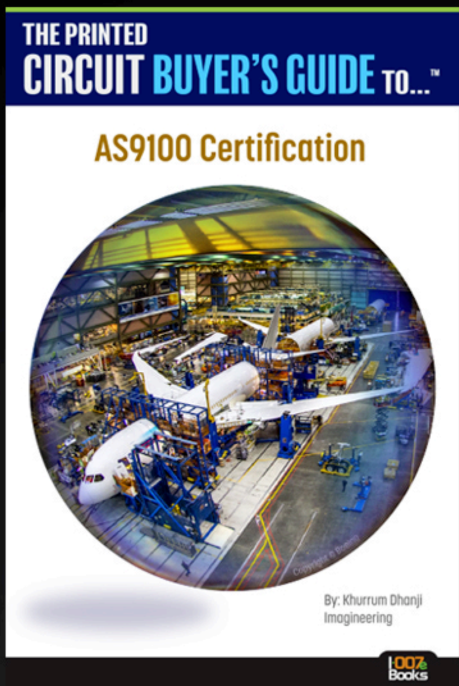
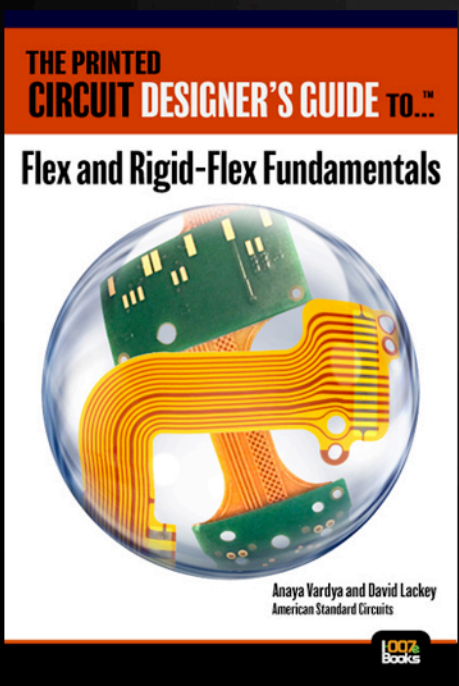
I-Connect007 Presents

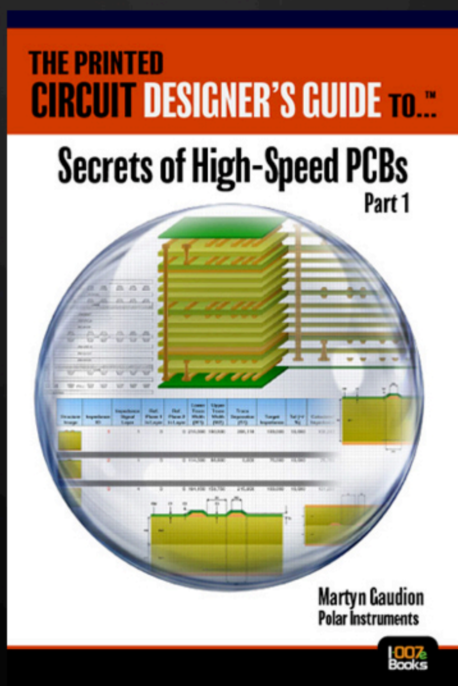
April 2017

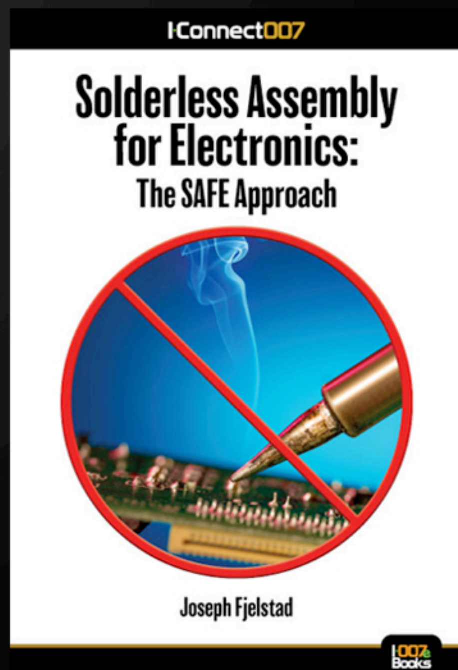
the pcb magazine

Check out the latest titles in our micro eBook library!









Written by industry experts, these free micro eBooks each contain valuable information on relevant topics in an easy-to-read format. Click on a title above or browse our entire library today!

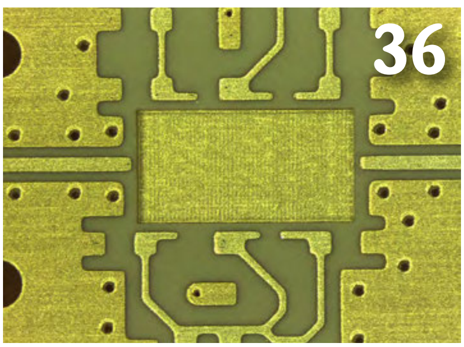
I-007e Books

IConnect007 Presents

the pcb magazine

April 2017

Featured Content



High-Speed Materials

Do we really need more speed in our connections? If we want autonomous cars, intelligent robotics, extended IoT, then we must press forward with the development of high-speed materials. Our contributors this month examine our industry's need for speed.

FEATURES:

April 2017
Vol. 7, No. 4
thepcbmagazine.com

More Content

185HR

High-Tg, Low-CTE Materials with High Thermal Reliability

FEATURES

- High Thermal Performance
  - Tg: 180°C (DSC) (Base Laminate)
  - Td: 340°C (TGA @ 5% wt loss)
  - Low CTE for reliability
- T260: 60 minutes
- T288: >15 minutes
- Lead-free Compatible and RoHS Compliant
- UV Blocking and AOI Fluorescence
  - High throughput and accuracy during PCB fabrication and assembly
- Superior Processing
  - Closest to conventional FR-4 processing
- Industry Approvals
  - IPC-4101D-WAM1 /98 /99/ 101 /126
  - UL – File Number E41625
  - Qualified to UL's MCIL Program
- Core Material Standard Availability
  - Thickness: 0.002″ (0.05 mm) to 0.060″/0.062″ (1.5 mm)
  - Available in full size sheet or panel form
- Prepreg Standard Availability
  - Roll or panel form
  - Tooling of prepreg panels available
- Copper Foil Type Availability
  - Standard HTE Grade 3
  - RTF (Reverse Treat Foil)
- Copper Weights
  - ½, 1 and 2 oz (18, 35 and 70 µm) available
  - Heavier copper available upon request
  - Thinner copper foil available upon request
- Glass Fabric Availability
  - Standard E-glass
  - Square weave glass fabric available

KEY APPLICATIONS

- Heavy copper, 6 & 12 oz automotive applications
- Military
- Medical
- Industrial

ORDERING INFORMATION:

Contact your local sales representative or visit **www.isola-group.com** for further information.

Isola Group
3100 West Ray Road
Suite 301
Chandler, AZ 85226
Phone: 480-893-6527
info@isola-group.com

Isola Asia Pacific (Hong Kong) Ltd.
Unit 3512 - 3522, 35/F
No. 1 Hung To Road, Kwun Tong,
Kowloon, Hong Kong
Phone: 852-2418-1318
info.hkg@isola-group.com

Isola GmbH
Isola Strasse 2
D-52348 Düren, Germany
Phone: 49-2421-8080
info-dur@isola-group.com

isola

Faster, Faster, Faster… or the Need for Speed, More Speed!

by Patty Goldman
I-CONNECT007

I wonder: Do we really need more speed in our connections? When will we hit that proverbial wall everyone worries about? Of course, if we want things like autonomous cars, intelligent robotics, and extended IoT, then we will continue to press forward—or rather you, the PCB manufacturer, designer, and supplier of high-speed materials will keep at it.

