teams are turning to their fabricators for advice, and the fabricators are giving advice based on what they already know.

Parent: Right. We're trying to bridge that gap and be a part of that solution, and we don't think that we have as much credibility approaching an OEM as a material provider if we do it without a fabricator customer. We believe that two heads are better than one when we're going to solve a problem with an OEM.

Johnson: What would Insulectro want the market to know about upcoming trends and developments for materials and consumables?

Parent: The challenge for our fabricator customers is knowing about and staying current with the materials that Isola and DuPont are bringing to the market. Many have a sales force representing not only the Isola and DuPont materials that may be coming through that shop but with two or three other competitors as well. It's very difficult to stay current on all of the capabilities of those materials. I would like our customers to lean on Insulectro to help bridge that gap and bring information to OEMs that help our customers win more programs.

Johnson: It seems that there is a definite need for organizations and all groups within this industry to step up and be a champion of education.

Parent: Yes. We believe that there is so much to learn about what's available to make circuit boards more functional—it's challenging—but we can help. We are part of that solution.

Johnson: Thank you, Ken.

Parent: I appreciate your time, Nolan. Thank you very much. **PCB007**

New Technique Could Pave the Way for New-generation Flexible Electronic Components

A team of engineering experts at the University of Exeter have pioneered a new way to ease the production of van der Waals heterostructures with high-K dielectrics–assemblies of atomically thin two-dimensional (2D) crystalline materials.

One such 2D material is graphene. While the advantages of van der Waals heterostructures is well documented, their development has been restricted by the complicated production methods.

The team developed a technique that allows these structures to achieve suitable voltage scaling, improved performance, and potential added functionalities by embedding a high-K oxide dielectric, which could pave the way for new flexible fundamental electronic components.

"Our method to embed a laser writable high-K dielectric into various van der Waals heterostructure devices without damaging the neighboring 2D monolayer materials opens doors for future practical flexible van der Waals devices such as field effect transistors, memories, photodetectors, and LEDs," said Dr. Freddie Withers, co-author of the paper.

The quest to develop microelectronic devices to smaller sizes which underpins the semiconductor industry has been stymied by quantum mechanical effects. To continue scaling devices ever smaller, researchers are looking at replacing conventional insulators with high-dielectric-constant (high-K) oxides. However, high-K oxide deposition methods are not directly compatible with 2D materials.

The latest research outlines a technique that allows for the creation of a host of fundamental nanoelectronic and optoelectronic devices including dual-gated graphene transistors, and vertical light emitting and detecting tunneling transistors.

The research is published in the journal *Science Advances.*

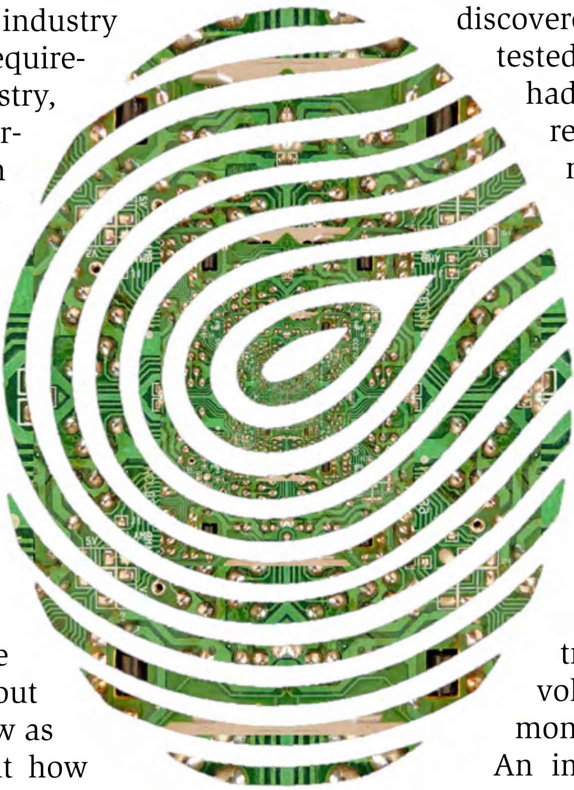
(Source: University of Exeter)

What Is Reliability Without Traceability?

The PCB Norsemen
by Jan Pedersen, ELMATICA

High reliability and compliance are hot topics at conferences all over the world. If you are a supplier to industries like defense, automotive, medical, and aerospace/space, high-reliability and regulatory compliance are strict demands for electronic device manufacturers. For example, the automotive industry has zero-kilometer failure requirements. In the defense industry, there are full life-cycle service requirements, function on demand, and traceability throughout the entire production process plus strict compliance and origin requirements.

In this column, I will discuss how high-reliability demands enforce the need for traceability, and at what level the traceability should be. Cost is a vital part of how much we invest in reliability. In the medical world, we talk about ALARP risk, meaning "as low as reasonably practicable." But how can we discuss a reasonable risk if life is at stake? And if we accept the risk, how can we limit the damage and cost?



Printed Board Traceability: Down to the Sheet of Base Material Used

Working with printed boards for decades, I have seen the result of how good traceability can limit the cost when a disaster occurs, and I have seen the contrary. In other words, we can turn the disaster into a problem that's still costly and involves lots of resources but avoids the pandemic feeling.

A good example would be if a big shipment arrived at the customer's door and they discovered when they opened and tested the boards that the PCBs had thinner copper plating than required. One's first thought might be to return the high-cost PCB, resulting in huge claims and costs. However, with good traceability markings, we could limit those boards down to a few production panels in the PCB factory. A case like this was settled by replacing a few boards instead of having a full shipment sent back to the factory in China. Thus, the traceability saved the involved parties both time and money.

An important role of traceability in printed board production is to confirm transparency and traceability of materials, production sites, and production processes. When traceability is used for cost limitation, we must add traceability to the printed board's position in a production panel, and a unique production printed board and panel identification. Ultimately, we should be able to trace down to the actual sheet of

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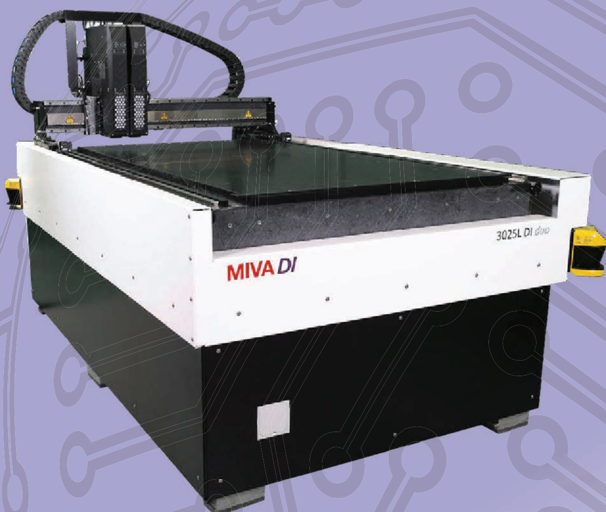

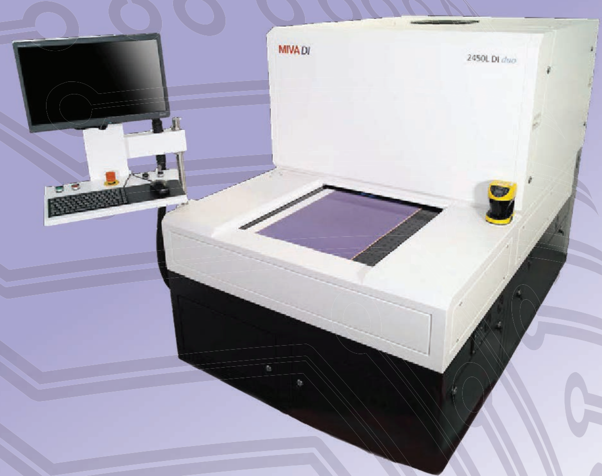

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base material used. This level of traceability is possible today but rarely implemented. With the implementation of full connected factory control, we will soon see such traceability even down to used chemicals and other process parameters that are impossible to achieve right now.

Today, in printed board production, we accept the fact that errors occur because of the high number of complex processes and simply because humans are involved. We also know that hidden failures will escape the outgoing control. This leads us to the importance of consequence and cost limitation when the failure potentially could jeopardize function and reliability in the end product, such as life-critical medical devices.

Today, in printed board production, we accept the fact that errors occur because of the high number of complex processes and simply because humans are involved.

Traceability in PCB Production: Not a Sufficient Focus

Being chair of two IPC task groups where we write performance standards for printed boards used in automotive and medical devices, traceability is frequently discussed. We experience how traceability has a focus in PCB assembly processes but is generally neglected in requirements to PCB production. Some companies understand the importance of traceability and implement different smart ways to trace one printed board back to its panel, or at least the production lot, and limit the consequential cost. Other printed board factories have implemented good systems. However, when the systems are not implemented into the performance standards, it's left to the customers and suppliers to apply for them, and they often don't. If the system was made mandatory in the performance standard, they would have to follow it.

Strict Requirements for Medical Devices: Not Consistent Enough

As a part of my work with the automotive and medical standards, I have learned that traceability is an area where some companies are good while others simply miss out. Very few, if any, excel. The closest are companies involved in human implant electronics. When I looked into the standard, I found the same as we see in medical electronics—the requirements are strict for the manufacturing of the medical devices, but not upstream to printed board manufacturing.

One might think that with the importance traceability offers, there would be several IPC standards describing how to handle it, but there are not. IPC-1782 is the only one describing the issue, and it is the standard for manufacturing and supply chain traceability of electronic products. Until now, this standard described traceability for electronic production, excluding the printed board. This is about to change. In the ongoing work toward a new revision, we have started to discuss how we can implement traceability for printed boards as well.

Compliance to Specification and Corporate and Regulatory Requirements

To secure traceability of compliance to product performance and requirements in an electronic device application, a computer-readable digital specification should be created during the product development process. This specifies the product requirements in all PCB procurement stages between buyer and seller through the complete product lifecycle, and encompass the parameters as written in the procurement documentation as a minimum.

It is a good habit to let the digital specification be part of the request for quotation to protect the buyer and secure that the seller has sufficient capability to meet the specified qualification and performance requirements. Such digital specification is not common today, but I am sure it will be in the near future because it is the best way to secure that all requirements are maintained through the complete supply chain.

In many industries, there are regulatory compliance requirements enforced by the country the electronic device is being employed. The most obvious is in the defense industry where traceability must show where all critical components are made. When procuring printed circuits or materials to the defense industry, there is no such thing as assuming or relying on questionable interpretations. There are no options for shortcuts whether your supplier follows the regulations or not. You must know the country of origin down to the printed circuit or material level of your products, and the bill of materials (BOM) should encompass a country of origin for every article.

Traceability: Not Just a Buzzword

In the medical industry, we have regulatory requirements from authorities such as FDA and EU Medical Device Directive. Good traceability routines are vital and can be the defining factor between failure and success, or even worse, life or death. If traceability and limitation of consequential cost are important for you, I recommend staying tuned to the development of IPC-1782 with its new revision being developed right now. From my perspective, this standard will give us an important tool, especially if you link it up to IPC-2581 and the CircuitData specification language. All of this is currently under development and will give the future an important tool to control your traceability needs. Stay tuned; we will come back with further news on this topic. For Elmatica, traceability is not a buzzword; it's one of our three core values. **PCB007**

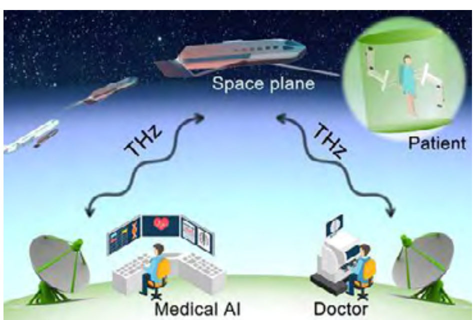
Jan Pedersen is a senior technical advisor at Elmatica. To read past columns or contact Pedersen, click here.

Terahertz Wireless Makes Big Strides in Paving the Way to Technological Singularity

Hiroshima University, the National Institute of Information and Communications Technology, and Panasonic Corporation have developed a terahertz (THz) transceiver that can transmit or receive digital data at 80 Gb/s using the channel 66 defined by the IEEE Standard 802.15.3d. The transceiver was implemented using CMOS technology, which would have a great advantage for volume production.

The THz band is a new and vast frequency resource expected to be used for future ultrahigh-speed wireless communications. Published in October of 2017, IEEE Standard 802.15.3d defines the use of the lower THz frequency range between 252-325 GHz as high-speed wireless communication channels.

"We presented a CMOS transmitter that could do 105 Gb/s in 2017, but the performance of receivers we developed—or anybody else did for that matter—were way behind for a reason. We can use a technique called power combining in transmitters for performance boosting, but the same technique cannot be applied to receivers. An ultrafast transmitter is useless unless an equally fast receiver is available. We have finally managed to bring the CMOS receiver performance close to 100 Gbit/s," said Professor Minoru Fujishima, Graduate School of Advanced Sciences of Matter, Hiroshima University.



"People talk a lot about technological singularity these days...you wouldn't want to have a zero-gravity operation on board a space plane without real-time connection with earth stations staffed by medical super-AI and doctors. After all, singularity is a self-fulfilling prophecy...It will be a distant outcome of what we develop today and tomorrow," said Fujishima.

(Source: Panasonic Corporation)

Laminate Suppliers Face Increasing Demands From Customers

Feature Interview

As a global laminate supplier with a large product offering, TUC is at the forefront of the growing customer demands that stem from a number of market segments pushing next-generation products. In an interview with Nolan Johnson, TUC North American President Alan Cochrane talks about the company's shift toward trending areas—including HDI, halogen-free, and RF—and how strategies like the adoption of thinner glass styles have helped make it all possible.

Nolan Johnson: Alan, please give us some background on yourself and TUC.

Alan Cochrane: I've been with TUC for a little over eight years, and I've been in the industry since 1978. I started in research and development at TRW (now Northrop Grumman). I was on the fabricator side until 2010 when I joined TUC. We've seen a substantial amount of growth, including $425 million in 2016, $525 million in 2017, and $630 million in 2018.

TUC has been in business since '97, making copper-clad laminates. TUC started with mid-Tg materials and quickly moved up to high Tg as well as halogen-free products in the mid-loss range. Since the marketplace keeps having more and more needs, we moved into low-loss and super low-loss categories. We break things down into a few different market segments: high-speed digital and HDI applications in that marketplace. We also have product offerings for the RF and the millimeter-wave applications as well as a small segment that is the high-Dk specialty materials.

The biggest focus these days is mainly in the high-speed digital and RF areas. And there's some crossover between the two of them. We have a product offering in the high-speed digital that's for the 56-Gbps applications that are out there, which is pretty well entrenched. That's the 12.5–14.5-GHz range that we've been servicing with a number of products. It's an APPE-based product lineup with different fillers, etc. We've done a lot of interesting testing with large OEMs to meet their needs.

We are releasing a product soon called T4 for 25–28-GHz applications. The magic number, from an OEM standpoint, seems to be a 0.7 dB loss per inch at 25 GHz with a 5-mil trace. So, as we get up into the 25–28-GHz applica-

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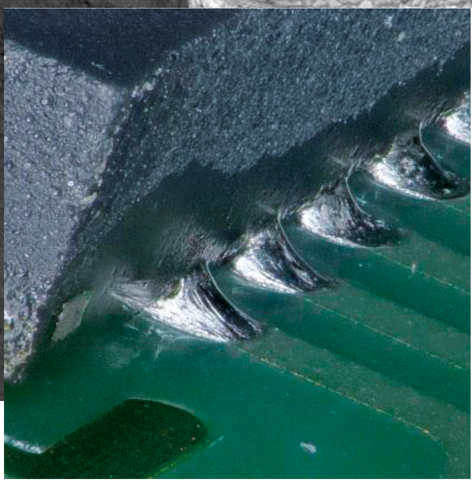
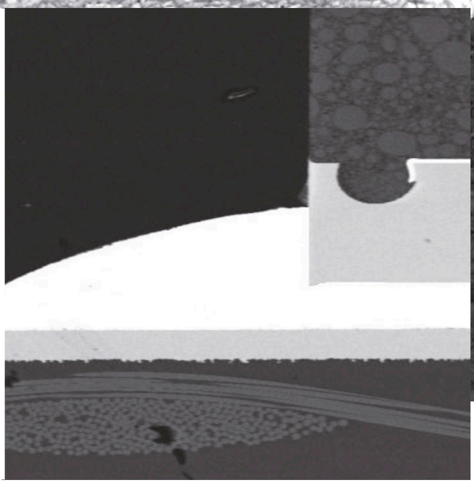


Excellent 3D solder joints for increased reliability



Enhancing corrosion resistance

Enables high tin thickness over (in µm)

1.4

Stanna-Q® is an engineered solution for the production of quad flat, no lead components. Because Stanna-Q® is an electroless process, bussing for electrolytic connection does not need to be engineered into the strip or carrier.

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tions, we have to look not just at our dielectric material but also at coppers that are starting to play a very big role in the overall loss of the product.

Johnson: What are some of the market dynamics that you're currently seeing?

Cochrane: Almost six years ago, it used to be low Dk to try to get thinner. Everything is shrinking and there's more miniaturization. Packages are getting smaller and smaller. To maintain that proverbial 50-ohm characteristic impedance or 100-ohm differential applications, we wanted thinner dielectrics with lower Dk so that we could maintain 50–100-ohm applications. However, we started getting into too low of a line width with resultant resistance to the overall losses, which became a major problem. Our focus for the last five years has been to look at lower loss for our high-speed digital customers.

Loss is the big driver followed by skew. The skew from trace to trace with differential pairs is determined a great deal by the glass weave that is utilized. What used to be a single-ply construction with a flat glass is evolving into multiple ply. The magic-ply count seems to be about a three-ply construction and to get into 5-mil dielectrics that we're looking at for a 5-mil trace, that means we have to use a thinner glass.

Now, we're crossing over to HDI. The 1027 glass—one and a half mils in overall thickness—used to be for laser applications for thin, stacked microvias. Today, we're using a lot more of that in high-speed digital. Within the last two years, we've gone from the standard glass being a 1078, for example, to a 1035 and now down to a 1027. We're getting thinner and thinner glasses to support that skew requirement as well as the loss requirements now even moving to 1017 and 1010 glass styles.

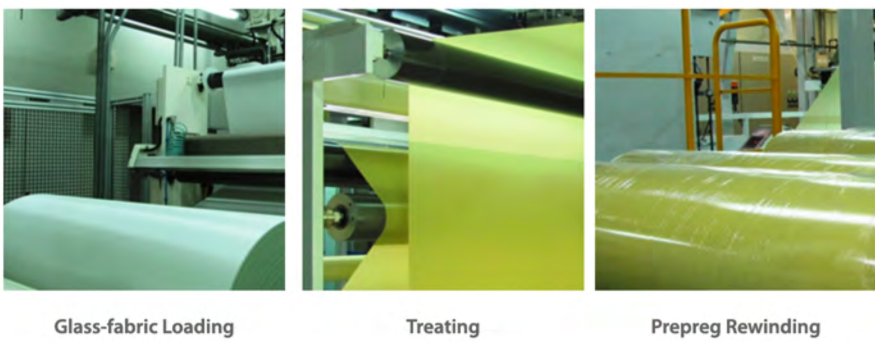
Johnson: Where do you see TUC's current sweet spot in your product portfolio?

Cochrane: We have two main areas right now. We've gotten very close to the magic number of the 0.70 dB loss per inch at 25 GHz, which is for the next generation of chips that are out there for the 112-Gbps or 400-Gbps switch. That's the lowest loss material that we have that is not in the PTFE range. We're getting a lot of traction in that area because of that need.

We're also seeing a resurgence of halogen-free. With the offering that we have in the halogen-free world, we still have a very low-loss material. We're seeing a lot more utilization of the super low-loss, halogen-free materials. There may not be a corporate mandate to use halogen-free, but designers are finding that they can get the kind of performance out of a halogen-free that they couldn't a number of years ago.

Johnson: Does the drive for the halogen-free seem to be customer demand?

Cochrane: Yes, in addition to their ability to have very low-loss and super low-loss materials. Then, we can easily get good performance in the 56-Gbps applications and the 14.5-GHz area. They're being good corporate citizens. We see demand coming out of Europe, Canada, and North America as well.



Prepreg manufacturing at TUC.

Johnson: That's an interesting point. Give design teams globally the opportunity to get high performance out of something that is greener, and they will choose it.

Cochrane: Definitely. That seems to be the trend. Another area where we're making inroads is in RF, which have been predominately dominated by PTFE. We're seeing two camps: 25-GHz applications for the side radar, and 77–79-GHz applications for forward radars. In the past, that has been dominated by the PTFE marketplace because of the consistency of the dielectric constant.

In addition, the packaging in the marketplace has shrunk down from what used to be a patch antenna, two-sided product, up to an 8-layer product. Due to the pitch, we're looking at some 0.8-millimeter and 0.65-millimeter pitch products with multilayer PTFEs. From what we're hearing from a number of OEMs, the yield is not very good. So, they're looking for a more thermal set product that can meet the dielectric constant consistency so that they can hit their numbers for frequency drift over the temperature range. We have a number of product offerings that fit into that category. We've been making a lot of traction in that area as well.

Johnson: My recent coverage of the industry shows that autonomous vehicle sensor manufacturers are moving computational chips onto the sensors themselves to distribute the computer power rather than try to have a central computer do it all. Do you see the autonomous vehicle sector as a major driver for market needs?

Cochrane: Cost is a big driver in that. This is a tough marketplace because they want the lowest cost and the highest performance all in one. At first, only high-end vehicles had all of the collision avoidance, lane assist, etc. But entry-level cars have them now. The price point of that product offering has dropped considerably, hence the move away from PTFE due to the cost of the base materials versus a thermal set epoxy type of material. When we look at it from a dimensional stability standpoint over the temperature range, we're having to test from -40°C to 140°C, and we have to look at what is the frequency drift throughout that whole temperature range.

This is also true with humidity. We have to go from 50% to 95% humidity. Then, there's aging,


Alan Cochrane

which is two times what the norm used to be. It used to be 1,000 hours of aging, but now it's up to 2,000 hours. And some interesting things tend to happen to some materials through that aging process at either 80°C or 125°C. Some materials don't maintain the consistency from an electrical standpoint. I think the market is growing in that area considerably.

A lot of different things are going on in the automotive industry, and they want low-modulus and high-modulus materials. They want high-modulus materials because they want the reliability for the lower Z-axis expansion, but they want low-modulus materials because they want to do a gasket sealing in something like a hermetically-sealed area so that they can prevent the degradation of the new chip-on-board applications. Then, because so many of these products are a direct chip attach, we have the XY movement of the substrate or the board that the IC is attached to, seeking less movement to match the silicon in that area.

Additionally, because of the small pitch, we look at the surface profile of the thinner glasses that we have to use. For example, TUC just put in three new treaters in a new factory in Taiwan. The focus for all three of those treaters is super low-loss materials and thin glass.

Johnson: We've just touched on a number of constraints and factors that need to be weighed

Mass lamination process at TUC.

when selecting a material for newer RF-based, higher-density applications. Engineers are increasingly being required to look for appropriate materials for these designs; FR-4 just doesn't cut it. You have all of these materials that you're working on. How best should a design team become knowledgeable with TUC's products? And how do OEMs analyze your portfolio and zero in on what they need?

Cochrane: We spend a lot of time giving seminars to our customers all over the world. Initially, we focus at the OEM level. It's a give-and-take situation where they reach out to us with a problem, and we need to try to find a solution for it. Sometimes, their current supply base might not be meeting their needs. We do our best to give a detailed presentation for any industry and show all of the testing that we do.

We do a ton of testing with different thicknesses and dielectrics with three-ply constructions versus single-ply constructions. Because TUC has the benefit of having a large mass lamination facility in our Taiwan factory, we can build test samples, then test them all and get proper results to share. Still, face-to-face meetings are the best way to go.

Johnson: You're finding that you definitely want to meet in person with the design team.

Cochrane: That's when the questions that come up. When we put together a detailed, high-level presentation from an engineering standpoint, there's a lot of verbiage and background that goes into that. The benefit from our standpoint is that we hear from the customer when we ask, "What are your challenges and needs?" That helps us to focus our R&D group on the needs of those large OEMs.

Johnson: The best part of that conversation with the design teams isn't after you've given them the information; it's the moment where they say, "Yes, but…" What follows is usually the good stuff.

Cochrane: Yes (laughs).

Johnson: You have all of this information and data. You're talking to customers to find out what's going on and reaching the, "Yes, but…" moment so that you can understand the challenges designers are facing. Is there a robust, complete place that an engineer could look at this information?

Cochrane: The best thing would be to contact the person in the region that you're in. For North America and Europe, that would be me. We can make sure that they get the proper information and the right individuals to interface with them so that they get the right amount of support.

Johnson: Do you see these changes in conditions and customer demands to cause adjustments in how TUC manufactures, stocks, and distributes?

Cochrane: Stock and distribution are key because North American technology needs are different than in Taiwan or in China, for example. We have a distributor that's centrally located in Minnesota supplying the North American marketplace. We still support a lot of the product, but even for 50% of our North American marketplace direct from Taiwan because it could be a unique copper weight, stackup, etc. We continue to build up that inventory so that we can mitigate outages. It's a big challenge in North America for most Asian suppliers; no matter our competition, they all have the same situation as far as travel time from the factory.

Our distributors have warehousing in both Northern and Southern California. Right now, we're supplying out of the Midwest within a couple of days to California, for example. But sometimes, they need it in a day. We're working with our customers to try to get a forecast to plan better, which is always a moving target. One benefit we have is our close relationship with the OEMs, and they will share the forecast with us. And when we know who their fabricators are because we're supplying them with the material as well, then we do a much better job of making sure there are no delays. They're not beholden to that inventory, but at least we have that feeling of what's to come.

Johnson: The dynamic tends to be that if the designers don't know what material they need, often, the first resource that they turn to is their chosen fabricator to ask for a recommendation. And the fabricator tends to recommend what they know. You were talking earlier about going out to the design teams to talk to them about what's available. Are you also doing outreach to fabricators?

Cochrane: Absolutely. Fabricators are our direct customers. We spend a lot of time with them. In the past, we might go to an OEM and give them a presentation, and then the OEM would go to the fabricator except the fabricator hadn't heard about that material. We're making sure that anything that for we're promoting to the OEM level, that we're getting that promotion to the fabricators as well as samples ahead of time. Because it doesn't do us any good if they come to them and have never heard of it. As I noted previously, we have a pretty good relationship at the OEM level, so in a lot of cases, we'll work as a team. We'll work with the OEM and suggest stackups. Then, we'll work with their fabricator's field applications engineers and reach a consensus to build a product.

Johnson: Thank you, Alan.

Cochrane: Thank you. PCB007

Electronics Industry News and Market Highlights

Taiwan's Solar PV Market Aims 1.5 GW in New Installations by 2019 ▶

The year 2018 will prove to be the most disastrous year for Taiwan's solar PV manufacturers, yet the best year in terms of solar PV system installations downstream, bringing new installations up to 1 GW for the first time in history. The government is now actively pushing towards a goal of 1.5 GW in new installations by the end of 2019.

As the Economy Slows and Wages Surge, Corporate Profits Likely to Decline ▶

In 2019, surging labor costs and slower revenue growth will likely lead to a decline in corporate profits in both the U.S. and other advanced economies, according to a new study on labor market trends.

Smart Speaker Shipments Reached a Record-breaking 7.5 Million Units in Europe in 4Q18 ▶

In the fourth quarter of 2018, the smart home market in Europe (Western Europe and Central and Eastern Europe) reached almost 33 million units, representing 15.1% growth annually, according to research by International Data Corporation (IDC).

Double-digit Growth Expected in the Smart Home Market ▶

The global market for smart home devices is expected to grow 26.9% year over year in 2019 to 832.7 million shipments, according to the International Data Corporation (IDC).

Edge AI Hardware Market Shipment to Reach 1559.3 Million Units by 2024 ▶

The edge AI hardware market is expected to register a shipment of 610 million units in 2019 and is likely to reach 1559.3 million units by 2024 at a CAGR of 20.64% during the forecast period.

Consumer Augmented Reality Market Continues to Grow ▶

By 2023, the revenues from consumer software and content will reach more than $8.5 billion while consumer AR smart glasses will reach four million-unit shipments by 2023.

Semiconductor Industry Calls for Bold Federal Policies ▶

As foreign governments take big steps to advance their domestic semiconductor capabilities, new blueprint lays out research, workforce, and trade initiatives needed to help keep America on top in chip technology.

Global Business Value of AI in Banking to Reach $300B by 2030 ▶

In 2018, AI in banking business was estimated to be $41.1 billion, which includes the cost savings and efficiencies of introducing AI technology compared to keeping existing infrastructures and processes.

March U.S. Manufacturing PMI Dips to Lowest Since June 2017 ▶

The latest PMI signaled a moderate improvement in operating conditions across the U.S. manufacturing sector in March, dropping to its lowest level since mid-2017 amid softer increases in output and new orders.

Semiconductor Manufacturing Equipment Market to Top $101B by 2027 ▶

The global semiconductor manufacturing equipment market accounted for $62.1 billion in 2018 and is expected to grow at a CAGR of 5.2% over the forecast period 2019–2027 to account for $101.58 billion in 2027.

IT-988G SE / IT-988G

IT-988G

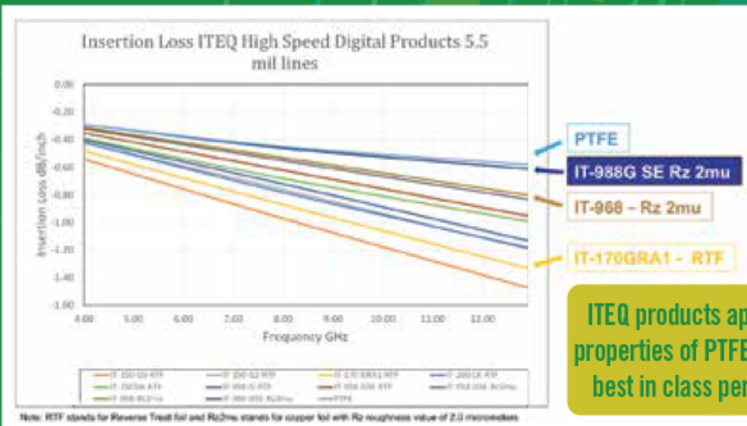
- Halogen Free
- Tg = 190° C
- Td = 405° C
- Dk = 3.46 @10GHz*
- Df = 0.0025 @10GHz*
- Available with low Dk Glass - IT-988G SE

IT-988G SE

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

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

Insertion Loss - Measured



Note: RTF stands for Reverse Treat foil and Rz2mu stands for copper foil with Rz roughness value of 2.0 micrometers

ITEQ products approach the properties of PTFE. ITEQ offers best in class performance.