As is our wont here at I-Connect007, we felt a strong need to survey you, our readers, on this subject. In our most recent survey for this month's topic, high speed materials, we asked several questions—some open-ended, some not—to gain a better understanding of what is really happening out there. The answers we received did not boil down to a simple two or three issues. So let's discuss further.

The first thing we asked was (our favorite question): What are your greatest challenges when working with high-speed materials? It was like opening a Pandora's box. Answers ranged from materials adhesion to bendability and thickness; from drilling and other processing to sourcing, price, and lead times; from impedance control and accurate testing to educating the customer. Sounds like this is not an easy arena to play in and when you read the discussions we had with fabricators, you will see that is indeed so.

Next, we asked the percentage of orders where the material is pre-specified by the OEM; the response was overwhelmingly on the high end with 60% of respondents putting the level above 50% (and a few claimed it to be near 100%). We asked a couple of questions on growth of this market, which may explain why so many are working with the high-speed materials and building these difficult boards (Figures 1 and 2).

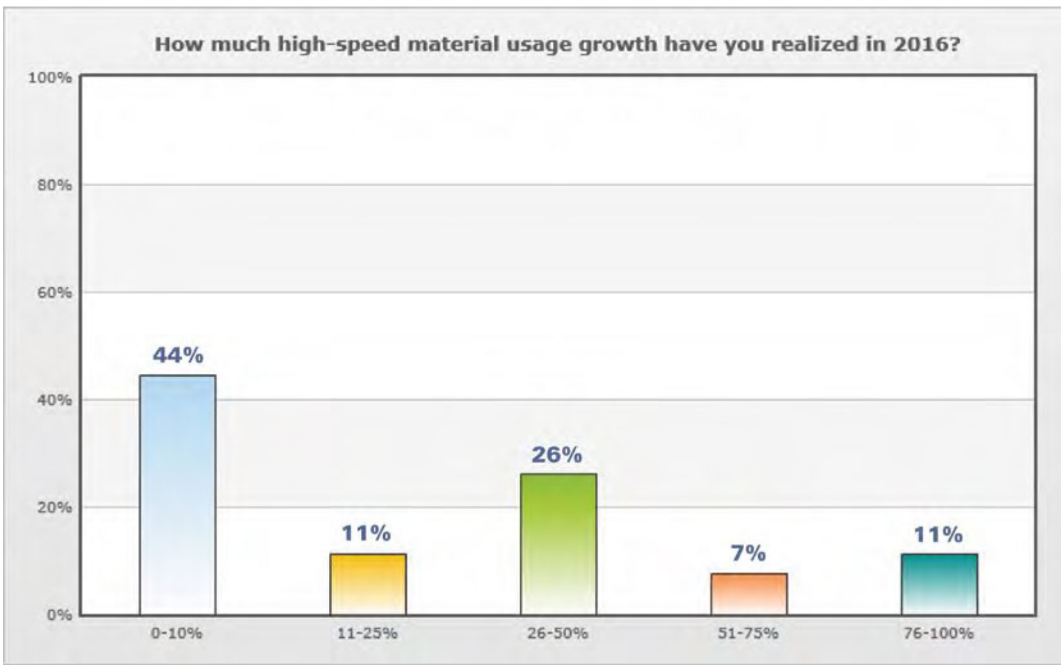


Figure 1.

AUCTION

DAPC
DYNAMIC & PROTO CIRCUITS INC.

Leading High Quality PCB Manufacturer
Circuit Board Mfg. Equipment as Late as 2015
Closure of a 50,000 Sq. Ft. Multilayer Facility

Bid: May 2nd - 3rd ▪ Location: Stoney Creek, ON

Entertaining Pre-Auction Offers on Select Machines!

BG The Branford GROUP

TheBranfordGroup.com
(203) 488-7020

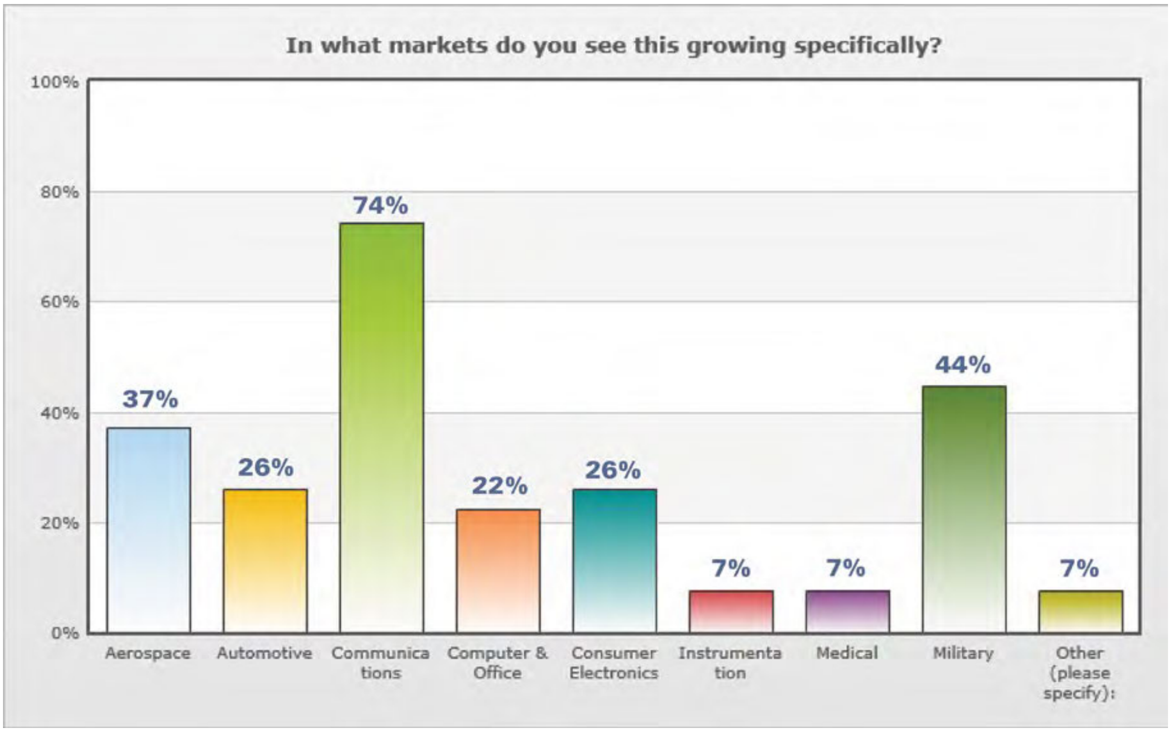


Figure 2.

Regarding which traditional markets are seeing the most growth of high-speed constructions, it appears that communications is leading the pack. But Figure 3 shows that, when combined, military/aerospace applications are right up there. Automotive lags but we can expect that, as the autonomous car begins to take hold, there will be a big jump in that area. Which makes one begin to wonder about the various markets that increasingly overlap: For instance, dashboard electronics in an automobile could be classified as part of the automotive, computer, communications, and consumer industries. Judging from what we learned from Dan Feinberg's recent CES show report, "CES: Disruptive Technologies," medical might also be on that list. Of course, I realize they still fall under the automotive jurisdiction.

Let's get to it and I'll tell you what's in store this month.

We start off with Sidney Cox of Cox Consulting, a long-time flex enthusiast from the (DuPont) materials side. He brings us up to date on materials for high-speed flex circuits—one of those growing markets, as you learned last month.

Next is a most interesting discussion we had with three fabricators making high-speed PCBs. They are Gerry Partida with Summit Interconnect, Joe Menning of All Flex Flexible Circuits and James Hofer at Accurate Circuit Engineering—definitely guys worth listening to and reading about.