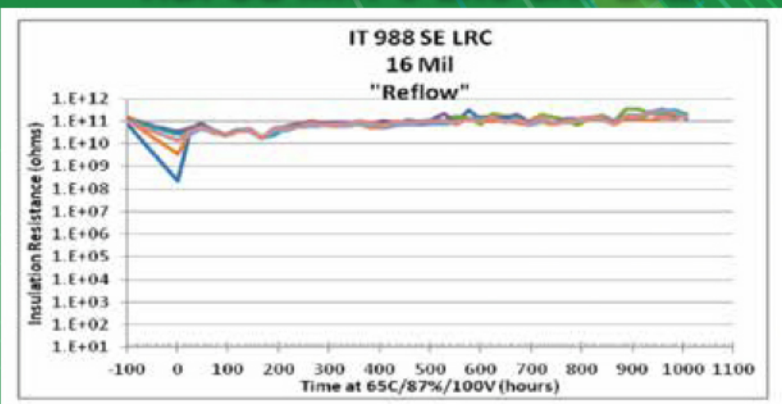
Sequential Lamination

7 Lamination cycle data

Lamination	DMA	DSC	TMA	T300 with CU	Solder Dip PCT: 1h @ 121℃	Td 2wt% / 5wt%
1	213	187 / 187	182	> 60	> 60	408 / 435
2	216	194 / 199	193	> 60	> 60	41 7/ 438
3	214	186 / 192	185	> 60	> 60	417 / 442
4	216	193 / 194	184	> 60	> 60	424 / 443
5	217	194 / 199	190	> 60	> 60	418 / 442
6	218	191 / 197	188	> 60	> 60	405 / 436
7	218	190 / 197	194	> 60	> 60	425 / 444

No themal degradation observable after 7 lamination cycles

HDPUG MRT-6 LRC CAF Data



IT-988G SE

- High Tg / Lead Free / Halogen Free
- Ultra Low Loss Laminate & Prepreg
- 100G / 400G Solution
- Lower Dk (<3.24 @ 10GHz)
- Ultra low Df (<0.0014 @ 10GHz)
- Very Stable Dk-Df across frequency
- HDPUG MRT-6 - LRC and HRC passed all thermal requirements
- HDPUG MRT-6 - LRC and HRC passed CAF requirements
- Proven thermal stability beyond 7 lamination cycles and suitable for HDI applications

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

*53% resin content

ITEQ


Sean Mirshafiei

ISOLA on Adapting Processes to Meet Customer Needs

Feature Interview

Sean Mirshafiei, chief sales and marketing officer for Isola, discusses the company's perspective on material market trends and how they are adapting product development processes to respond to new customer needs.

Nolan Johnson: Sean, can you tell us about what Isola does?

Sean Mirshafiei: Isola is a global laminate supplier for the PCB industry. It's a conglomerate made up from multiple laminate suppliers, such as Isola, AlliedSignal, and even AlliedSignal's predecessors. As a global player, we are manufacturing in North America, Europe, and Asia, and we've been servicing those markets for years. In North America, we have a presence on both the West and East Coasts. In Europe, we're stationed out of Germany, and we have four facilities in Asia, including two in Taiwan and two in Mainland China. Our predominant product focus is high-Tg FR-4s and high-speed digital materials as well as RF microwave laminates. We service certain niches within the market. Our revenue is realized primarily in Asia with fair representation in Europe and North America.

Johnson: What do you see as the current market dynamics globally, and how is Isola responding to those?

Mirshafiei: Market dynamics are a mixed bag. In North America, you still have strong growth driven by the aerospace and defense market as well as continued investments in higher-end telecommunications and automotive safety, such as radar systems. There's also telecommunications equipment for next-generation 5G applications, and strong defense spending which is bolstering demand broadly across our North American PCB customers.

When you look at Europe, it's a little bit of a different story. The European market is very much tied to the automotive electronics industry as well as industrial applications. We have seen softness there in both markets. Some of our customers have had to take time off, and there have been some weakness between Q1 and Q2; we've had to respond accordingly. We

think that two effects are happening. Vehicle production has slowed, but automotive electronic content has continued to increase, particularly with safety systems.

In Asia, we see a negative impact in our business due to a certain degree of market slowdown compared to 2017 and 2018. The tariffs have contributed to some of the slowdown, but there have been large changes in automotive demand as well. Additionally, we have seen softness in certain market segments, which impacts the entire supply chain and increased competition. Some OEMs, for example, are recognizing this scenario and are looking to cost savings since they have excess capacity available. Thus, we've had to respond. We're seeing more price pressure and more sporadic and irregular order patterns from customers, which creates a fairly complex market dynamic with growth in the U.S., softness in Europe, and a higher degree of competition in Asia.

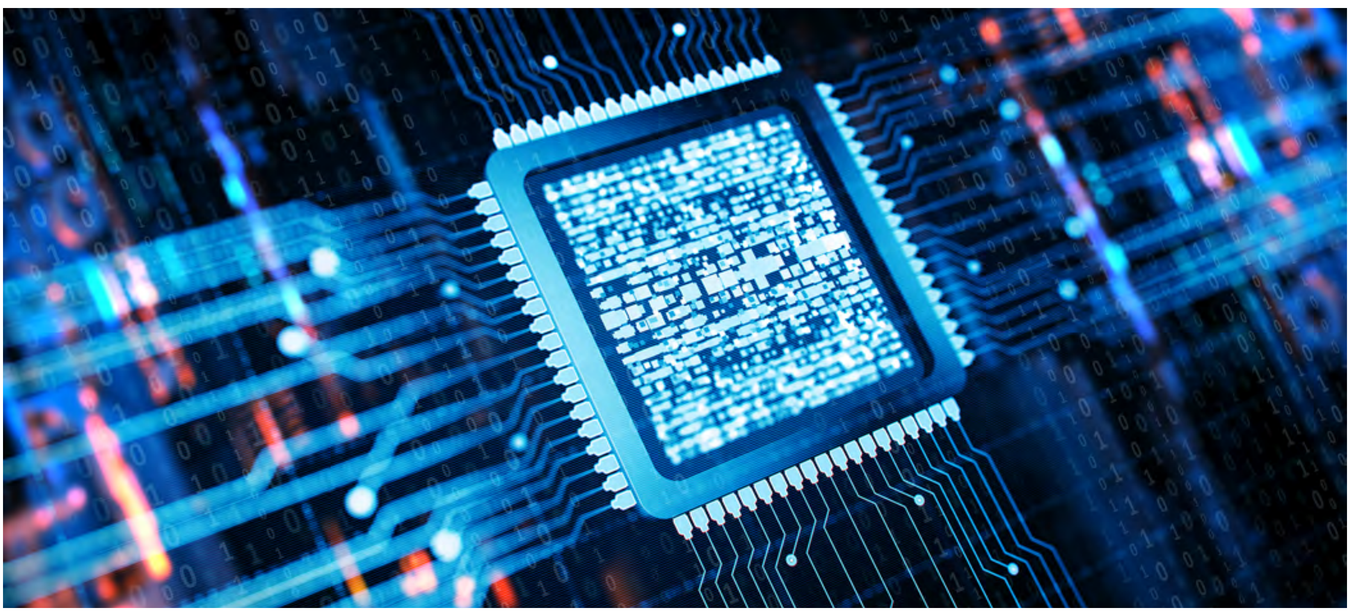
Johnson: What are the dynamics in technologies and what are the features of the materials that you're being asked to deliver based on the dynamics?

Mirshafiei: Our development strategy relies on assessing the technology shifts and understanding the underlying technical challenges to determine whether we are best positioned to address those challenges. Since these technology shifts span multiple segments, solving the technical issue for one segment will benefit another segment.

One scenario is that there's a push for increased safety systems throughout entire model offerings, not just as high-end offerings. But with increased content making its way through automotive companies' model lineups, there's a huge push to drive cost down, and existing RF/MW materials are often too expensive to integrate into mainstream vehicles. So, there's a need to investigate other options.

It's great because when these technical problems show up, and there's motivation, automotive Tier 1s will spend the R&D dollars to find alternatives to incorporate safety systems into vehicles. Those technical problems that come as a result of these changes, creating opportunities for PCB manufacturers as well as laminate suppliers.

Another scenario, which also ties back into automotive, involves higher-temperature applications as well as electrification. The higher-temperature applications are interesting. The feedback we've seen is that there's increased push from the automotive Tier 1s to put the PCB closer to the point of operation instead of using as much cabling, etc. Maybe that's due to the intention of reducing weight plus a myriad of other reasons. That leads to increased attention on the operating temperature of these PCBs, which creates new prob-



lems and opportunities for PCB manufacturers as well as materials suppliers to address these underlying technical challenges.

Despite the fluctuations in the general market demand today, what's exciting to see is there's continued investment in addressing technology. We can look forward to the deployment of 5G technologies as well as more advanced automotive electronics, including safety and high-temperature applications and greater electrification to continue to demand innovation in our industry.

Johnson: So there is a definite push into needing some new materials. What's on the roadmap for product development to make the next sweet spot for Isola?

Mirshafiei: We've done our best to narrow our focus on those two end markets: telecommunications and automotive electronics. For telecommunications, we have focused on solutions for backhaul and wireless applications. More recently, our focus has been to develop next-generation, ultra low-loss materials that are suitable for 400-G applications as well as offering alternatives to RF/MW materials for 5G antennas. For automotive, we have had a long history of offering high thermal reliability materials and leading through the lead-free assembly transition. More recently, our product development focus in automotive electronics has narrowed to automotive safety with products positioned for radar and high-temperature, high-power, and high-current applications that are being considered for automotive electrification.

One noticeable change in our industry is that the traditional high-speed digital applications have continued to evolve and require high-performance materials, which are now encroaching on the performance of more exotic RF/MW materials. This convergence will allow the industry to benefit from increased flexibility in material choices and flexibility in design.

Johnson: You're suggesting that there may be a bit of convergence in materials somewhere down the roadmap?

Mirshafiei: Yes, and we're seeing that today. A lot of the requirements that have traditionally been present for RF and microwave applications have far exceeded what was necessary in the past for routers, switches, and servers, and as you said, there is a convergence—a confluence of those two markets. Although they may share a similar platform, the individual requirements differ. The platform of the product may be similar, but you can't just take product X that has been used in high-speed digital applications and simply badge engineer it to use in RF/MW.

Johnson: It seems like we're on the verge of a philosophical shift. Until now, the substrate was a substrate. Now, engineers have to think of the material they're using as an active participant in the behavior of the circuit.

Mirshafiei: Absolutely. The advancements in materials, such as more building blocks generally found in digital applications, may allow designers flexibility to integrate more digital and RF/MW applications into the same design. It enables designers to rethink how they can build their packages and systems. Meanwhile, it creates quite a bit more complexity. One of the things that is often very difficult in this situation is how does a designer get an objective view of materials and a better sense of how to decide what category of materials they need for the design.

In the past, when materials suppliers engaged with OEMs, they did it on their own, and the OEMs took the information directly, and the PCB fabricator wasn't as involved. That was to the detriment of the OEM as well as the materials supplier because the best way to understand how these materials function is to establish a relationship with the three parties. There should be a representative of the OEMs and a representative of the PCB manufacturers to ensure the design is manufacturable, plus a materials supplier to understand what characteristics need to be controlled and managed to arrive at the performance that's necessary for these OEM designs.

The PCB manufacturer is a crucial element of the process, and OEMs have recognized that they need to be a key part of their decision making, so consortia have formed. One in particular that many materials suppliers work with, as well as PCB manufacturers, is the High Density Packaging Users Group (HDPUG).

Johnson: Where do you feel like you're getting the most effective traction in having that conversation?

Mirshafiei: All the methods that you discussed gain traction whether they are trade shows, webinars, or one-on-one meetings with OEMs. But fundamentally, the most effective for us has been when we are partnered with PCB manufacturers, have them evaluate our product, and touch the broadest array of OEMs. They can assess the capability of the product both from a thermomechanical evaluation as well as an electrical performance standpoint. This gives the most meaningful feedback about product capability.

Johnson: With your role in marketing, where do you see Isola's upcoming rising star products? What has Isola excited about the product development that you're doing?

Mirshafiei: We have two products that we're very excited about. Tachyon® 400G is our product that we positioned for the 400-Gbps application. This is the successor to our Tachyon® 100G. The electrical performance that we're seeing is a substantial improvement based on what we've tested ourselves and the feedback we've received from some leading OEMs. In addition to that, we have a product that we'll be launching shortly in 2019, our IS550H, which is the product that we've positioned for high-power and high-temperature applications for automotive.

Those are new products that we're launching that we believe address some of those key market trends that we discussed. Looking at where we are at today with existing products, the one I'm most excited about and experiencing the greatest traction is in the automotive radar space. Our Astra® MT77 is getting a lot of market traction in automotive radar applications as well as antenna designs. We're seeing that proliferate in North America, Europe, and Asia, so it's covering broad market segments.

Johnson: Why is Astra® getting such great traction in those applications? What is it about that material that's so appealing to those sectors?

Mirshafiei: There are a few different elements that are unique about it. It has gone head to head with materials that are based on a ceramic-filled Teflon® platform, and there's no doubt that those materials have phenomenal electrical performance. But there are some challenges that come with those materials, and with Astra®, we're not building it off of Teflon®. We're building a more traditional, high-speed digital platform that we've developed processes around to maintain consistency and performance at 77 GHz. The other advantage that we see, and this is where we see flexibility come into the picture, is that we offer it in the form of laminates as well as prepregs, which allows greater design flexibility for OEMs.

We've seen some interesting designs in North America where they've hybridized Astra MT77 with high-end, high-speed digital materials that we offer, such as our Tachyon® 100G. What speaks volumes is the flexibility that it gives in design, and it's also at a much more cost-competitive position. That makes it a very compelling solution for customers. Another thing that's important here is that the traction that we're seeing with the product is taking time because the RF market's a very conservative market. People have never been fired for using company X. There's a lot of risk aversion, but there are underlying competitive dynamics, whether it's automotive applications or 5G. You're not talking about small quantities.

Johnson: Not to mention the field reliability that they're going to need.

Mirshafiei: Right. That doesn't change at all. When I look at where we see opportunities for innovation, it's going to continue to be responding to the flexibility of designs and the

need for enhanced thermal reliability because remember, the changes aren't just limited to the substrate. Changes are occurring in packaging, and the interest in integrating chips into packages more and more creates thermal management issues. Again, these are all exciting challenges. Each materials company and PCB manufacturer has to decide whether their core competencies align with these technical challenges.

Johnson: There's a process here to figure out what your company's particular sweet spot is and ensure that you're not distracted by all of this fracturing of product opportunities. It sounds like Isola is being very conscious of that and keeping development focused.

Mirshafiei: We're applying a rigorous stage-gate process to make sure that we're narrowing our focus, and we're basing it on what we understand the market needs. For R&D, one of the most difficult aspects is to kill projects. You can't continue to develop products forever. You have to make sure that you're hitting these timelines. Sometimes, if you're not seeing the innovation occurring at the rate you need it, or if you're seeing a shift in the market need, you have to make the decisions to kill projects.

Sometimes, if you're not seeing the innovation occurring at the rate you need it, or if you're seeing a shift in the market need, you have to make the decisions to kill projects.

Johnson: With all of this change, what would be your advice to OEMs for getting better informed? How would you recommend that they do that?

Mirshafiei: OEMs need to work closely with PCB manufacturers that are "class leading" in technology innovation and reliability. Doing this in concert with some similarly innovative laminate manufacturers, will lead to faster development cycles. You need to be inclusive in that regard because working with only laminate suppliers will give you a limited view and will potentially limit the opportunity to learn about the capabilities of the material in your design. It's important to try to integrate those PCB manufacturers looking to help solve your technical needs because those PCB manufacturers often work closely with the materials suppliers.

Johnson: Is there anything that you'd like to cover?

Mirshafiei: For Isola, our view of being successful and moving forward is not only developing the right products and having a focus but also making sure that we're servicing the markets that we're in appropriately. The market in Europe, Asia, and North America differ. In particular, in North America, our focus is having a quick-turn solution that allows us to service the North American market with these products but in a much faster manner. We recognize that in the long run, with an import model, maybe you can take some advantage of Asian manufacturing costs. But we believe that the better approach is a hybrid model where you have the ability to use materials that are partially manufactured in some locations. Then, they're customized to fit the needs of the North American market.