We've been working to hear more from European PCB fabbers, and next up we have an article from Optiprint, a company specializing in RF and microwave PCBs. Jim Francey and Terry Bateman give us a wonderful dissertation on the technology requirements for millimeter-wave interconnects and antennas covering materials choices as well as circuit design and manufacturing requirements.

We had a great opportunity to speak with TTM's Craig Davidson about embedded optical interconnects and we present that conversation. TTM is far along this path and Craig gives a great overview of the technology and what drives it forward.

Well, that's a lot of heavy-duty technical info to take in. Let's move off topic to other no less important tidbits from a few of our columnists. Gardien's Todd Kolmodin (aka Testing

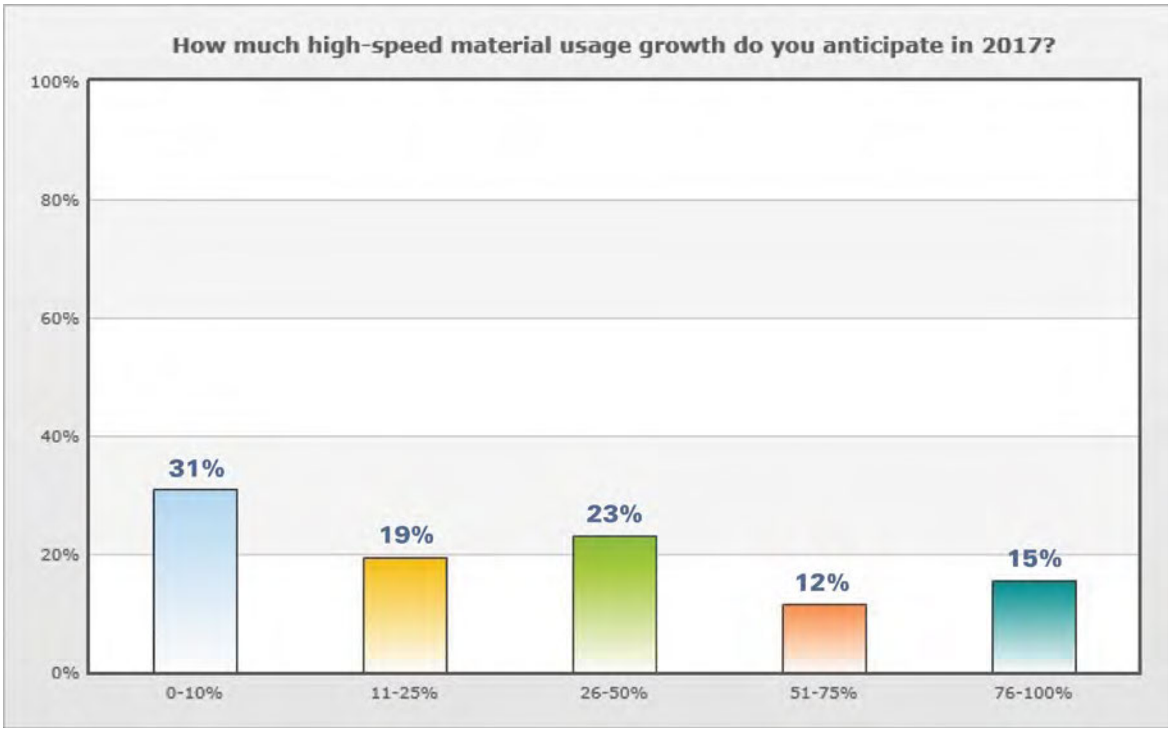


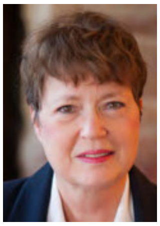
Figure 3.

Todd) describes a system to improve the flow of information that will help ensure correct electrical testing and minimize delays and errors. Keith Sellers, NTS–Baltimore, provides a detailed explanation of several thermal shock and cycling test methods which many should find very useful. RBP Chemical's Mike Carano gives us some good basic troubleshooting info on peeling copper circuits.

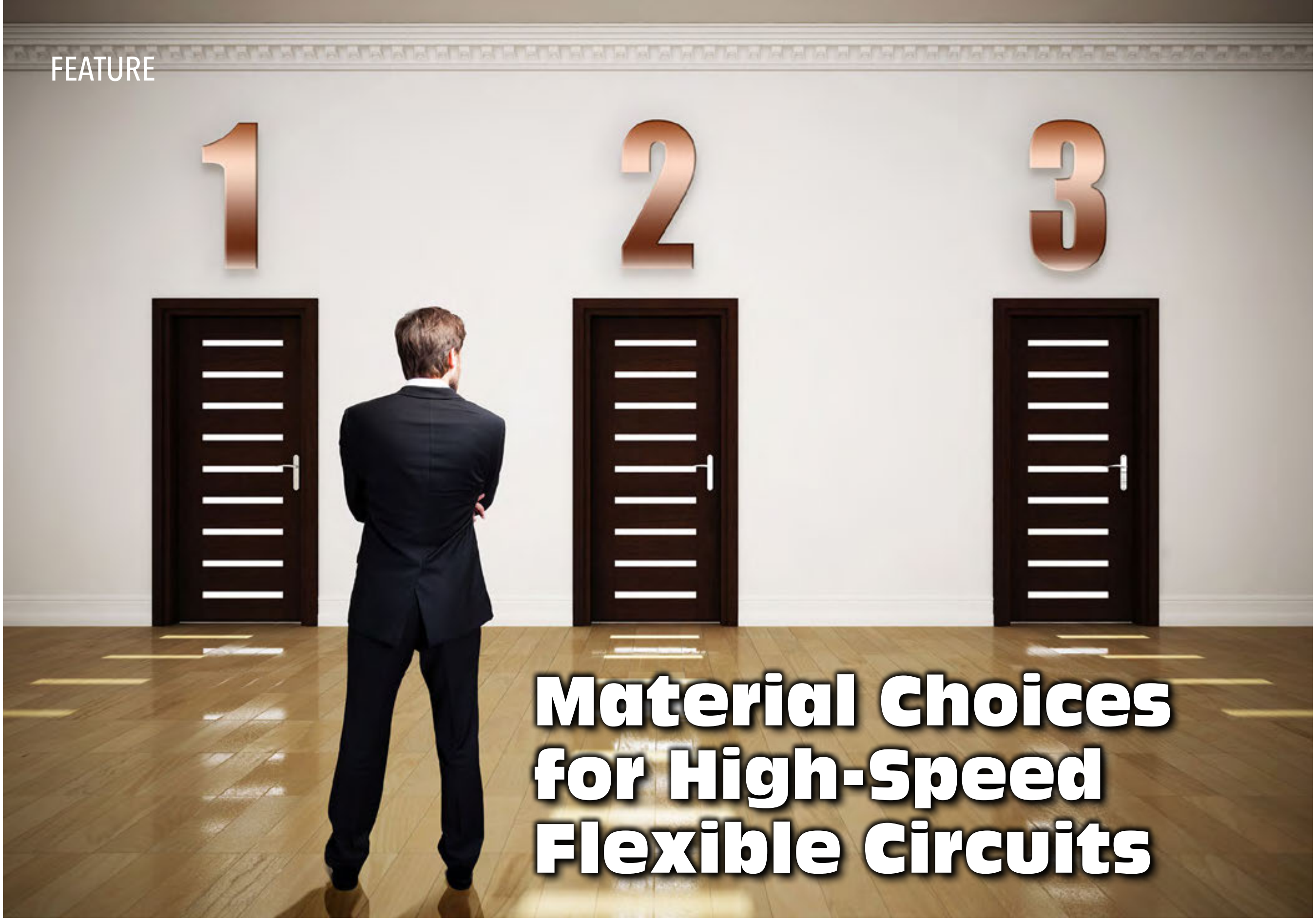
But we're not done, by a good bit. As always, we have a technical paper unrelated to the theme. This one is by Steve Vetter of the Naval Surface Warfare Center in Crane, Indiana (USA) with other authors. The subject is implementing a trust accreditation process for PCB manufacturers, so this is worth a careful read. To quote a short passage: "…the trust accreditation process will be critical for securing the DoD, PrCB [PCB] industrial base going forward…"

Our regular columnist, IPC President John Mitchell, presents three manufacturing policy initiatives for the Trump administration to consider to help strengthen manufacturing. And of course, last but not least, the Launch man Barry Cohen gives a primer of best practices for crafting worthwhile news releases. Do read these!

Next month, we stray from the typically heavy technical content to a personnel subject. One of the things that is almost always brought up in conversations at meetings, over drinks, in interviews, or almost any time, is the "graying" of our industry and what to do about it. So we're calling our May issue "Help Wanted!" and it will focus on the challenges of finding and retaining younger workers that will become the next generation of PCB manufacturing gurus. If you haven't already, subscribe now to get it delivered to your inbox the moment it's published so you can dig right in. **PCB**



Patricia Goldman is a 30+ year veteran of the PCB industry, with experience in a variety of areas, including R&D of imaging technologies, wet process engineering, and sales and marketing of PWB chemistry. Active with IPC since 1981, Goldman has chaired numerous committees and served as TAEC chairman, and is also the co-author of numerous technical papers. To contact Goldman, click here.



Material Choices for High-Speed Flexible Circuits

by G. Sidney Cox
COX CONSULTING

Abstract

High-speed rigid boards have existed for many years, with fluoropolymers being the most common dielectric used. More recently, flexible circuit materials have been developed, and these new products use a variety of polymer (including fluoropolymers) and composite film approaches to allow high-speed flex circuits. This article will provide guidelines on how to compare the different options. The electrical benefits of the different polymers and constructions will be reviewed as well as the physical and flexible properties of different constructions. As with any new materials, the ease of processing is an important consideration, especially since some of these new products use thermoplastic adhesives or require high-temperature lamination of bondplies and coverlays.

Introduction

High-speed rigid boards have existed for many years and continue to improve. Initially, most high-speed rigid boards used fluoropolymer dielectrics (fluorine-containing polymers like Teflon®). Now many new dielectrics have been developed for high-speed rigid boards, which has broadened both the material supplier base and the number of fabricators that can make high-speed rigid boards.

Materials for high-speed flexible circuits are a much more recent development. This article will review the key material choices for making high-speed flexible circuits while also explaining why older flex materials were not a good choice for today's high-speed circuits.

When talking about high-speed circuits, we are really talking about controlled impedance applications. This could be either microstrip or stripline designs. This paper will discuss flexible clads, as well as bondplies and coverlays. For controlled impedance circuits, the electrical properties of the clad and bondplies are critical for striplines. The electrical properties of the clad and coverlay are critical for microstrips.

Electrical Properties

Older flexible circuit materials are not good for many high-speed applications because of the high dielectric loss (loss tangent). The dielectric constants for these older materials were very reasonable for high-speed (most were

3.0–3.5). The old assumption was that the issue was the polyimide. It was known that the earliest polyimides did have high moisture absorption. However, as Table 1 shows, the dielectric losses of the standard flexible circuit adhesives (acrylics and epoxies) are much higher than the polyimide film. In fact, some more recent polyimide formulations have very low dielectric loss, which means that some all-polyimide dielectric clads are quite good for high-speed circuits. But not all polyimides are the same; some are higher loss than others, and there is a correlation between dielectric loss and moisture absorption for most polymers but clearly this is true for polyimides. A good initial rule is that dielectrics that have high moisture absorption will have high loss[1, 2, 3].

Table 1 also shows some other dielectric choices that have been used recently to create high-speed flex materials. Fluoropolymers, the mainstay of high-speed rigid boards, have now been incorporated into flex materials by several material suppliers. Fluoropolymers have the lowest dielectric constant of any polymer class and have very low dielectric loss.

The issue is that pure fluoropolymer films do not have good enough mechanical properties to be used alone. Some suppliers have tried using special woven glass with fluoropolymers for flex applications. Some have added fillers to improve properties as is common in rigid high-speed materials. And one supplier is using a polyimide core with fluoropolymer as the outer layers and as the adhesive. All these modifications help with both the flexible/mechanical properties and in some cases with processing ease. However, these modifications increase the dielectric constant and dielectric loss, so the pure polymer properties cannot be achieved in actual products. These new materials are in many cases very good materials for high-speed flex[4,5].

Polymer	Dielectric Constant	Lost Tangent
Fluropolymer	2	<0.001
Liquid Crystal Polymer	2.9–3.0	0.001–0.002
Polyimide	3.1–3.6	0.003–0.012
Acrylic Adhesive	2.9–3.5	0.02–0.03
Epoxy Adhesive	3.1–3.7	0.02–0.04

Table 1: Comparison of dielectric properties of flex polymers (data measured at 1 GHz).

Liquid crystal polymers (LCPs) also have good dielectric properties including very low loss and very low moisture absorption. LC polymers are used in both clad and the bondply. The fluoropolymer constructions are also used in both clads and bondplies[6].

The primary clads that are being used for high-speed flex circuits are based on fluoropolymers, liquid crystal polymers, and low loss all-polyimide constructions. Bondplies and in some cases coverlays are available in both the LCP and fluoropolymer constructions. However only recently have low loss coverlays and bondplies been made with all polyimide constructions. In fact, low loss coverlays have been the most difficult to develop and are only very recently available.

The expansion of materials for high-speed rigid boards has been led by new low-loss thermoset adhesives. Variations of these low-loss adhesives are now becoming available in flexible circuit materials and this should provide more options for bondplies and coverlays. While traditional adhesives used in flex are high-loss, this does not mean that all thermoset adhesives are high-loss.

The dielectric constants of almost all the polymers in Table 1 are fairly low and in a fairly narrow range as they exist in actual flex materials. And although there are some advantages of lower dielectric constant, the dielectric loss is the most important dielectric property when choosing materials for high-speed flex. The spread in dielectric loss is much wider that dielectric constant for the full range of flex circuit materials.

When discussing dielectric loss and high-speed controlled impedance circuits, two factors must be considered: the speed of the circuit design (1 Ghz or 20 Ghz) and the length. All all-polyimide clad has been used for 20 Ghz circuits at 1″ long signal lines. This would not be possible at 10″ in most cases. So, the best material for each application depends on both the speed and the length.

With any of these new materials, there will always be a tradeoff of the three areas we discuss in this paper: electrical properties, flexible/mechanical properties, and ease of processing. All material suppliers are trading off these three areas to reach the right compromise in their final products. Both fabricators and end users must understand the tradeoffs and make material choices with a clear understanding of the compromises made. Bottom line is do not pick materials just based on electrical properties; flex properties and ease of processing are still very critical in functional high-speed flexible circuits[7].

Mechanical and Flex Properties

Most traditional flex materials have been optimized for flexibility and ease of processing at the expense, in many cases, of dielectric properties. Of course, at the time of the development of these early materials, "high-speed" was well below 1 GHz. Finding polymers with low loss is just the first step in developing new flexible circuit materials.

Fluoropolymer films by themselves do not provide strong enough mechanical properties to be used directly in flexible clads. The strategies use by material suppliers to support fluoropolymers are to use special flexible woven glass, particle fillers, or a polyimide core. All help with improvement of mechanical properties. The woven glass and particle filler approaches will limit the flexibility of the clads or bondplies, and therefore will not be the best choice for applications that require multiple flexing at sharp angles and/or small bend ratios. They should be fine for some flex applications.

> "Fluoropolymer films by themselves do not provide strong enough mechanical properties to be used directly in flexible clads."

Liquid crystal polymers work well as free standing dielectric films for high-speed flex clads. The mechanical properties are good enough for most applications. They may not have the high flex capability of all polyimide constructions but should be good enough for most applications.