All of these companies, whether it's PCB manufacturers or material suppliers, have had to adapt their supply chain model to be cost-competitive and recognize that the needs in one segment differ from the needs in another. We look forward to growing our business and being mindful of products, supply chain, and customer engagement.

Johnson: Awesome. Thank you.

Mirshafiei: I really appreciate it, Nolan. Thank you so much. PCB007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Help Wanted! How to Train New Employees in Today's Digital World

The Right Approach

by Steve Williams, THE RIGHT APPROACH CONSULTING

A very sobering fact is that in six short years, millennials will make up around 50% of the global working population. And with our ever-increasing culture of information overload that we have all been subjected to since the mobile revolution began, you may have overlooked news about shrinking attention spans. While millennials seem to be the subject of much of the reporting on Digital-Age attention spans, the effect can be seen across all age ranges. How can you train anyone in this environment? Read on to find out.

Diminishing Attention Spans

A 2015 Microsoft study of 2,000 Canadian participants was conducted using electroencephalograms (EEGs) to measure brain activity and the average consumption of media information. The research concluded that the average attention span had fallen from 12 seconds in 2000 to eight seconds today, which now means we have a shorter attention span than the average goldfish at nine seconds.

In the study, attention span was defined as "the amount of concentrated time on a task without becoming distracted." I tried to read the entire 54-page report, but I lost interest. What I do remember is a quote from Microsoft CEO Satya Nadella that was very telling. Nadella said, "The true scarce commodity" of the near future will be "human attention."

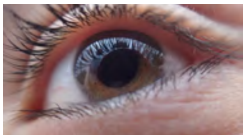
The good news from the report is that our ability to multitask has dramatically improved in the mobile age. But the bad news is that people with heavy screen time find it more difficult to filter out irrelevant stimuli and are more easily distracted by multiple streams of media.

Combining the already difficult job of training people for our industry with an eight-second attention span results in a seemingly impossible task. Today's workers are faced with unlimited distractions around them at all times from entertainment to social media. The bottom line is that many people find it difficult to grasp and retain information delivered in lengthy or continuous formats.

What Can You Do?

You can leverage technology, which is easy to say but harder to do. Today, some people would rather text the person in the next cubicle than walk over and talk face-to-face. Others want to make all of their purchases online, and get their entertainment and social engagement through their phones, tablets, or computers. There is a lesson to be learned from studying this behavior that can be applied to training; make it visual, provide it electronically, and break it into short increments.

Visual Learning



Throughout my undergraduate and MBA studies, I discovered that I am both a visual and experiential learner. I gain and retain knowledge far better by seeing and experiencing rather than merely reading long, boring texts. Of course, I read the books, but my comprehension and retention were a step function greater when using visual tools like mind mapping to condense the critical aspects of a chapter into a one-page picture. And visual learning is not just for millennials; here are a few facts [1] that may change the way you learn or teach:

- Of all the information transmitted to the brain, 90% is visual
- As opposed to text, visuals are processed 60,000 times faster
- Humans are capable of getting the sense of a visual scene in less than one-tenth of a second
- 40% of nerve fibers are linked to the retina
- Our brain can see images that last for only 13 milliseconds
- The human eye can register 36,000 visual messages every hour

e-Learning

What is e-Learning? Electronic learning is the delivery of learning and training through digital resources. Although e-Learning is based on formalized learning, it is provided through electronic devices, such as computers, tablets, and cellphones connected to the internet.

E-Learning began strictly as an educational tool primarily in universities that later filtered down through the entire educational system. In a traditional e-Learning environment, people typically learn the training content in a secluded, self-paced environment. But many millennials prefer being in groups of other like-minded people. Collaborative learning provides an opportunity for them to interact with fellow learners and share learning experiences. This also encourages active learning where each learner can actively participate in learning activities.

Microlearning

Microlearning can be simply understood as providing e-Learning and training material in small doses. I have long been a fan of breaking up complex projects, like ISO implementation, into small, manageable "buckets" to avoid people being overwhelmed. These training materials could be anything that can be comprehended in a short time, such as infographics, flipbooks, interactive videos and PDFs, whiteboard animations, etc. This is in contrast with traditional content and heavy training courses, which get monotonous with time.

Some collateral benefits from microlearning include that:

- You can quickly close a small knowledge or skill gap
- It's budget-friendly and has a laser-focused scope
- Learners can gain quick achievements from a short learning session
- It's less disruptive for your company

Accept and Adapt

As difficult as it is to swallow our ever-decreasing eight-second attention span, our job is to accept the constraint and develop solutions that allow us to continue to provide high-quality training to new employees in this millennial age. **PCB007**

References

1. Jandhyala, D. "Visual Learning: Six Reasons Why Visuals Are the Most Powerful Aspect of e-Learning," eLearningIndustry.com, December 8, 2017.

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

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ITI & IPC Conference on Emerging & Critical Environmental Product Requirements

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Supplier Highlights

ITEQ's Tarun Amla Discusses 5G Inflection Points ▶

ITEQ Corporation Executive VP and CTO Tarun Amla discusses effects of 5G on materials and shares general observations on the 5G rollout at DesignCon. He also talks about the challenges for their customers, and how they help them address their issues.

Ventec Focuses on High-mix Manufacturing ▶

The I-Connect007 team recently toured Ventec International Group's Suzhou factory where a modern, flexible manufacturing concept designed for fast delivery is enhancing their established volume manufacturing of specialty, high-reliability epoxy laminates and prepregs. Read on to learn more about Ventec's ongoing investment in the facility to offer flexible, world-class, high-mix manufacturing capabilities for polyimide, thermal management, low-loss, and signal integrity material solutions.

Flexible Thinking: A Few Simple Lessons in Designing Reliable 3D Flex ▶

We all have a tendency to stick close to the familiar and use the tools we know to create solutions to problems confronting us; we're only human. Unfortunately, using only familiar tools limits our ability to come up with optimal or even superior solutions. This column will help you avoid some of the traps conventional wisdom doesn't always give guidance on.

Alun Morgan on Thermal Management and LEDs in Automotive ▶

Guest Editor Judy Warner met with Alun Morgan, technology ambassador for Ventec International Group, to discuss topics addressed at the Automotive Executive Forum that took place at IPC APEX EXPO 2019. Morgan describes his presentation and findings centered around thermal management in automotive, specifically LEDs, as well as the unique set of growing thermal management challenges Tier 1 suppliers are now facing in the automotive sector.

Insulectro Promotes Megan Teta to Design Services Product Manager ▶

Insulectro, the largest distributor of materials for use in PCBs and printed electronics, has promoted Megan Teta to product manager for design services.

ACB Invests in New Lamination Lines Technology ▶

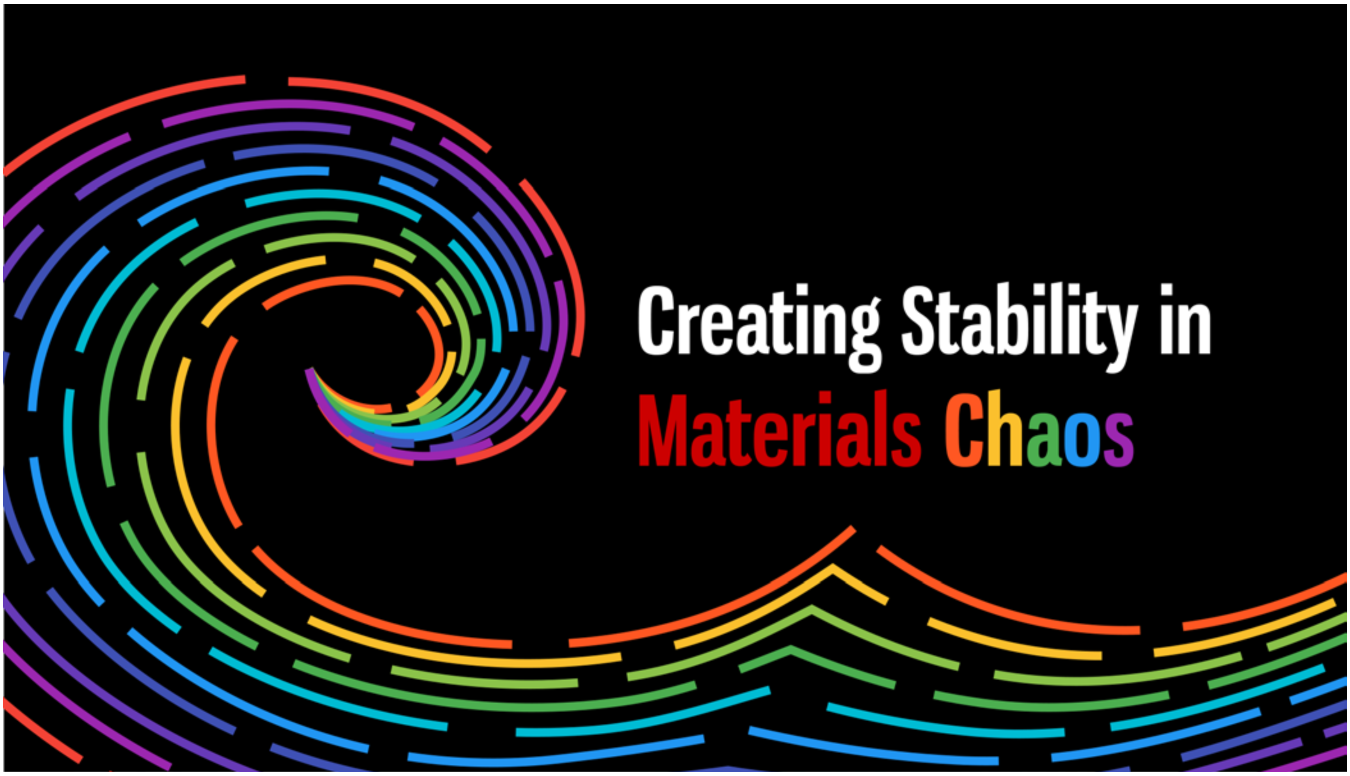
Automatic Lamination Technologies (ALT) under brand name Dynachem are pleased to announce that ACB NV (Belgium) has installed successfully two state-of-the-art dry film lamination lines for inner and outer layers.

FCCL Firms Eye Orders from China Handset Vendors for Growth ▶

Taiwan-based FPCB materials suppliers Asia Electronic Materials (AEM) and Taiflex Scientific expect more orders from Chinese smartphone clients to drive their revenue growth in the remaining quarters of the year after experiencing lackluster revenue performances in the first quarter of 2019.

TTM Invests in Two Nano Dimension Additive Manufacturing Systems ▶

TTM Technologies has expanded its relationship with Nano Dimension by purchasing two additional DragonFly Pro systems to complement the existing single unit at the facility.



Creating Stability in Materials Chaos

Feature Interview

Nolan Johnson and Tony Senese—manager, business development group, Panasonic EMBD—discuss the evolution of the materials marketplace over the years from a time when the market aligned for the rise of Panasonic's MEGTRON 6 to the ever-changing materials industry of today. With the ramp-up to 5G and everyone pushing product development, Tony describes a chaotic materials market flooded with new companies and materials. To succeed in such an environment, Tony says that the key is creating stability through high-level partnerships.

Nolan Johnson: Tony, there is a definite trend in the marketplace, moving away from FR-4 being the answer to everything. Increasingly, designers need to consider the following: high speed, low loss, high performance, environmental extremes, reliability, flex, smaller packages, and new technologies for chip mounts. With all of these dynamics, it's no surprise that manufacturers' product portfolios are fracturing. What's the Panasonic perspective? Where is the market going?


Tony Senese

Tony Senese: I will give you a general overview, and then if we need to go into specific product lines as they relate to those market segments, we can talk a little more. But the thing that has changed in the 40 years isn't as obvious as you might think.

FR-4 has been the mainstay of multilayer since the late '70s. Other products that existed then have mostly faded away. We've gone through several phases in material development, and a lot of those throughout the '70s were driven by military technical needs and specifications. FR-4 was the mainstay for most PCBs then; it was a low Tg product, but it was very easy for people to manufacture double-sided boards successfully up to six or eight layers at the time.

Soldering has always been a problem. Some people believe that lead-free soldering was the beginning of the problem, but we've always had problems with soldering, moisture absorption, and thermal reliability. In 2005, the RoHS directive prohibited lead as well as other

A facility visit may include the Panasonic Megtron Lab.

materials. An exemption for certain network equipment was given through 2010. Low loss materials of the time didn't work in lead-free soldering. That was a disruptive event for material suppliers. All of the things that the material suppliers had been working on for 15–20 years were now more or less obsolete. And there were materials that might have worked, but most of them were never commercially successful.

Panasonic was in the right place at the right time with some good technology and even better OEM marketing. I think that term has fallen into disuse, but it was smart people in the materials business talking to end users and figuring out quickly that they had an immediate need for a material—a material that was thermally robust, low loss, and low Dk, so that they could prepare to use lead-free solder in IT equipment by 2010. Companies like Cisco, IBM, and many others all had designs that worked until lead-free solder came around.

There were a number of offered solutions in the materials business, but the one that hit both of those notes happened to be a Panasonic material—MEGTRON 6. Using a material made in Japan was more than just a technical challenge. North America was still driving most of the designs; most NPI boards were being built here, and there wasn't a good supply model for a material like MEGTRON 6. Some of the materials that were tried just couldn't be supported by the supply chain.

Panasonic had a new distributor in North America that committed to keeping a whole bunch of inventory. It enabled low-volume, high-mix usage of a couple of Panasonic products that the OEMs were able to make work. This meant that OEMs that had strong connections with North American laminators had their successful experience with an Asian laminator on the high end of the business. And that changed how the world looked at who could supply and would develop the next materials.

This enabled a two-step process for developing products. We would do new product development and evaluations at the high-end shops with high-end materials, in North America. We started early in production, maybe even early mass production, and then quickly transferred to Asia. Companies like TTM and Sanmina, etc., were able to do that successfully for the first time because they were accustomed to fabricators with local supply and laminators due to the need to get raw materials quickly.

We've now gone through several generations of increasing speed in the IT business. Other product markets, such as mobile and automotive—which are the largest users of materials in the world—didn't have that same kind of model. They saw that type of model working, though, so for developing technologies for their next-generation products, they started doing the same thing. The latest developments in some of the high-frequency ranges have pushed those products away from basic halogen-free FR-4s into some non-FR-4 type products. FR-4 is still over 50% of all the material used in the world, but some of these fairly high-volume applications are moving to other things.

And that's a new story. The largest laminators in the world are primarily FR-4 suppliers. Even large suppliers in Asia have tried to enter the high-end market because they believe that even though FR-4s probably are never going to go away, the ability to support a $1–3 billion materials business is becoming less likely.

Johnson: What are some of the market dynamics driving the new materials?

Senese: The primary dynamic is that the base business—I always think of it as an iceberg underwater, and it is underwater in more ways than one—is a losing business proposition. The cost of materials that we use—such as resin, glass, and copper—are lower than they've ever been. There's not a lot of room for anybody because they're either not making money or they're in single-digit income. That business proposition makes it very difficult for fabricators in the middle because they have constant pressure from all of the largest OEMs to reduce the price for their boards.

If you can't squeeze that rock anymore, you have to find a better way to make the devices. Our industry has always made devices to handle more information at the same price, essentially going faster. While less expensive devices like phones are made with materials more expensive than FR-4, they're less expensive because they're getting so much more data.

Johnson: That's an interesting perspective. Can we put numbers to that?