All polyimide dielectric clads provide the best mechanical and flex properties of all the choices and if the flex requirements are very high then they are the first choice. However, even the lowest loss polyimide clads are still slightly higher loss than most fluoropolymer or LCP constructions.

We will discuss more about mechanical properties of these clads in the section on ease of processing.

The choices become more complicated when discussing bondplies and coverlays. Many high-speed clads can only be used with specific bondplies. The fluoropolymer/polyimide composites are mainly used with bondplies made of similar fluoropolymer/polyimide composites. The LCP polymer-based clads are also primarily used with LCP-based bondplies. Both approaches use thermoplastic polymers films that require high-temperature lamination. Many fabricators now have high-temperature presses that can reach the temperatures required for these new materials (270°–310°C). However, as we will discuss further in the next section, the learning curve for processing these materials is steep.

The low-loss bondplies and coverlays that are compatible with the all-polyimide clads have only recently been available. One option is a fluoropolymer core coated with a low-loss thermoset adhesive. It has been tested with both all-polyimide clads and with some of the fluoropolymer clads. One advantage is that the thermoset adhesives are laminated at more standard lamination temperatures.

The other option which is quite new is an all-polyimide bondply and coverlay. It was developed initially for high-temperature applications when combined with all-polyimide clads. However, this new bonding film is low loss (0.003) and in the same range as the best all-polyimide clads. This new bondply does require high-temperature lamination but for now is the only method to make all-polyimide flexible cir-

Panasonic

Ultra-low Transmission Loss Multi-layer Circuit Board
Materials for ICT Infrastructure Equipment

MEGTRON7

Laminate **R-5785(N)**
Prepreg **R-5680(N)**

H-VLP2 Cu and Low Dk
Glass-Cloth Specifications

Features

- H-VLP2 copper foil and Low Dk glass-cloth allows for 30% loss improvement than MEGTRON 6
- Glass transition temperature (Tg): 200°C (DSC)
- Reduce process cost (Improve drill processability and ENIG (Electro-Nickel Immersion Gold))

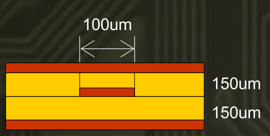
	Dk	Df
R-5785(N) + H-VLP2 Cu	3.4	0.002 @ 12GHz
R-5775	3.6	0.004 @ 12GHz

Applications

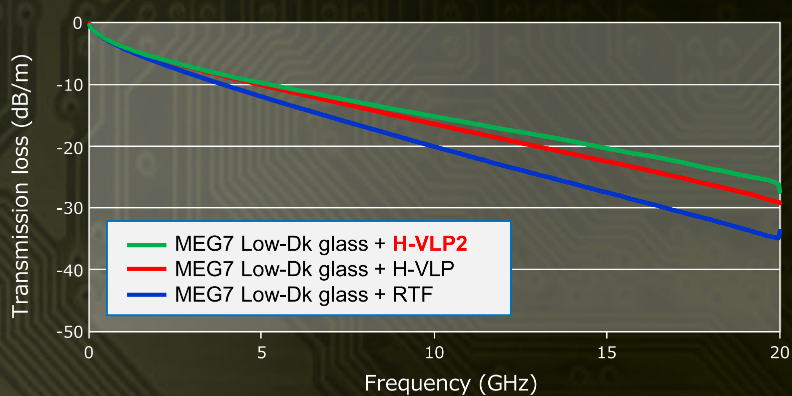
- High-end servers, High-end routers, Supercomputers, and other ICT infrastructure equipment, Antenna (Base station, Automotive millimeter-wave radar), etc.

Trasmission Loss

- Evaluation Sample



Line Length	1000 mm
Impedance	50 Ω
Copper Thickness	18 μm
Inner Cu Treatment	No-surface Treatment
Core Type	#1078 (RC67%) x 2ply
Prepreg Type	#1078 x 2ply



Contact us

More information

cuits. This product is new so the fabricator base is still small, but it is growing. The all-polyimide construction is by far the best options for high-speed circuits that also require high-temperature capability[8].

All the choices of bondplies mentioned above can be used as coverlays except for the fluoropolymer/polyimide composites.

All the choices of bondplies mentioned above can be used as coverlays except for the fluoropolymer/polyimide composites. As stated before, a low-loss coverlay is only important in microstrip applications. Many of the high-speed flexible circuits made so far with these new materials are striplines, where only a low-loss bondply is required.

Processing

Processing of many of the new materials has been the biggest delay in wide acceptance. This is to be expected when introducing new materials.

Several of these new materials require high-temperature lamination. This includes the fluoropolymer/polyimide composite, the LCP materials, and the all-polyimide bondply. Many fabricators now have presses that will reach the required temperatures of 270°–310°C (520°–590°F). However, these higher temperatures require new press pads and good temperature control. Fortunately, many new options for high-temperature press pads are becoming available. The limited press pad options did slow the acceptance of these materials but that should not be an issue from now on.

Some of the fluoropolymer options and all the LCP options use thermoplastic films in both the clads and bondplies. To work well, the lamination temperature of the clad must be higher than the lamination temperature of the bondply. Lamination of the bondply at a temperature too near the lamination temperature of the clad can cause circuits on the imaged clads to move during lamination (sometimes called swimming). This can be prevented by tight control of lamination temperature, but is best prevented by designing the materials with a wide spread in the lamination temperatures. The fluoropolymer/polyimide composites were developed with a 35°C differential in clad and bondply lamination temperatures. This is wide enough for most fabricators. The early LCP clad and bondply combinations had lamination temperatures that were too near each other which made processing exceptionally complicated because of the very tight temperature control required. Many of the newer LCP options have been developed with a wider difference between lamination temperatures. When comparing any new thermoplastic materials, this delta should always be a key question.

Dimensional stability is another important consideration when looking at processing ease. First, movement of the clad after etching can be higher with some of these new materials. The all-polyimide constructions are typical of most flex used today. Some of the other dielectrics may have more movement and may require different artwork compensation strategies. However, most of the material suppliers have managed this property well in their final products.

The bigger issue is movement of the circuits during lamination of bondplies or coverlays. This is particularly an issue with thermoplastic dielectrics and/or if high-temperature lamination is required. Even all-polyimide clads will expand more during lamination at 300°C versus the expansion at normal lamination temperatures of 190°C. This movement can be contained with proper lamination process control and experience in the amount of movement expected.

Drilling and plating must also be optimized for these new materials, particularly the fluoropolymer and LCP containing products. Both materials can be drilled and plated, but will require careful optimization of the drilling process as well as the desmear and hole preparation process. Most materials suppliers can provide processing recommendations for lamination and drilling/desmear.

	All Polyimide	Fluoropolymer/polyimide composite	Fluoropolymer core/Thermoset Adhesive	Liquid Crystal Polymer
Dielectric Loss 1 GHz (Loss Tangent)	0.003 or higher	0.0015–0.002	0.002	0.0015–0.002
Bondply Lamination Temperature C	290–300°C	280–290°C	200°C	280-290°C
Dimensional stability	Good	Fair	Fair	Fair
Drilling, Hole Preparation, and Plating	Good	Needs Optimization	Needs Optimization	Needs Optimization

Table 2: Property comparison of high-speed flex material types.

In general, as with any tradeoff in design, the products with the lowest loss and in some cases the lowest dielectric constant are the more difficult to process. From a fabricator's view, if you can become one of the first to master the processing of these new materials, you will get first choice of end users. From an end-user (OEM) view, always ask materials suppliers which fabricators they would recommend. Most materials suppliers work hard with a select group of fabricators to make sure that have some proven facilities to recommend to early end users. Table 2 shows a comparison of these properties.

Suppliers

The primary suppliers of high-speed flex materials are mainly either existing flex suppliers, or high-speed rigid board material suppliers. The primary high-speed material developers in North America are DuPont, Rogers, and Taconic. Some low-loss polyimide and LCP suppliers are based outside the U.S., such as Panasonic and Ventec International Group. Recently some of these materials are becoming available in North America and Europe through distributors.