Senese: When I started in 1979, a piece of 059 FR-4 material went for about $2 per square foot, and it had 105 Tg. It used all 7628 glass, which is very inexpensive, and standard copper, which was very inexpensive. Laminators that no longer exist—such as Norplex, GE, and Westinghouse—were able to make a 10–11% net income business at the time. If you could buy that similar material—which you can't—the price would be half that now. There are certainly economies of scale; the businesses are all bigger, but there isn't a lot of room for anybody to wiggle when the market slows down. That creates this pent-up demand from the supply base regarding what is the next thing that we're going to be able to sell that people need for performance and not price.

Right now, everyone is saying that 5G networks and devices are something that will drive a high volume. The calculations for how many devices are going to be needed to cover the normal network areas are hundreds of times more than anything that's ever been deployed for communication before. Those devices all have to be inexpensive, and that creates a "good enough" mentality. In other words, can I make the cheapest thing work? Well, probably not. Then, what is the next cheapest thing that I can make work? This drives some of that desire for halogen-free materials because some halogen-free FR-4s in the past have been less expensive than standard, brominated FR-4s. And that image in the market makes people think that's the way to go, but it may or may not be, depending on the complexity of the board.

In Panasonic's materials division, we have to balance these two things out. If we make a material that's extremely robust and it costs a little bit more because of the raw materials or the process we use to make it, we don't get paid for it. And either the product doesn't sell, which is the primary way that we don't get paid for it, or the product goes in at a certain cost point within a very short time. And when I say a short time, I mean less than a year, that product is only driven by price because most of the companies that develop these devices will have at least two sources; they'll do what any good company does to make money, and they will push the pricing.

Panasonic doesn't intend to be the price leader in the business. On the other hand, if we invent a bunch of materials that nobody is going to buy because they're 10 times more expensive than the current product, that's not useful

Koriyama Plant (West Factory), Fukushima, Japan.

Panasonic industrial devices materials (Suzhou) .

either. Fifteen years ago, Panasonic developed our original MEGTRON 6 product without regard to cost. We knew that if we didn't have a product capable of 5–7 lead-free reflow cycles while maintaining electrical properties that could be usable in virtually every fabrication shop on the planet, it wasn't going to be successful.

The game isn't like that anymore. A lot of people are competing for this business because it's more profitable and there's a lot of visibility. I'm the chairman of the board of directors of the High Density Packaging User Group (HDPUG), and we're on our sixth phase of the lead-free materials reliability project. Selecting the materials for the next phase is about a two-year process because we can only do about 10–12 materials at a time. We had almost 50 materials on the list that different stakeholders had brought to us. A high percentage were new materials, but others had just never been tested by us before.

Johnson: The numbers seem to back up the observation that new materials are filling different application types.

Senese: Exactly. We have four different product roadmaps for materials currently in production. We have three stages when we develop materials. The alpha phase is finding out what the targeted values for a given product type and market are and coming up with our version of what we think we can do without any actual lab work at first. We take that out to some customers, asking, "If we develop this, would that interest you?" Then, we go back to the lab in the alpha phase and come up with some ideas to see if we can get to where we were told the product would need to be. If we get close in the alpha phase and come up with a product that seems to work, we might do a couple of very small short-term evaluations with a few customers to see if it's close. But once we put the stake in the ground and say, "This is the formulation and these are the raw materials we're going use," then the product specifications are frozen, and we go into the beta phase.

In the beta phase, we pick key OEMs and fabricators to work together to evaluate the material and see if it's ready for primetime. Sometimes that takes a year. During that year, because most of these products are commercial, we're doing long-term aging with Underwriters Laboratories (UL) to get the product recognized. Sometimes it takes a couple of years because we get into that beta phase and find out there's something that needs to be changed. If the thing that we change doesn't affect UL, we continue; we don't reiterate the first part of the process. If it does require us to change something— generally, it has to do with the chemistry in the resin system—we loop back through UL again. That loopback can take anywhere from six months to one year depending on how close the the formulation is to an existing product. That process is true for almost everything we make.

Most of the mobile companies now have at least some reference to UL recognition because of long-term aging. In the automotive business, several other standards have been developed over the years. And because of the growth in the technology in automotive and the kinds of devices that are being built, there are a lot of extra tests that are unique to the automotive industry. For example, the conductive anodic filament (CAF) testing that's common in the IT business is taken to a whole new level with some of the current automotive requests for essentially an electromigration test. Those automotive requirements jump the voltage from 50–100 volts up to 1,000–2,000; that's created its own cottage industry, inventing how to do that testing.

Johnson: For you to do your work well as a material manufacturer, you talk to key teams and involve expert customers to help guide you in the product development. The 80/20 rule probably comes into play here where 80% of the product is made by 20% of the companies. The other 80% of the companies are probably not in a place to be serving as a key expert for you, but they still need to be looking at the materials that are available and figuring out what works for them.

Senese: Right. When Panasonic's electromaterials division first ventured into this type of research, we called the group "research and marketing." We had three people 12–15 years ago. I was not with Panasonic then, but I happened to know the people involved, and the team was targeting one specific type of product and a couple of big OEMs, so they could drive it. It was not even 80/20; it was like a 95/5, and five was all the bandwidth we had. It has become a bigger program now and has expanded around the globe. We have research and marketing people in all the global areas, and in the areas that we don't cover, we travel a significant amount.

As products become successful and customers look at the product and say, "Well, that's working for them. I need to try that product," we can't talk to every single person who's developing a product in the segment. The 5G arena is a perfect example (laughs) because there are a lot of new companies and types of technology, and it's very hard to figure out at this point, who, what, where, when, and how is this going to roll out over the next 5–10 years.

Panasonic industrial devices materials (Taiwan).

Our bandwidth is expanding by getting more people involved. Realistically, though, we have to narrow our focus to some key players that we think are going to drive the technology.

We have a group developing next-generation materials to compensate for the kinds of chips that are going to be put on a substrate. That group of people probably drills down into the top half of the companies that design new ICs. That's a very tough business to predict what's going to happen next.

Johnson: I think you're spot on. You can only go so deep into the market that you're going to be able to penetrate proactively. You're going to need designers to reach out to you too. How should a design team become knowledgeable with these products that are in Panasonic's portfolio?

Senese: As our products have become more well-known globally, we have expanded our sales force. We have trained specialists. Because we're developing for every segment of the market a little bit at a time, we have people in charge of the roadmap for each of those areas. And if we get an inquiry through our sales group, we direct it to the specialists. If the inquiry is technical enough, we'll do some sort of a seminar, lunch-and-learn event, face-to-face meeting, or conference call. We try to cover everyone we can.

Unique to North America, we also have a distributor that we've been working with for about 10 years. Everybody talks about distributors as value-added partners, but what they're usually talking about is somebody with a warehouse, a shear, and a refrigerator, cutting, tooling, stamping, and shipping material. While that's definitely a part of the value-added partnership with the distributor, a higher-level partnership is required when you're dealing with so much global NPI.

Some customers want to know specific details, including the Dk at 10 GHz of a construction that uses 1035 prepreg and a 5-mil core. Twenty years ago, the only person who could answer that question was a fairly high-level OEM marketing person within one of the manufacturers. Now, that kind of knowledge is being driven down to front-level people within our partners around the world. These folks are not Panasonic employees; they're working with Panasonic on a much higher level than just, "Here's a piece of literature and data, and if you have any questions, call Panasonic."

Johnson: The approach, then, is technical training further down—deeper and wider—into the organization.

Senese: Correct. You can't just go call on your three favorite customers, drop off some laminate in the afternoon, and play nine holes of golf; that doesn't work anymore. The most successful marketing and salespeople in our business are able to expand. Somewhere in the late '80s and early '90s, most of the American laminators developed the model where all of the salespeople had to have some technical expertise and all of the tech service people had to be a little more sales and marketing oriented. The division between those roles became blurry, and a lot of people took over sales areas doing both jobs. Panasonic has evolved to that model in North America and it is continuing to evolve in Asia and Europe to the point where it's hard to tell who you're talking to.

Johnson: That must make for a powerful feedback mechanism for product development.

Senese: And it means that if we need an answer to a question, we have a lot of people to ask. We have a lot of interested parties within our partners and within the company. Panasonic is a large Japanese company that has been around for 100 years and maintains a collaborative culture. There are very few single-person decision makers in our company. There are, to my frustration for a few years, a lot of meetings where you have to come to a consensus. Because of that, there are a lot of points of intersection. We can handle getting a lot of information.

Our biggest problem going forward—even our CEO talks about it—is how we take that culture of people talking to each other throughout the world and make it go fast enough that the industry can keep going and doing what it needs to do. And that's Panasonic's challenge for getting through the next 100 years.

Konosuke Matsushita museum.

Johnson: Do you see these changing conditions affecting or causing Panasonic to adjust how you're manufacturing, stocking, and distributing?

Senese: Historically, Panasonic is a company that found a niche—either a single customer or several customers in a certain geographic area—then built a factory to meet the needs of those customers. If that expanded other places, mostly within Japan, they would do a "copy perfect" plan. They would take the first factory and organization and build a new one somewhere else. That's still our basic philosophy for building factories and manufacturing. It doesn't always work, though, in terms of how you go to market, listen to the market, and develop new products to go forward.

That is where we are evolving the most. Panasonic as a company has millions of distributors for all of our different products and has a been successful commercializing the products we make. Distribution plays a much bigger role for us than Panasonic as a whole in the form of how we pick and partner with the distribution. Being a laminate distributor has had a high mortality rate over the 40 years I've been watching. A lot of successful distributors don't exist anymore because the partnerships were not valued. And as money became precious and as prices went down during bad times, it was very difficult for some of the smaller laminators in the world to support those people.

So, I think the attitude that has to shift is that when you have somebody that's your partner, they can't worry too much about their normal business cycle. They have to be stable, as all of our employees are in our business, and believe they're going to be there for a long time.

Johnson: Readers are looking for new materials, starting with basic research. Is calling the most effective way to contact Panasonic to find out about your products?

Senese: There are several ways you can look up Panasonic EMBD. On our company website at https://industrial.panasonic.com/ww/electronic-materials, all of the inquiries that we receive go to local representation, which is easiest. However, our customers have all kinds of information about our materials. Some of those customers just publish what's on the data sheet while others do the research themselves. There is data out there to help you understand what's important and what's not.

Whenever one of our salespeople receives a call, we take it to the appropriate level and the person in charge of that segment to put on their list of customers to call and talk to. I did a couple of them last week myself, and it's not even my primary function. We are in the midst of disruptive changes that all material suppliers are having to deal with, and we're all evolving. This model of supply chain partnerships may be almost as disruptive as lead-free soldering.

Johnson: Thank you for the information and taking the time to go through this.

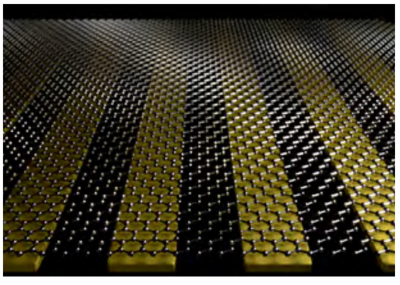
Senese: Nolan, it has been good talking to you. **PCB007**

New Graphene-based Device Paves the Way for Ultrasensitive Biosensors

Researchers from the University of Minnesota College of Science and Engineering have developed a unique new device using graphene that provides the first step toward ultrasensitive biosensors to detect diseases at the molecular level with near perfect efficiency.

"To detect and treat many diseases, we need to detect protein molecules at very small amounts and understand their structure," said Sang-Hyun Oh, University of Minnesota electrical and computer engineering professor and lead researcher on the study. "Currently, there are many technical challenges with that process. We hope that our device using graphene and a unique manufacturing process will provide the fundamental research that can help overcome those challenges."

Attempts have been made to improve biosensors using graphene, but the challenge exists with its single-atom thickness, especially with light absorption. Previous research has only demonstrated a light absorption rate of less than 10%.



University of Minnesota researchers combined graphene with nanosized metal ribbons of gold and utilized a homegrown high-tech nanofabrication technique called "template stripping" to create an ultra-flat base layer surface for the graphene. By shining light on the single-atom graphene layer device, they were able to create a plasmon wave with unprecedented efficiency at a near-perfect 94% light absorption into "tidal waves" of electric field. When they inserted protein molecules between the graphene and metal ribbons, they were able to harness enough energy to view single layers of protein molecules.

The research team included University of Minnesota electrical and computer engineering postdoctoral researchers In-Ho Lee (lead author) and Daehan Yoo, Professor Tony Low, and IBM Fellow Emeritus Dr. Phaedon Avouris. The research was published in *Nature Nanotechnology*.

(Source: University of Minnesota)

The Evolution of Probers and Fixture Testers: Blinded by Science

Testing Todd
by Todd Kolmodin, GARDIEN SERVICES USA

Electrical test today has changed dramatically since the "pin-in-hole" technology of yesteryear. Although you may still find these designs today, predominantly you will run across the mind-altering designs of our current generation. It boggles the brain to think that computers once inhabited entire rooms to process just "bits" and "bytes" of data. Now, your smartwatch processes more data than many of those computers combined! The smartphone that you use every day has more computing power than the computers used in the Apollo 13 spacecraft!

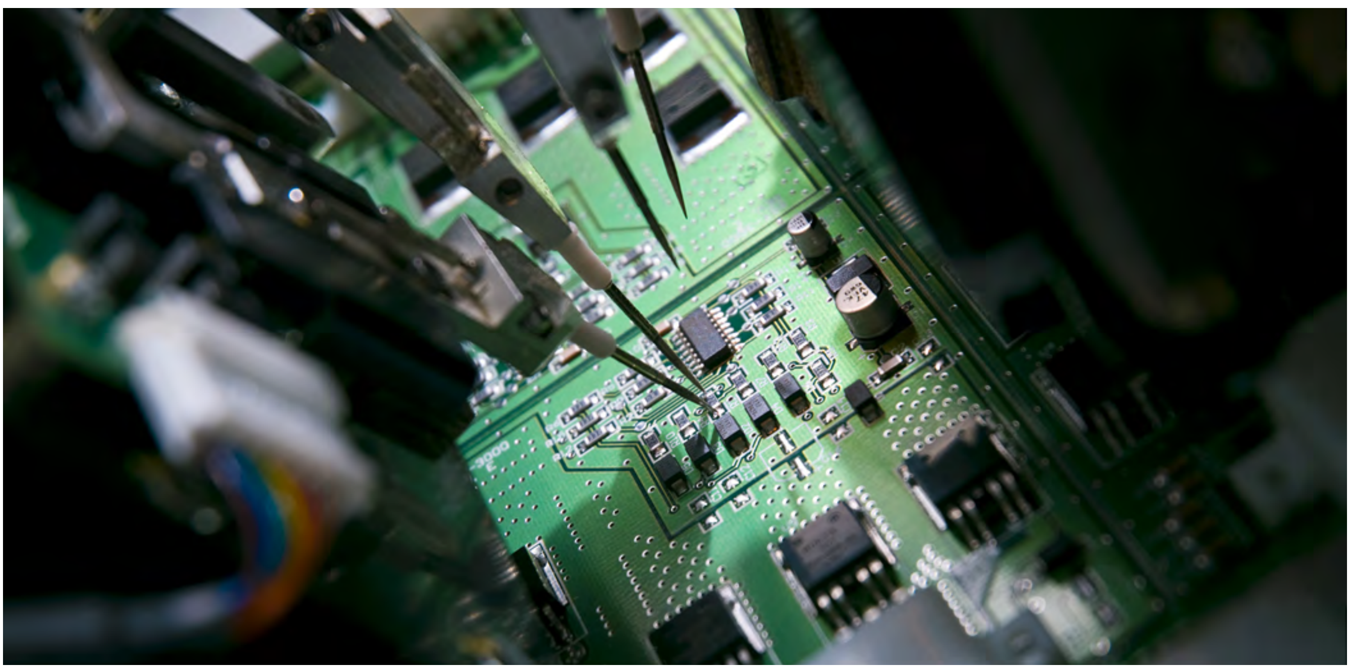
It's no wonder that today's requirements have become immensely important in guaranteeing success in the products produced. Shorts, opens, impedance, capacitance, dielectric breakdown, and resistance are all major factors in the success or failure of today's PCBs.