Another option to consider is mixing products from different material suppliers. Flex circuits have been tested at material suppliers and made at fabricators mixing a clad from one company and a bondply or coverlay from another company. Again, make sure the compatibility has been tested, and the processing optimized before ordering new flex circuits.

Copper roughness does affect signal loss at high speeds. We did not discuss this in this paper because the rolled-annealed (RA) copper foils that are the standard for flexible circuits are smoother than the traditional electrodeposited (ED) coppers used in rigid boards. Many of the high-speed rigid materials are now made with low roughness copper foils. The smoother RA copper has been a high-speed advantage for flex clads before the high-speed dielectrics were available.

The North American suppliers of these new high-speed flex materials have been very good about making sure that the Flex Material Specifications (IPC-4204 and 4203) and the Flex Processing Specification (IPC-6013) have been updated for these new materials. In some cases, this required updating materials specifications sheets for 4204 and 4203. In other cases, this meant submitting new specification sheets. The Flex Performance Spec (6013) has already been updated in several sections for both thermoplastic dielectrics and fluoropolymer dielectrics. In most cases this just involved updating IPC-6013 with wording from IPC- 6018, the performance specification for high-speed rigid boards.

Summary

Materials to make high-speed flexible circuits are now available from many material suppliers. In deciding which materials to test or use, remember the tradeoffs the suppliers made in categories we discussed: electrical properties, mechanical/flex properties, and ease of process-

ing. A choice should only be made after considering these options. Remember with any new materials it is very important to find fabricators that are knowledgeable about processing these new materials. **PCB**

References

1. Glenn Oliver and Sidney Cox, "Design, Fabrication and Electrical Analysis of High-Speed Flex," IPC International Conference on Flexible Circuits, June 2012.

2. Glenn Oliver, Thomas McCarthy, Steve Kelly, "Lower Loss and Process Friendly Multi-Layer Flexible Interconnect," DesignCon 2016.

3. Glenn Oliver, Jim Nadolny, Deepukumar Nair, "Lower Loss and Process Friendly Multi-Layer Flexible Interconnect," DesignCon 2012.

4. Sidney Cox and Glenn Oliver, "New Materials in Flex Circuit Applications," IPC International Conference on Flexible Circuits, June 2011.

5. Sidney Cox, "New Low DK, Low DF Flex Laminate for High-Speed Controlled Impedance Applications," IPC International Conference on Flexible Circuits, June 2010.

6. Rogers Corp. article: "High Frequency Circuits" by John Coonrod

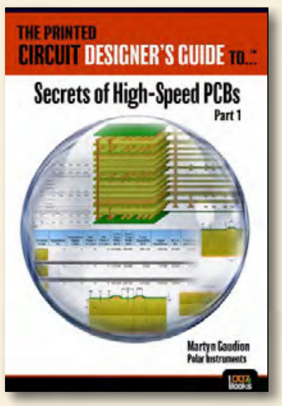
7. Dupont article: "Using Flex in High-Speed Applications" by Glenn Oliver.

8. Sidney Cox, "Flexible Circuit Materials for High Temperature Applications," IPC APEX EXPO, February 2015.

G. Sidney Cox is the principle at Cox Consulting.

I-Connect007 Launches *The Printed Circuit Designer's Guide to... Secrets of High-Speed PCBs – Part 1* Micro eBook

I-Connect007 is excited to announce the release of *The Printed Circuit Designer's Guide to... Secrets of High-Speed PCBs – Part 1*, by Polar Instruments.



The Printed Circuit Designer's Guide to...is an ongoing series of micro eBooks specifically dedicated to the education of PCB designers. This book series stands to become the gold standard for people seeking the most relevant design information available.

Authored by Polar Instruments Martyn Gaudion, it is written to assist EEs, PCB designers, procurement professionals, and PCB fabrication professionals and managers at all levels, and offers the greatest benefit to design and procurement people by illustrating what can realistically be achieved in the final product. With this knowledge, engineers can design producible boards, and buyers can purchase PC boards using realistic specifications.

"The concepts presented are applicable to most PC boards in today's products, but are particularly suited to very high-speed systems and PC boards," said Rick Hartley of RHartley Enterprises. "Throughout the eBook, an emphasis is placed on cost-effective design and fabrication."

Eric Bogatin, Ph.D., Dean of the Signal Integrity Academy, said, "*The Printed Circuit Designer's Guide to... Secrets of High-Speed PCBs – Part 1* rolls back the covers to illustrate the practical principles behind many of the confusing topics that arise in the overlap between manufacturing, materials, and signal integrity performance."

The Printed Designer's Guide to... Secrets of High-Speed PCBs – Part 1 is an excellent guide to understanding PC board impedance control and material losses, with solid emphasis on what can be designed versus what can be fabricated, and how to bridge the two disciplines.

To download this book for free, click here. Find all the titles in our eBook series by visiting our library at www.I-007eBooks.com.

Fabricators Speak Out on High-Speed Materials

Recently, I-Connect007 Publisher Barry Matties and his editorial team joined with two PCB fabricators to discuss the state of advanced materials. The meeting included Gerry Partida, director of engineering at Summit Interconnect and Joe Menning, program manager at All Flex Flexible Circuits. The discussion centered on the processes, challenges, and procurement of high-speed materials, as well as need to work with customers during the design stage.

***Patty Goldman:** We are here to talk about high-performance and high-speed materials. We've spoken with a few laminate suppliers, but we also wanted to get the viewpoint of the guys making the boards. We asked you to join us so we can find out how fabricators are dealing with these materials, what you need from suppliers, what you think our readers should know about advanced materials.*

***Barry Matties:** When we start talking about high-speed materials, what are the greatest challenges you face with high-speed materials, from procurement to processing and delivery? Maybe even from OEMs specifying materials or not? Gerry, why don't we start with you.*

Gerry Partida: Thank you for allowing us to share this. This is very important stuff. A lot of the RF materials are very hard to register when you laminate or process the materials. There are many RF materials that are not glass-reinforced or very loosely glass-reinforced. When we planarize the material for epoxy fill, or blind via lamination structures and we epoxy fill, the material stretches out. We call some of it bubble gum because you can just distort the material as you planarize an epoxy-filled via. Also, the material just moves a lot, in some cases three times greater than standard glass-reinforced epoxy materials.

That's one of the biggest challenges—maintaining registration and controlling it, knowing where it's going to end up. The material is very expensive. I like to use the analogy with people that building FR-4 boards, regular, digital or something that's straightforward versus

an RF board is like playing craps. The difference between FR-4 boards and RF boards is that the FR-4 boards are like playing craps Saturday night in Laughlin, Nevada, which is a $5 minimum bet, where RF is like playing the Bellagio at 9 o'clock on Saturday night where the minimum bet is $25. Same rules, same game, but the buy-in is huge because of the registration and the other fun stuff that goes with it. You can lose fast or you can win a lot.


Gerry Partida

That's one of the greatest challenges—the material itself, its softness, its registration, as well as processing. One of the things is holding registration and the material. The other parts that are a challenge for the materials are the ability to deposit electroless and maintaining peel strength. A lot of them have low peel strength. Many RF materials can have smear. We call it flat, but it's smear when you drill and you cover the inner face of an innerlayer pad; it violates the IPC-6012 rigid PCB performance spec. It's allowed somewhat in IPC-6018, the performance spec for high-frequency/microwave PCBs—but smear is always a concern on a lot of high-speed materials.

Some of the other challenges with materials are Teflon or PTFE surfaces, where you have to do special treatment to get the soldermask or legend to stick to it.

Matties: When you talk about the registration, how do you mitigate the problem?