With that said, the evolution of the PCB has come a long way in the last 30 years. The science of electrical test has had to travel that road as well. It's not just a question of screening for opens and shorts. Today, the library extends to interrogating passive components, efficiently and cost-effectively evaluating dielectrics with multiple planes and pairs involved, and adhering to strict requirements from the military, export regulations, and OEMs alike. So, it is easy to understand that ET has become much more of a science than history remembers.

Probers Versus Fixture Testers

Probers

Today's probers (flying probes) are much more advanced than their distant relatives of days gone by. Probers not only provide the



Panasonic

Under development

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

Halogen-free MEGTRON 6

NEW

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

*Low Dk glass cloth type

Features

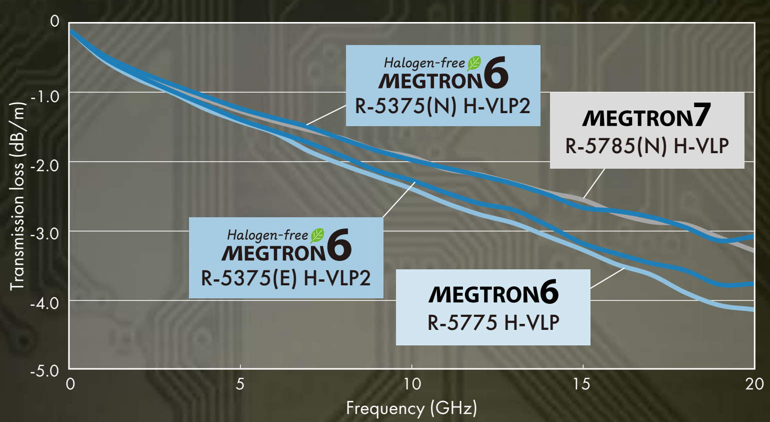
- Excellent HDI and thermal performance **with Halogen free**
- High speed and ultra-low loss material
- Low transmission loss

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

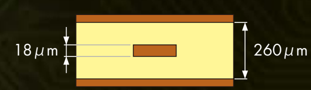
Applications

- 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

Contact us

More information

standard opens and shorts test but also buried passive, four-wire Kelvin, and HiPot testing. They can still provide the strict, resistive-only test still required by some OEMs and high-reliability applications, but probers can also provide indirect testing by signature comparison. This is accomplished by developing a capacitive master from a test specimen that has gone through and passed the strict resistive test. The subsequent boards have their capacitive signature compared to the master, and any nets that are atypical compared to the master are retested in resistive mode to guarantee they are acceptable.

Historic requirements of PCBs did not allow probers in some military requirements or performance classes. This was due, in part, to the lack of ability to detect defects in the 3D environment. Probers of today have the ability to scan the horizon as well as the third dimension or the Z axis. This is known as "line of sight" horizontal or "Z-axis" vertical adjacency. Statistical probabilities have been accepted that if a defect is going to occur, it will occur in a given window between two adjacent nets. This is referred to as the "adjacency window." Historically, this was limited to the horizontal axis or the same layer. This window can now be expanded to layers adjacent in the vertical axis. This enhancement in prober technology is one of the main reasons that some military and higher-performance class products can now be tested utilizing flying probes. This has allowed quicker turn time and reduced cost for electrical test.

Historic requirements of PCBs did not allow probers in some military requirements or performance classes.

However, you will not find this technology available in older probers. Software and metering systems in older equipment just didn't have the capacity to perform some of the required tests of today. One needs to inquire about the capabilities of the given prober versus the requirements you may have. Remember your deliverables. Some equipment may provide only some of your solutions while others may deliver the full package and more!

Fixture Testers

There is still no question that fixture testers provide the ultimate opens and shorts test. The fixture tester still provides the full parametric test. The simultaneous compression and test of all nets will still detect possible defects that no flying probe will ever find. This is because the fixture tester applies stress to the PCB. The simultaneous compression may detect microfractures to traces and/or barrels during the test that a flying probe may not. They also do not have the limitation of the adjacency windows as the flying probes have. The isolation test covers all nets to all nets regardless of proximity. A gross short defect covering a long distance will be detected where on a flying probe, it may be out of the adjacency window and not tested. Although rare and statistically low in occurrence, this type of defect would always be detected on a fixture tester.

Fixture testers are still the answer to high-volume production. Automation and dedicated fixtures process thousands of boards per time segment compared to a much smaller amount with flying probes. Although automation does exist for flying probes, they will never be able to handle the volume per capita compared to the fixture tester.

Conclusion

As you can see, the evolution of the PCB and electrical test have come a long way in the last few decades. The advances in PCB manufacturing and design have forced the evolution of ET and the methods used. ET has become as much of a new science as the new manufacturing designs coming from the OEMs. Just checking for opens and shorts is no longer enough. Requirements now not only include the opens and shorts test but also the guard zones of buried passives that are independent of the IPC performance class continuity requirement. Along comes multiple voltage requirements within the same board, HiPot requirements, and in many cases, time domain reflectometry (TDR.) Again, ET needs to supply all these services as efficiently and cost-effectively as possible, which is why finding the right equipment solution is imperative.

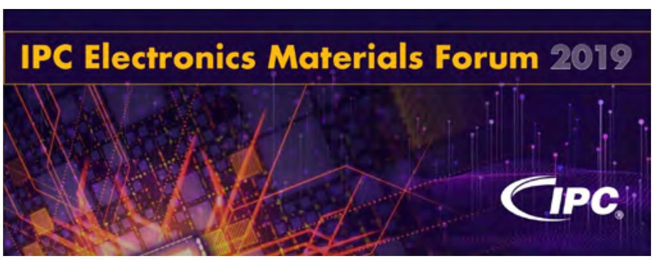
Test requirements continue to change as the designs advance. When searching for the right solution, gauge your requirements against the deliverables of the equipment. The advancements in prober technology will now provide multiple solutions within the same package. Do your homework, and you may find that the science of electrical test is not as ominous as you thought. As a colleague of mine once said, "I can't even spell ET." We can find answers to black holes. Whether you are doing electrical test yourself or have a partner to turn-key it for you, I hope this bit of knowledge I've passed along helps in decision making and understanding some of the science behind ET. ET is a much bigger process than what it used to be, so give those folks a chance when the delivery heat is on. It takes a little more time nowadays to "git 'er done!" **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.

First Annual IPC Electronics Materials Forum

On November 5-7, 2019, in Minneapolis, Minnesota, the electronics manufacturing industry will get a chance to be part of the first conference focused on electronics materials. Sponsored by IPC, the Electronics Materials Forum offers a platform to discuss the wide range of materials used to manufacture and assemble bare boards. This forum approaches the issue of materials from two different directions–first, based on their function in the manufacturing process, and second, to survey new electronics industry technologies and compile the required materials advances needed to make them possible.

Historically, IPC has looked at materials from two different standpoints: first, the permanent materials for either board fabrication or assembly with their associated requirements and properties enumerated in IPC standards; and second, process (consumable) materials used to create some manufacturing step but are not a permanent part of the product board. IPC tends to give criteria for successful use of these process chemicals but gives the fabricator wide latitude in selection.



At this time, proposals for presentations are still being accepted. The following are some key areas of interest for this conference:

- Permanent board fabrication materials will be addressed in a session with paper topics including substrate materials, novel board laminates, surface finishes, and solder mask advancements
- Permanent board assembly papers will concern new and novel solder alloys, thermal interface solutions, conformal coatings, adhesives, underfills, and new protective materials with properties such as water repellency
- Process considerations include new materials for producing HDI or substrate-like bare circuits or in assembly, new fluxes, and cleaning chemistry materials
- Assembly strategy papers may also be presented

Separate technology sessions will address the required properties to be developed in materials to implement the following new technologies: 5G communications, substrate-like boards, printed electronics, flexible circuitry, and wearable circuits.

These papers, with participation from OEM companies and trailblazers, will help shape the development of new materials for our industry. See you in Minneapolis for the Electronics Materials Forum! (Source: IPC)

MilAero007 Highlights

FTG to Acquire U.S.-based Circuit Board Company ▶

Firan Technology Group Corporation has entered into an agreement to acquire a U.S.-based circuit board manufacturing company focused on the aerospace and defense markets.

IPC's U.S. Export Control Compliance Workshops ▶

Given the increased scrutiny the U.S. Government is giving to all trade issues, IPC is encouraging the industry to ensure compliance with all federal export rules, including those laid out in the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations (EAR).

NASA "Nose" the Importance of Humans, Robots Exploring Together ▶

NASA is sending humans to the Moon, this time to stay. Upcoming expeditions to the Moon will require making every moment of astronaut time outside the safety of the Gateway in orbit and lunar lander system on the surface count. Robotics will enable lunar crews to do more while minimizing their risk.

NASA's Mars Helicopter Completes Flight Tests ▶

Weighing no more than four pounds (1.8 kilograms), the helicopter is a technology demonstration project currently going through the rigorous verification process certifying it for Mars.

Defense Multinational Acquires Nano Dimension Printer ▶

Nano Dimension, a leading additive electronics provider, has announced that one of the top 10 largest U.S.-based global defense and aviation providers has bought a DragonFly Pro 3D Printer.

Testing Todd: Confidence in Inspection ▶

The job of third-party inspection is to provide an unbiased review of the customer requirements versus the final product manufactured. This inspection can include both physical and functional criteria. Read on to understand the growing acceptance and requirement of third-party inspection in many areas of the manufacturing industry, including military, aerospace, and medical.

Next-gen NASA Instrument Advanced to Study the Atmospheres of Uranus and Neptune ▶

Much has changed technologically since NASA's Galileo mission dropped a probe into Jupiter's atmosphere to investigate, among other things, the heat engine driving the gas giant's atmospheric circulation. A NASA scientist and his team at the Goddard Space Flight Center in Greenbelt, Maryland, are taking advantage of those advances to mature a smaller, more capable net flux radiometer.

DARPA Seeks to Make Scalable On-chip Security Pervasive ▶

Program to focus on addressing the economic and technical challenges associated with incorporating scalable defense mechanisms into chip designs.

World's First Flight of Pioneering "Lighter Than Air" UAV ▶

A new type of unmanned aerial vehicle (UAV) has made a successful maiden flight thanks in part to the expertise of engineers from the University of Southampton.

Microtek Labs: Providing Trusted Testing in the Chinese Market

Feature Interview

It has been over 15 years since Bob Neves started Microtek Laboratories China to service the local Chinese market. On a recent visit to Microtek's Changzhou facility, Barry Matties, publisher, and Edy Yu from the I-Connect007 China team spoke with Bob, who serves as the chairman and CTO. Bob discusses the changes he has seen living and doing business in China over the past 15 years, most notably the increased importance of standards and testing as China moves into manufacturing more high-reliability products.

Barry Matties: First, we're here at your facility in Changzhou, and Microtek Labs has been at this facility for 12 years. Can you talk a little about Microtek?

Bob Neves: Microtek is a laboratory that specializes in testing for the supply end of the electronics industry. The primary companies that we do testing for are PCB manufacturers. We do testing and validation for the suppliers to the PCB industry, and people that buy PCBs and use them in assembly. The top end of our testing services for our customer base usually starts at the solder joint, and we do

Bob Neves at Microtek's Changzhou facility.

evaluations from the solder joint all the way through the raw materials, such as glass, epoxy, copper, and all of the other things that go into making a PCB. We become involved in the relationship between the supplier and customers as an independent source to determine whether the product does or doesn't meet the requirements. Sometimes, it's just routine, and we check on ongoing things, but other times, when there's an issue, a problem, or a discrepancy, we mediate.

We test to IPC standards primarily, but we also test to local GB standards. We test to IEC standards and a variety of customer internal standards, the biggest of those being from the transportation industry right now. Transportation is the fastest growing segment of the market because it's also the fastest changing. People in the transportation segment have to

design and integrate things into their vehicles that they never have had to do before, so there are lots of new designs, chips, and components going into their electronics. And the expectation is that these electronics are going to last a very long time. Right now, most of the commercial market has been geared toward the things that don't last a long time, such as cellphones and cameras where if they fail, it's not as critical, unlike if something in a vehicle would fail, life is at risk.

Overall, there's a lot of effort around automotive as well as the transportation market in general, which is where we see our biggest growth. China is opening up its internal airplane market and creating their own airplanes for both commercial and cargo use and trying to export those. The same thing is happening with trains and subways. China has train cars and subways in 100 countries around the world, and they have several active builds of trains around the world right now and are bidding for a bunch of others. China is looking to be an international supplier of public transport and a leading supplier of electric buses and vehicles in general around the world.

Overall, there's a lot of effort around automotive as well as the transportation market in general, which is where we see our biggest growth.

Matties: Is there also a space race going on in China?

Neves: It's interesting. The government side of the electronics industry is a totally closed market, and they have their own supply chains. China is doing something similar to what the U.S. used to be back in the old days when military contractors like Rockwell, Honeywell, Lockheed Martin, etc., would have the entire supply chain as their own. We don't see anything coming from the space, aerospace, and military sides of the market; that's entirely their own industry. People attend trade shows seminars from those segments, but not as often. They don't participate in the commercial side of things as much.

Matties: You've been living in China for many years now.

Neves: I've been living there full-time for about 15 years, but I started coming in the early '90s almost every year, so it has been interesting watching the differences between China from then to now.

Matties: You mentioned automotive, and looking at the sheer number of cars on the road compared to just eight or nine years ago is quite incredible.

Neves: Yes. I gave a paper on that at IPC APEX EXPO 2019 with a whole bunch of numbers as far as the number of cars that are being sold in China and that are on the road. It dwarfs anything that's happening anywhere else in the world. China struggles to keep up with the infrastructure. Being a foreigner, you have to go through registration, insurance, and all of the things you take for granted. I've watched that whole process become a lot more streamlined and successful. China monitors emission to make sure that cars are not spewing too much junk into the air, and the Chinese people want to get ahead with good quality of life. Overall, China has gone through many progressions and stages lately.

Matties: How has that changed in the type of testing or work that's coming through your facility?

Neves: If I go back to the early days, the one thing that we brought to the market from our U.S. business was integrity—people relied on us to always give them an unbiased opinion of what we were testing. In the early market, China was so focused on getting ahead and qualifying for things that testing and certificates were merely a barrier to registering or shipping your product. Chinese customers didn't see it as a necessary part of the whole process. A lot of things happened where the expectation of our customers was that we would let them pass regardless of actual results, but we wouldn't do that. The first five years of our business was very challenging because we had a reputation for not being flexible in our testing methodologies.

As China became more interested in the transportation industry and other industries that require high reliability, companies became aware of this and were very concerned. Customers started looking for someone that they could count on to give them unbiased opinions, which is when the market really changed for us because we had developed a reputation for integrity. It almost killed us in the first few years, but now it has made us a leader in this particular market in China because all of the customers that utilize our testing services know that they're getting unbiased data from us.

Matties: It's data they can trust.

Neves: Absolutely. Our testing is a fraction of the price of the value of whatever we're testing. For a $100–300 test, customers might be making decisions that affect millions of dollars of product, so what the test costs is rather meaningless; our customers aren't as concerned with that. They want to make sure that they're making the right decision on their two to five million dollars' worth of product. We've managed to keep that value proposition, which has caused us to be successful in a market where the price is everything. Usually, cost is one of the first three questions customers ask. But we've been able to maintain our price levels to sustain growth and all the other things we do here without the pressure that some competitors have to cut corners on what they supply the customer. We sell with integrity, and people want that, so they buy from us.

Matties: And for a lot of dealings in China, that's starting to matter more and more on a lot of different levels. You mentioned earlier that you're dealing with suppliers to the fabricators. Is this primarily around the base materials?

Neves: Our main tier with the relationships between the board fabricators is base materials, solder mask, and copper suppliers—the primary supply base for materials. We also work for them and their suppliers. Copper-clad manufacturers receive copper foil, resin, and glass. We verify the capabilities and properties of those materials whether it's organic, inorganic, or metallic because they have become complex in the last 20 years. We used to have a handful of supply materials, but now we have hundreds of options.

Matties: Materials are a big opportunity and problem all at the same time because there are so many to choose from, as you mentioned. Who's driving the change in the board shops to use new materials?

Neves: The real change was to lead-free materials. Lead-free drove the materials from what they were to what they are today. The problem was that the increase in temperature that lead-free provided does a lot of damage to organic materials, and the solution wasn't simple. As you increase heat resistance and change your

The flame lab.

Thermal shock (RTC) lab 2.

organic formula to do that, the material becomes untenable for other properties. Materials become more brittle, more prone to fracture and increases in the coefficient of thermal expansion, and have more problems with adhering to the glass. It creates a bunch of problems that people have worked to fix for approximately 15 years. Resin systems now are very complex and usually make up three, four, or sometimes even five different resin systems, fillers and additives that prevent fracturing, and bonding promoters, UV blockers, etc. People don't realize how complex the makeup of these materials is.

As you add complexity to a batch process, there are more opportunities for things to go wrong. That's where a lot of the materials have changed over the years. You also have a change in operating frequency. There are lots of changes happening in RF and autonomous driving that require lidar or radar, which are all happening in the high GHz range. Typical organic materials don't do well in that area; they tend to absorb the radiation, which isn't good. These devices are very low radiation, and if your material is absorbing all of the radiation, it doesn't get to your chips. Companies have had to change materials to adjust to that, or they've had to use different combinations of these materials or multilayers that might have a layer of material specifically for high frequency.

Other materials deal with lead-free, expansion, and holding holes together, so you have all these weird composites. The advent of rigid-flex has become more mainstream because an average vehicle has kilometers of wiring in it. All of that cable adds weight and cost; there's a big interest now in reducing that with flexible cables. The flex industry has also made bigger movements from a standpoint of where they were percentage wise to where they are today.

Matties: When you look at the different markets here, aside from automotive, where do you see the larger areas of growth?

Neves: In addition to automotive, which is an established industry that's growing rapidly with a lot of R&D and engineers and a market that everybody is chasing, there's also the whole 5G market and everything that will eventually connect to 5G, including IoT. There are things that you never thought would be connected to the internet. Now, there's an expectation of having 30–40 devices connecting to your home network. Buying a router and plugging it in is not a good solution anymore because that might not connect to a camera in the far corner of the house or the doorbell, thermostat, or oven that wants to tell your smartphone or watch that your turkey is done.

All of these things now have to be integrated, and some companies that need to do this are not used to dealing with electronics at all. Some are used to making mechanical parts, but now they have to bolt on electronics that talk to the internet or an internal router or server through a combination of sensors, CPUs, RF, and software. Many companies are trying to figure out

Humidity lab 2.

how to do this economically. Another layer of OEMs, the Foxconns and Flextronics of the IoT market, are working their way through the system right now and offering these services to companies. They're going to be the suppliers of the bolt-on electronics, and as these companies grow, they're going to bring it in-house.

Matties: When you travel through China, it's clear that they've embraced technology in a big way on a lot of different fronts. I can go to a local fruit stand and they won't even accept cash, for example; everything is e-pay now. Traffic signals and cameras everywhere, so there are a lot of electronics. What has it been like for you to watch this transformation from a technology point of view?

Neves: It's quite challenging because the rate of change is unlike anything I've ever experienced before. The interesting thing is watching how the locals accept it. The average Chinese person has become accustomed to this pace of change, and it's just normal to them. They expect that when they leave and go on vacation for a couple of weeks, they're going to come back to something different, such as a new road, building, or technology.

China is used to change, but not everyone in the world is. I can go to places in the U.S. or Europe that haven't changed in 15–20 years. Meanwhile, none of what we passed driving from the train station to our office existed when I first arrived 15 years ago; it was just farmland. Where this building now sits used to be in the middle of nowhere. But now there's solid development the entire way to the city center. The Chinese are used to it and don't spend a lot of time planning details ahead of time because plans change so rapidly, and otherwise, nothing would ever get done. If they need fiber optic cables, they dig up a road and put some in. If they need a road or a drain system, they put one in, etc. They plow ahead, and if they make a mistake, they fix it and move on.

Matties: Back to the testing, when should people consider a testing service?

Neves: If I look at the documents and IPC test methods out there that talk about testing, they're very basic guides; they only tell you generally how to accomplish a test. For instance, there is a long learning curve associated with doing a humidity test. You can't just buy a humidity chamber and a meter and start testing. There's a huge amount of understanding you have to gain about your water system, environment, cleanliness, the wires you use, the techniques to put the samples in the chamber, and how to put the meter together. Dozens of little things aren't a part of what's published out there, and that knowledge only comes from having experience.

Microtek started in '86. We've been doing testing in this market for a very long time, so we have a lot of learned knowledge. It has been passed on and acquired from doing what a lot of competitors don't have. Other companies say, "Let's get into the automotive market. We'll buy some chambers and meters, and we'll be an automotive test laboratory right now," but they haven't spent 30 years doing testing in the automotive market. For example, we started with Delphi and Sun Microsystems eons ago back when they were the early leaders in reliability and technology of PCBs.

We gained a lot of experience from the automotive and the U.S. aerospace market with satellites—things that people rely upon. We tested the boards on the Spirit and Opportunity Mars Rovers that lasted 6 and 15 years respectively after they were expected to die. And that's what customers want to find; problems cause their company pain, money, time, and time to market, so it's not about a few dollars in testing. Maybe the purchasing agents compare, but the engineers certainly don't. The engineers want to have good data so they can fulfill their responsibilities. We've been doing this for so long that we know about everything that could affect your test results.

Matties: Pain and the associated problems are big motivators for testing, but do people look at it as an opportunity? Do they say, "We want to expand into a new market, and we need to prove a process," for example.

Neves: Not really. We do some testing associated with material changes and things that they can't do internally. If they want to improve a process, it's usually a material change, so they'll send us something, and we'll determine if the material is better or worse. But again, that's usually driven from higher up in the supply chain. Somebody at the OEM level says, "I would like to make a change to this material and want to verify how you're able to manufacture it."

Matties: Do you ever deal with the circuit board designers?

Neves: They never go to the test side of it. They read and learn by trial and error.

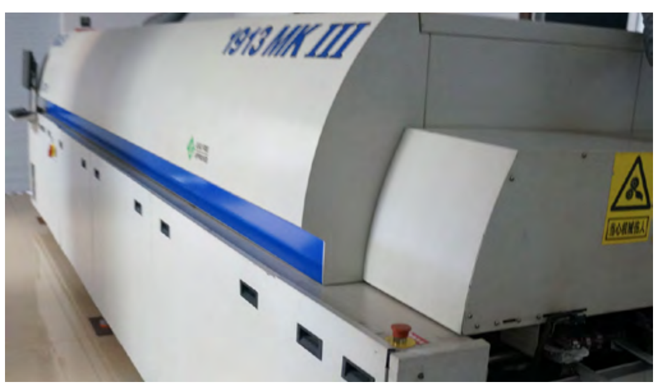
Matties: Is there an opportunity to gain knowledge to help improve circuit design?

Neves: The material suppliers have seen that their materials get specified in at the design phase. They've developed an entire sales focus based on informing the designers of the blessings of using their materials and how they can solve the design problems that they're facing with their materials. There's a lot of information focused on the material supplier to the OEMs and the designers within those OEMs. But most of the supply chain doesn't care all that much. They've all just said, "We'll do what you want us to do. If it works, great, but if it doesn't, we can build it again." The bigger PCB shops have teams that review designs and will work with the designers, saying, "We've seen this before, and this isn't going to work. You should probably redesign this."

There is communication between the board shop and the design team supplying the product. That has been a sales point for smaller and larger OEMs. The smaller ones that are doing design work don't expect to get the production order—their job is to work with the design team. And the large OEMs can't afford a $50 million mistake. Their customer would not be happy with them and would ask why they didn't catch it before it happened.

Edy Yu: You said China is focusing on all types of transportation. What standards are you testing for transportation or aerospace?

Neves: One of the things we've seen with the China market is that there's a push by the government to use GB standards. But just like the IEC standards, GB standards—like all international standards—tend to lag behind the market a little bit. IPC has really pushed the effort to try and meet the needs of the transportation market. For example, China Rail Group and Comac have worked with IPC and their efforts



Reflow simulation lab.

in the transportation business to upgrade IPC standards. Now, you're seeing automotive and transportation addendums, such as IPC-6012, which is a board standard, as well as IPC-A-610 and J-STD-001, which are assembly standards. Now, we have input from all other markets as well. They're all part of IPC's Task Groups Asia, which is working on adapting these standards to meet these requirements. The domestic high-reliability market has realized that IPC standards are at the forefront of this. Eventually, the GB standards will catch up. Historically, IEC and GB standards have taken a lot of technology from what's been developed by IPC groups and adopted it to their standards. Rather than waiting, they've chosen to be proactive, adopt it now, and then work internally in the GB system to move that into their internal documents. And we're happy to do that. We want to get as much input from as many different industries as we can.

We want to get as much input from as many different industries as we can.

Yu: That's interesting the Chinese train company wants to work with IPC.

Neves: They do. GB standards are domestically developed. Our technical team has worked on some GB committees as well because the problem with international standards is that they have to be translated into Chinese. If you adopt an English standard, then you have to translate it. Each industry has its own language, per se, because since Chinese is an old language, it doesn't have a lot of relevant technical terms in it, so it's hard to find the right translator to translate the English technical standards into Chinese standards. And that's where IPC's Task Groups Asia has come in. They've taken technical experts from the Chinese industry and put them in at the ground floor of the documents.

Instead of having a translation after the fact, translations are an ongoing part of the development process. I chaired the IEC's PCB testing committee for 15 years, having to translate English documents into French, Russian, and other languages. While I was there, I became much better at writing English standards and using words that were easily translated into other languages. That's now coming into IPC documents because people who speak other languages are asking what things mean. When I'd look at the English version, I'd say, "I know what it means, but it wasn't well said in the document," so we would wordsmith it. Now, we're writing documents in a format that's easier to translate into other languages.

Yu: Back in 2003, you had just moved to serve the local market. When you look back, was this the plan all along?

Neves: When I looked at the China market and decided to open a business here, unlike most people who wanted to take advantage of the low cost and exporting things out of China, I came in to service the domestic market. Five years ago, 98% of our business was just China, and that was on purpose. Because of our expertise in the Asia market, we've seen an influx of business coming to us externally. That probably makes up 8–9% of our business coming in from outside of China because we've established ourselves as a world leader. We receive stuff from Europe and other places as well for some of the specialty things that we do better than anyone else in the world.

But the goal has always been to service the local market locally because you can't service the Chinese market from outside of China; it's almost impossible. The one thing I've learned from all of my years since coming here in the '80s is that China is a very unique place. Everything runs a little bit differently, so unless you're fully here and integrated, you cannot run a successful business from outside. And the market caught up with us. When we first arrived, we were a service business. Nobody understood, and they would ask us what we made. When I'd say, "We don't make anything," they didn't understand our service-based business. Now, they're beginning to understand. China is starting to shift toward a more service-based model, whether that's from an app or a software standpoint to specialty businesses like Microtek that provides high-end services.

The big companies are still going to do everything themselves, such as Huawei, ZTE, and Haier. Those companies have decided that if they need to do something, they will build a division. They don't want to subcontract anything. And every place that has undergone development goes through that process where they bring it all in, and then at some point, they spin it all off. But that hasn't happened yet here. That's another development in the future that will help us grow—when larger companies start realizing that their laboratory and testing services are all cost centers. They don't make them any money; they're just full on cost. And they have significant burden of overhead that we can save them. Microtek can save them money because we spread our burden of overhead over a bunch of companies while they're stuck with it just for themselves.

Matties: But in many cases, everything in China is a secret. There's still some of that mentality out there.

Neves: A lot of the innovation comes from looking at what's in the industry and doing it better ourselves—not necessarily spending a lot of time doing the innovation themselves directly, but innovating on how to make it better, faster, and cheaper. And that's always been China's success. And another thing that's changing is the people, education, and engineering here is leading to a lot of new and unique stuff.

Matties: Maybe less copycat stuff?

Neves: I don't know if copycat is the right word. It's looking at a product and saying, "Wow, that's expensive. I can do that cheaper."

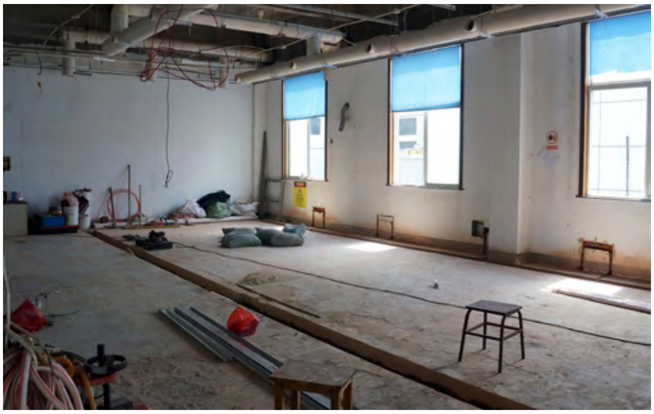
Matties: Well, there was a foundation of copycatting, which is part of the ongoing negotiations between China and the IP. With that aside, I understand that you're saying they've reached a level of innovation where they're innovating on their own.

Neves: Correct. But every market economy has gone through this. When the new Americans left Europe to come to America, they carried a lot of innovation with them. When Japan was rebuilding after the war, they gained a market as the cheap electronics copy place and evolved into what they are today. It's happening in a similar way in China.

Matties: When you look at China 15–20 years ago, there weren't the manufacturing processes and knowledge that there are today. Back then, they were learning through partnering with US OEMs. Now, they're capable of manufacturing and competing on a world-class level with their own product lines because they have the experience.

Neves: When you look at the local experts who have been doing it for 5–6 years, they're good, but in the West, we wouldn't consider people "experts" unless they've been doing it for 20+

Humidity lab 1.



Future humidity lab 3.

years, and nobody has that here. However, if a particular field has only been open for 10 years and someone has 10 years of experience, then I'd consider them an expert.

Matties: And the shift in manufacturing to smart factories and the reduction of operators by law in some regions is playing a big role in China on the economic makeup.

Neves: Automation is a natural progression of the increase in the cost of labor that China has been undergoing. For our first 10 years in business, our cost of labor at the lab increased 15% year on year; now, we're down to 6–8%. It's leveled off, but it's still significant. If I look at the cost of doing business today versus when I started, it's well over double.

Matties: But I would think that the jobs you offer at Microtek are more desirable than the traditional manufacturing jobs.

Neves: I would like to think so because I value people and the training that I put into employees. Some companies say, "We don't want people to stay more than a year because we don't want to have to pay them more money. We'll piece our jobs so they're easy to train and I can cycle people in and out." Microtek doesn't do that. I can't hire a kid out of college who will have the knowledge that's gained from running all of the tests that we do because there's just no school for that. We have a training program here and levels of operators and educational courses that we run so that they can earn their way through our system. As they gain more knowledge, they gain more benefits and we provide more incentives to keep them growing and learning more. Our turnover rate here is very low.

Matties: It's a specialty job.

Neves: Right, and we're very careful who we hire. We want to hire people that intend to stay for a long time.

Matties: A career path rather than a stepping stone.

Neves: Absolutely.

Matties: How many employees do you have?