Partida: What we do is we use software that collects data on every panel we build, every resin system, and every lamination cycle. This information is a feedback system to predict future builds to be on target the first time, to reduce the risk of losing material. Sometimes, if we look at a structure we've never seen before, we'll do a pilot run to dial in the scale factors, or we work with a customer saying, "You know, you want a Class 3 board but this is an engineering board. Can we have Class 2 as we learn the scale factors for this construction and this stack-up?" Sometimes they'll work with us on that.

The RF community really works very well with the printed circuit board manufacturers. We have to work together in order to be successful, so we use those tools. The other challenge, too, with a lot of the high-speed RF materials or parts is that there are unbalanced constructions. For example, one of the first boards we built was a 1 to 2, 1 to 5, 1 to 7, 1 to 9, 1 to 11, 12 to 14 and then final 1 to 14 lamination structure. With our predictor, we got on target the first time.

Matties: Wow. Is this over-the-counter software or is this proprietary software that you've developed?

Partida: It's a software that I believe won an award at the APEX show, three or four years ago, for the best product of the show. The company's name is XACT PCB. When you're working with high-speed RF with high frequencies, there are so many different combinations of materials that the engineers use that you're always challenged, whether you have it in your database or you're learning for the first time, in which case the predictor tells you, "I've never seen this before. Good luck."

Matties: What about from the flex side, any challenges for you, Joe?

Joe Menning: On the flex side of things I would echo a lot of the same concerns. Even though we don't do a whole lot in the high-speed materials area, I'd echo the concerns on the processing. Obviously in the flex world we're used to materials moving and changing shape, but I would reinforce the fact that a lot of the high-speed materials that we've had experience with are even more challenging than typical flex materials. Regarding the comment about PTFE, it's a great high-speed material but it doesn't bond well to anything, really, unless you have some sort of pre-treatment, so it's got a lot of challenges on that front.

Matties: In the flex world, you've been dealing with material movement for a long time. How do you deal with the registration issue?

Menning: For us, it's about really understanding your base materials and how they move. Unlike Gerry, we don't have the software to monitor it in real time, but we try to limit the number of base material configurations we have and, when necessary, we'll do engineering evaluation runs to develop scale factors so that we can predictably scale the artworks to compensate for that shrinkage.

Matties: A lot of the new process equipment can make modifications on a per-board basis. They're finding best center for alignment and x-rays and that sort of thing for drilling the optimum hole. Is that technology what you guys are seeing and utilizing?

Partida: We're using that with the XACT software, so what it does is not only tell you how far off the layers the registration is, it tells you what to do for the next time you build that same panel or tool. It will put in brand new tooling to square up the panel so that all of them will pin to the drill machine consistently the same. So if there is any variation, it kind of zeroes in on the variation of each panel and squares it up.

Matties: Per panel. I understand you're pushing lots through, but when you're processing a panel, making modifications to individual panels, that really brings it down to that lot size of one mentality though, doesn't it?

Partida: What it does is it gives them all the same zero tooling on all the panels. If one is, let's say, slightly rotated half a degree to the right and the other one is half a degree to the left, one is shifted down one mil, one is shifted up one mil, when the new tooling goes in they've all been squared to each other back to one zero. It improves registration tremendously when you go and drill on the machines. Rather than having random pinning now you have brand new pristine tooling, pristine, never-used, and they're all squared up with each other and it is a big boost in final registration and cross-sections for meeting annular ring.

Matties: Regarding tooling, there are the pin systems and the pinless systems. Have you explored both of those and do you have any opinion on those, for the registration issue?

Partida: I have an opinion on the pinless one. What they do is they weld the outside of the panel core to core through the pre-preg through heat, but I don't subscribe to the theory. Cores will shrink. The different glass styles or the glass weave in a core is what's going to allow that core to shrink and the pre-preg is the activator that moves it. If you have a 14-core 2-ounce over 2-ounce and a 3-core signal, they will want to move differently.

You can't weld the outside and tell them to stop and not do it. I don't believe that works. With the information we have with our registration software, we track our yields and we know how many panels we scrap, when I tell the folks with the pinless system, where they align the cores, the number of panels we scrap per year, they're shocked at how low it is. It's not a problem. We scrap less than 12 panels a month for missed registration.

I don't see the need to change the system that's been working tremendously for us with jobs that have no reinforcement and multiple lamination cycles. As long as we have a prediction of what it will move, it generally will keep us in a safe location when we're done laminating. It took about two and a half years to put the whole system together, the complete feedback system, but it's a wonderful system.

Matties: That's great. It sounds like you guys have really put a lot of thought into this. It's never easy, you know. It's 90% planning and then once you implement it you just reap the benefits for years to come.

Partida: I think that's what has helped us to be successful with the RF community. It's very critical that these features are where they're supposed to be for the best performance. In RF, you could look at it cross-eyed and it will act different or act funny. We've been working with RF materials, but it was mostly for semiconductor customers. When we started with the RF community about 9 or 10 years ago, customers would call us back and ask, "What are you doing?" and we'd say, "What do you mean?" "All the parts look exactly the same." I'd say, "Aren't they supposed to?" They'd say, "Yeah," and then they'd giggle.

It's process control. If a board shop doesn't have process control and they run panels through the etcher at different times for the same lot, if they run one core through the oxide multiple times but not the other cores in the same lot, if they laminate at different times for the same lot, if they run through the electroless and do some re-work, if we do all this variation to process, at the end there is not one panel that was processed like the other panel in that lot. That's the variation the RF guys just pull their hair out on.

You've got to have process control from beginning to end. You want to have the finished product behave the same from board to board, panel to panel, lot to lot.

***Matties:** Yeah, that's the ideal, is having them identical. But it's a rarity for sure.*

Partida: I don't want to forget; there are a lot of exciting laminate materials coming out that are processed like FR-4. Megtron 7, Megtron 6 is pretty good for a lot of RF. Megtron 7 will be great. Isola has I-Tera, Astra, Tachyon, that we're seeing customers using in the RF world. We don't have the processing issues of PTFE materials where we have to use particular plasma cycles. It's low peel-strength and you can't etch it back. These new materials have almost the same performance as the PTFE but they're glass-woven and so they're more stable.

> These new materials have almost the same performance as the PTFE but they're glass-woven and so they're more stable.

We can control the registration. We don't have to go through difficult plasma cycles to deposit electroless copper in the holes. We can planarize the boards without distorting the panel. There are more selection and dielectric sizes in these new materials that are coming out, which are giving the RF community options it did not have before because they had to use a certain bond ply in a certain location or a certain core in its location. Now they can use very different core thicknesses and use pre-preg and core interchangeably in a stack-up as needed.

***Matties:** So, this offers a lot of flexibility?*

Partida: It really, literally opens up. There were things that required using a core and the registration had to be perfect and they moved a lot, and there was just no way you could make it happen. Now you can just use a pre-preg and a foil and there's no chance of misregistering and you just register to the innerlayers through your precision registration software and you can dial in your drill into that one critical core and you can now do things you couldn't do before. This new material is pretty exciting. It's been out for about two or three years, which is new to the electronics industry but they seem very promising. For some of the RF PCBs that have been built, I've heard excellent feedback from our customers, who say, "We built the first board and it worked, we matched the other boards to the same configuration and they all fired up exactly the same ..." Then when you respond with, "Doesn't this always happen?" And they say, "No, it doesn't always happen."

***Matties:** You know it doesn't always happen when you ask that question; it's just fun to ask.*

Partida: And you want the feedback on the new materials too, right?

***Matties:** Yes. We've talked to some of the material suppliers and one of their big issues is the length of time that it takes to get new material approved. They're saying it could be a multi-year process to get a new material approved into the workflow. How does that impact your material selections? We know that some of the material is being used before it's approved by Cisco or some of the recognized vendors.*

esi

A portfolio of flex via drilling solutions that presents you with possibilities... not limitations.