Neves: We just passed 50 people at the end of last year, so we've hit that level where every company has to create mid-management positions. We've had to restructure things these past few quarters to go to the next level. Growth has been very consistent for us due to all of these changes in transportation and IoT, and those market segments are also expecting huge growth.

Matties: You keyed in on it earlier. Your success is really tied to the rate of change that happens here serving a domestic market. And it looks like the change is happening at an accelerated pace on a daily basis.

Neves: You can't sustain 15% year on year forever because it's an exponential curve. At some point, to keep a steady rate of growth, you have to reduce your annual percentage, and China is seeing that now. How is that going to work instead of the expectation of a 6% growth, which would be fantastic anywhere in the world, when people are looking at it, saying "Meh?"

Matties: It barely keeps us moving. But it looks like 5G is going to be a big factor in this for the coming years.

Neves: In China, 5G is dominated by just two or three players. For them and their supply chain, it's going to be phenomenal But as far as infrastructure is concerned, it's going to have minimal impact on the overall market on the big picture of things because the supply base is very limited.

Matties: It winds up in the consumer market though, doesn't it?

Neves: Once the infrastructure is there to be able to use 5G, and that's still a year or two down the road. The infrastructure part is going to be a lot of it, but it's going to be through a few very narrow channels. There are three phone providers in China, and there are three or four main equipment suppliers as well as their supply base. They're going to do very well over the next few years because it's an unbelievable volume of infrastructure that has to be put in to support this.


Bob Neves

But I don't think it's going to hit the general market other than some of the material suppliers seeing volumes go through the roof. In general, you're not going to see that widespread benefit from 5G being implemented; only after it's implemented does the market takes off. You can take a picture, and it would be published on the I-Connect007 website a little while later. Soon, you're going to have hardware and software vendors saying, "I can upload that immediately." That's the kind of stuff and innovation that is going to happen once you have that ability to transmit that volume of data back and forth so quickly. Then, you have the whole idea of computing switching from local processing to central processing.

There's also going to be a regression of all of this stuff where the tablets become more and more powerful. Communication is going to become powerful, and all the processing is going to be done somewhere else. Instead of sending to your CPU inside your product, you're going to send it to somebody else's CPU to crunch the stuff and then send it back to you. For companies like Amazon who are looking at decentralized processing, 5G is going to change their markets substantially. But it's not going to be a good thing for the phone manufacturers, etc., because the need to have the "A52" processor in your iPhone XXI is not going to be there anymore. A lot of the main apps that we use are starting to use more service-based models and to move their processing off of your phone onto their servers on the edge of the internet wherever you're at.

Matties: Well, it's nice to catch up with you, Bob. Is there any advice that you would give somebody looking to do business in China?

Neves: As I mentioned earlier, you can't do it from afar; you have to do it internally. You have to make the commitment to physically pick up from where you're at and do business in and from China. There's no easy way to learn; you just have to come and dive in. It's a big change, and it's different than anywhere else in the world. But if you're going to be successful here, that's what it takes. If you hope to bring a Western philosophy, then you have to bring Western people to instill that philosophy because that's not natural here and would be a struggle. Even after 15 years, it's still a challenge for me to find that middle ground.

Matties: Right, what you know doesn't necessarily work everywhere. Thank you very much, sir.

Neves: It's always a pleasure. **PCB007**

The Travelling Engineer, Instalment 2

Ladle on Manufacturing

by Marc Ladle, VIKING TEST LTD.

In this second instalment, I hope to continue to give you a small insight into how the reality of working as a travelling engineer for a machine supplier matches up to the job description. After 15 years of working for Viking Test Ltd. and having the opportunity to visit a variety of interesting locations around the world, any illusions I previously held have been shattered. The details that follow may not be 100% accurate, but they are how I honestly remember the experiences.

Smartphones and satellite navigation have made a massive difference to our ability to find our way from place to place and make arrangements for hotels and travelling. My early experiences travelling for Viking pre-date any mass-market devices to help with navigation, which added a whole extra level of preparation to find my way from place to place and make bookings for places to stay.

The job that I undertook was the installation of one of the first drop-on-demand legend printers installed in Europe—a machine made to print component identification and markings on the surface of circuit boards. The process is now reasonably well established, but back then, it was an exciting new process.

My boss briefed me before starting the journey. This was the first time I had worked on this type of machine, so he arranged for me to meet an engineer from an office in Europe who had travelled to the machine manufacturer in Japan for training. The plan was for me to work alongside the experienced engineer to learn the correct installation method and how to commission the machine. I was basically going to be there to help with the heavy lifting and to watch and learn.

The trip started with the standard drive to Heathrow Airport to catch an early flight to Frankfurt, Germany. I landed and picked up a hire car to drive me to meet up with my colleague for the week. The normal method for finding my way to the destination was to have a written plan of the route with motorway junctions and road names. I was heading for a small town called Idstein, and so far, all was going to plan.

Frankfurt Airport Terminal 1, circa 2009. (Creative Commons)

For those of you who are not used to hiring cars in countries that have the steering wheel on the other side of the car, the first few times are an interesting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experience. When you start to relax, it is easy to reach for the gear lever with the wrong hand and also a bit disconcerting when you glance at the rearview mirror and see the top corner of the door.

Once I arrived in Idstein, I drove around and around looking for the right road. The problem with having a written set of instructions is that it does not allow for anything going off course. All you can do is to try and retrace your steps until you get back to one of your listed waypoints. When I finally found the right place, it was within a residential area, so right until the last minute, I was still convinced I was going the wrong way as I was expecting an industrial area with other commercial buildings.

I walked into the office and realised immediately that something was very wrong. To date, I still remember it as one of the most difficult moments I have had to deal with. There were two men and a woman who were at the back of the room, and all of them were quite visibly upset. I had never met any of these people before, so I carried on, introduced myself, and explained who I was intending to meet.

Quite a few seconds passed before one of the gentlemen said, “You don’t know, do you?” I was still wondering how I should respond when he explained to me that the engineer I was travelling to meet had been killed the day before in a car accident on the motorway. In that tragic situation, there was so little I could do or say to comfort the people involved. The three people at the office had just lost a colleague and friend. I apologised profusely for my intrusion, left the office, and sat for a while in my hire car. I had never met any of these people before, but I still experienced a huge feeling of loss and sadness.

After some time, I thought about what to do next. I guessed that the customer still knew nothing about the situation, so I decided to travel to the factory to explain what had happened and to help in any way that I could.

I had a mobile phone, but the capability at that time was limited to voice calls and texting. I called the Viking office in the U.K. and took down an address and some rough directions for reaching the customer site. The hour it took me to travel there was long enough for me to decide that I should make all efforts to proceed with the machine installation if only to try to keep pressure off the grieving people at the Idstein office.

Figure 1: CraftPix machine.

The customer was very understanding and helpful and did not put pressure on me. He showed me through to the machine and the associated packages and left me to it. The machine was supplied by Microcraft in Japan, and I have to give them some serious credit for an excellent machine manual (Figure 1). There was a stage-by-stage installation guide along with pictures. It gave good details of what parts to connect where, how to connect the computer, how to load the software, and most importantly how to fit, level, and calibrate the print head.

I got lost in the task in hand. I wasn’t aware of the time passing, but progress was being made, and I remember feeling a solid sense of achievement when I could see the first bright white images appear on the green calibration panel. I looked at my watch and realised it was almost 10:30 p.m. in the evening. I thought I should probably stop for the evening and try to find my hotel and get some sleep.

I had the name of a hotel, and I knew it was located in the nearby town, but that was the limit of the information I had been given before travelling. I found my way into the sleepy, small town, and managed to track down the hotel, but I was faced with some problems again. There was nobody to be seen. The hotel was locked, and my slightly suspect German-language skills were enough to work out from the written information on the board outside that it was an unmanned reception and I needed to type in the entry code on the keypad to get inside.

However, there was no phone number visible on any of the signs outside, and it was starting to snow a little. I didn’t have the entry number, and there was abso-

lutely no one around to help me. I headed back to the car, and I drove around the town looking for an alternative place to stay or anyone I could ask for advice, but everyone was asleep and the whole town was quiet and locked up for the night. I parked the car and contemplated the best course of action. I had a couple of days' worth of clothes in a bag to cover me for the trip, and I put them all on. It was definitely going to be a cold night and not the most comfortable.

Sleeping in the backseat of a small car is not something I would recommend. I don't think there is any way I could do it now, but even in my late 30s, it was not a pleasant experience. Before trying to sleep, I called my wife and explained the events of the day. While she was supportive as always, I could hear the concern and worry in her voice, but I was sure it was the right thing to do. At least somebody now knew where I was and what my plans were.

I didn't sleep very much, and instead, I quite literally counted the minutes until the morning. I was so incredibly cold and had to run the engine for a while just to add some heat and stop shivering. My son, who was a member of The Royal Air Force Air Cadets at the time and was used to camping outside in all types of weather, suggested to me later that sleeping in a car is similar to sleeping in a fridge and I would probably have been warmer sleeping outside.

The next morning, I messaged my wife to let her know I was okay and headed back to the factory as early as I could to continue the machine installation and start to work on printing images onto real panels. Between the screen room supervisor and myself, we managed to get through the printing process, preparing data and printing panels.

Drop-on-demand legend printing has some pretty strong advantages over screen printing or photoimageable processes, especially when applied to small batches. The data is all electronic, so there is no need for any artworks or screens to be made. This cuts quite a lot of time and effort out of the process.

Because the machine is CNC-driven, it is possible to make a very accurate alignment to the copper image etched onto the panel. Microcraft does this very well, and there is a consistency to the results that it is hard to achieve using the screen-printing process. A camera alignment system automates the process to ensure accurate repeatability from panel to panel.

Now, the process has evolved and is well-established with offerings from a few established suppliers. Solder mask machines are also becoming available, which offer similar levels of advantage for printing solder mask on smaller batches of panels. There is even the opportunity to print multiple colours or to print both solder mask and ident ink in the same operation. Print times have improved as well as the print head technology. For the right factory, the inkjet process has some very interesting possibilities.

Returning home from Germany, I took some time to reflect on the experience. It remains one of the most difficult trips I have ever undertaken. I learned quite a lot about myself and gained considerable confidence in my ability to work on a wide range of machinery. But the most significant thought that remains with me from this trip is to enjoy each day. We can never be certain what is around the corner. **PCB007**

Marc Ladle is a director at Viking Test Ltd. To read past columns or contact Ladle, click here.

Editor Picks from PCB007

1 Standard of Excellence: Buy Based on Value, Not Price ▸


Anaya Vardya

There are only two ways to buy PCBs; the first is based on price, which is the wrong way because it encourages a very shallow relationship based on just one thing—the price of the boards; and the second, and right, is based on value. A great company should understand what it means to buy value.

2 Automation on Full Display at China Exhibitions ▸

With the rising cost of labor in China, the growing demand for automation has never been stronger. At productronica China 2019 and other accompanying shows, one hall was packed full of automation technology. This video gives you a glimpse into what was on display and the new workforce.

3 It's Only Common Sense: Seven Tips for Cold-calling Success ▸


Dan Beaulieu

Dan Beaulieu argues that cold-calling is a lot harder today, but it is not dead. Don't despair. Here are seven tips for cold-calling success.

4 EPTE Newsletter: Printable and Flexible Electronics in Taiwan ▸


Dominique Numakura

Dominique Numakura was invited as the keynote speaker of Printable and Flexible Electronics, a two-day conference held at the Industrial Technology Research Institute (ITRI) in Taiwan. His presentation included current business trends and future forecast for the global printable and flexible electronics industry. Here's a recap of the event.

5 AT&S Demonstrates Efficiency and Robustness of Embedded Power Technology ▸

To improve the efficiency in modern cars on the way to electromobility and in challenging industrial power conversion applications, the power density has to be increased without limitations on performance and reliability.

6 The Right Approach: The New Frontier of Manufacturing ▸


Steve Williams

While M2M and H2M connectivity are the primary focus of Industry 4.0, the true underlying benefit of Industry 4.0 comes in the form of machine-to-business (M2B) connectivity or the "machine-as-a-service" concept. This is changing the way we purchase equipment.

7 The PCB Norsemen: A PCB Broker's Guide Through the Galaxy of Automation ▸


Jan Pedersen

A smart factory is defined by its ability to harness manufacturing data flowing throughout the enterprise and then convert that data into intelligent information that can be used to create improvements in productivity, efficiency, savings, yields, automation, enabled traceability, compliance, and reduced risk of errors and rework. All of these items are crucial factors when manufacturing printed circuits.

8 Advance Your Company Through Automation ▸


Yash Sutariya

Yash Sutariya discusses with Patty Goldman the labor shortage he has experienced in the Detroit area, the impact automation can have in the manufacturing process, and other strategies to advance your company.

9 University Students Point to the Future in Their Research ▸

Cutting-edge automation, AI, machine learning, and Industry 4.0 are all part of the response to the increasing demands for printed circuit boards that are not only faster, smaller, and cheaper but also higher-frequency, lower-loss, more temperature tolerant, and higher reliability. In many cases, it will be unique and advanced research coming out of the university system that will help move the industry forward.

10 Stacked Microvia Reliability: Ongoing Work and Upcoming IPC Conference ▸

One year ago, Happy Holden's review of the 2018 IPC High-Reliability Forum reported the presentation of J.R. Strickland and Jerry Magera who described research at MSI Applied Technology into overcoming the risk of stacked microvia failures escaping standard quality assurance procedures. Their report provided a basis for the IPC white paper IPC-WP-023, which addressed reliability issues associated with stacked microvias and included data collected from several other printed circuit manufacturers.

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Career Opportunities

Sales Personnel, Japan

The Gardien Group is looking to expand the sales team in Tokyo, Japan, and seeking highly motivated team players with a positive attitude. Prior experience in the PCB industry is an advantage but not necessary for the right candidate.

The role involves working closely with the customer to identify their needs and deliver the right solution. The candidate should be able to offer a high level of customer satisfaction to ensure ongoing sales.

Training will be provided along with a competitive benefits package, excellent growth opportunities, and periodic bonuses.

Interested candidates, please contact us at careers.jp@gardien.com with your resume.

Kindly note only shortlisted candidates will be notified.

apply now

Sales Representatives (Specific Territories)

Escondido-based printed circuit fabricator U.S. Circuit is looking to hire sales representatives in the following territories:

- Florida
- Denver
- Washington
- Los Angeles

Experience:

- Candidates must have previous PCB sales experience.

Compensation:

- 7% commission

Contact Mike Fariba for more information.

mfariba@uscircuit.com

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Career Opportunities

Career Opportunities

BLACKFOX

Premier Training & Certification

IPC Master Instructor

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

For more information, click below.

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YOUR JOB AD HERE

For information, please contact:
BARB HOCKADAY
barb@iconnect007.com
+1 916.608.0660 (-7 GMT)

I-Connect007
GOOD FOR THE INDUSTRY

Events Calendar

Medical Electronics Symposium 2019 ▶
May 21–22, 2019
Elyria, Ohio, USA

Industry 4.0–Smart Factory ▶
May 29, 2019
Tel Aviv-Yafo, Israel

EIPC Summer Conference 2019 ▶
June 13–14, 2019
Leoben, Austria

NEPCON Thailand 2019 ▶
June 19–22, 2019
Bangkok, Thailand

PCB Pavilion @ LCD EXPO Thailand ▶
June 27–29, 2019
Bangkok, Thailand

NEPCON South China 2019 ▶
August 28–30, 2019
Shenzhen, China

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

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

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

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

Additional Event Calendars

Coming Soon to *PCB007 Magazine:*

JUNE: Everything Starts With Design
Designers need more information to estimate their design choices, and fabricators ultimately build what the designers specify. How can we make this conversation more efficient?

JULY: Failure & Reliability
The pressure to improve failure and reliability performance is increasing. We look at the latest developments in reliability improvement for PCB fabrication.

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