GemStone™ 5335xi™ Flex5335™ RedStone™ LodeStone™

As a leader in PCB, ESI's flex PCB laser processing systems are used by the top ten FPC processors and are based on decades of laser-material interaction expertise applied to challenges in production. Our flex systems portfolio is designed to address a wide range of applications, enabling you to easily match the right system to your unique set of challenges and processing requirements.

Whether you're just getting started with FPC processing or are optimizing around specific applications, rely on ESI to provide the right laser technology and manufacturing expertise, paired with premier service and support, to drive quality results, higher profits, and shorter time to market.

Learn more at esi.com

Partida: For the military industry, they're not going to use anything that hasn't been approved and it's official. There is a required amount of time they have to continue to produce it, so the laminate suppliers want to make sure that it's done. When you're dealing with the end customer, especially military, it has to be an established product. We're fortunate enough that for many years we tested the material with different laminate suppliers before it even had a part number. So they paid us to laminate the boards and we're getting paid to learn how to use the material, and then we get all the feedback on how well it performs. We've been fortunate as a company to benefit from this relationship for about six or eight years.


Joe Menning

Menning: On the flex side, most of our materials are coming from people like DuPont or Panasonic and we kind of operate the same way. If we've got a customer need that doesn't fit into the current available material set, we'll work closely with those suppliers on new materials and do evaluation runs for customers to help them get comfortable with these materials that are new to the world. From our end, a lot of the requests are surrounding not so much high-speed but high-temperature. Traditional acrylic adhesives typically would work up to 150°C, and if we get customers like downhole drilling applications, where it›s really high-temperature applications, it pushes into new material sets where traditional acrylic adhesives would not survive. Those high-temp materials also are of value to us in our flex heater business and we also can combine flex heaters with flexible printed circuits for applications where they want a localized heat source and they also want to have high-temperature durability in the remainder of the flex circuit.

Matties: With the amount of new materials coming into the marketplace, how difficult is it to get a customer to try something? So many of them have specified their brands and stick with them. Are you finding they're motivated to change?

Partida: I think a lot of times when they're stuck in a design where the existing materials are not working for them, whether it's registration, dimensional, or they can get the right dielectric thickness, then they're open to it. Again, as I said earlier, the RF community is the most open-minded to suggestions and working with fabricators that I've ever seen in the electronics industry, and I've been in it for 30 years. It's fun to walk into a room with literally 10 PhDs and they ask you good questions. They're very enthusiastic about working together and trying different methods to solve a problem. They're open to new materials, but when they have a product that's been used in a particular construction or material selection and they're just making small modifications to it, they will not deviate from it because they know it works.

Matties: They know it works and they're not going to be driven by a few dollars on pricing when they know it works.

Partida: Right, I would say that's a very accurate way of stating that, yes.

Goldman: You both talked about pre-treating something like a PTFE, and I was wondering, what you do to stabilize that or how do you have to pre-treat those very smooth surface materials?

Partida: In most cases, plasma will work with the hydrogen cycle at the end and then a purge. This will make the surface sticky so the electroless will attach to it. Sodium etch will have the same effect. Even soldermask and legend, it's so slippery a surface you can put soldermask down and tape test it and it will peel every bit of it off during a tape test. You have to activate the surface and (we like to use real technical terms in fabrication) to make the surface sticky and then the soldermask will adhere to it.

Menning: Yes, we do the same on the flex side. The plasma treatments are typically what we would use for activating the surface. The trick, of course, is that those treatments tend to be transitory or time-based. So it basically changes the chemical surface or creates available bond sites on the surface of the material, but if you don't do your coating or laminations or solder mask very shortly after that process, it will deactivate in open atmosphere. So you've got a short time window to take advantage of that treatment.

Matties:* *I was talking with Alex Stepinski over at Whelen Engineering. He said by not letting your work queue up, it actually saves so much process time and, exactly what you're saying, it just makes good sense to not let your boards queue up and sit around. You're making that case too.

Andy Shaughnessy:* *Gerry, we've talked to these laminate suppliers over the years and they've said recently that they're working on the next sort of midway high-speed material, something that has the pros of PTFE without any of the cons as far as manufacturability. Are you all seeing any more of these sorts of high-speed laminates that have the processability of FR-4?

Partida: Yes. Megtron 7, Megtron 6, Isola's Astra, I-Tera and Tachyon. They're being used and they're performing very well. It also has 4000-20 I think, or 4350-20, that seems to be not as popular as the other ones but it is getting some traction.

Shaughnessy:* *That's good to hear. They were really pushing for this. In the last couple of years, they said they had many people that just automatically would ask for PTFE and would over-constrain and would end up making the boards twice or three times more expensive.

Partida: Yeah, that's when you lose big in Bellagio.

Matties:* *Go outside and watch the water show. Is there anything else that we should be talking about that we haven't covered yet regarding high-speed materials?

Partida: I think one of the things you'll see more in the high-speed materials is a lot more critical GD&T (geometric dimensioning and tolerancing). They'll have very critical etch launches that they line up to tooling for other features. For the internal cut-out for an etch launch they have a very smaller tolerance than you normally see in a printed circuit board so those sometimes can be a challenge. You have to use precision rout machines so you would line up to the etch features before you do an etched, routed feature or a cut-out on a board based on where the etching pattern is at so that you're within a 2-mil window in some cases. That's getting pretty tight.

Menning: On the flex side, it's not necessarily for high-speed, but a lot of times we'll end up doing extended length circuits north of 100 inches that are flex and obviously registering a traditional coverlay layer that's routed to that image pattern is pretty difficult. One of the tools that we're using more and more often now is we'll lay coverlay over the whole pattern and we'll use a local registration feature near the critical areas of the flex and we'll laser ablate the coverlay off and then use a plasma to plane off the carbon. That way we've basically taken away the need for a scale factor and the coverlay will to match the etched feature, much like Gerry was talking about.

Matties:* *A lot of moving parts in all of this, that's for sure.

Partida: That's the challenge, isn't it?

Matties:* *You know, there are just so many variables that it's hard to think that people can produce quality boards time after time after time.

Goldman:* *I would guess it's also a moving target because you don't get to sit back and say, "Well, we're set for the next year with this particular style of something or other or this material." Everything's moving forward all the time.

Partida: Right. The usage of RF and the demand for it, especially the military and even commercial, it's just going to keep growing in a very big way.

Matties: *Oh, we're seeing it everywhere. I'm sure you're starting to see it in your factories too and with the equipment talking to each other and so on. This is really a fast-moving time. I certainly appreciate you gentlemen taking the time today to share your thoughts and insights with us.*

Goldman: *This ought to help our readers a great deal.*

Matties: *Our whole point is how do we help the industry improve overall and you guys are helping with that and it's good for all of us to have a strong industry, so thank you.*

Partida: Yes. Thank you.

Menning: You're welcome. **PCB**

Ray Pritchard Looks Back at IPC's Beginning and His Role in Getting it Started

I have known Ray Pritchard for a long time—as long as I've been involved with IPC, in fact. He directed the organization for 35 years before turning over the reins. One could say he grew up with the organization—or vice versa. Ray was always a bundle of energy and still is, still joking and warm; he is a great people person, and I am sure he had a little something to do with the spirit of camaraderie and cooperation that is the hallmark of the IPC organization we know today.

That's why it was such a pleasure to sit down with Ray Pritchard in a quiet corner during this 60th anniversary year and listen to him talk about his early involvement in getting a fledgling organization, with just a handful of members, off the ground and running.

Patty Goldman: *Ray, it is so wonderful to see you. The founding members brought you in to run the organization back in the beginning, am I correct?*

Pritchard: That was an interesting story. These young entrepreneurs, they were a new industry. Nobody knew them. Nobody had heard of printed circuits at the time, because everything was plugged in with wires.

They were meeting in Chicago at the Palmer House in 1957, and they said, "You know, we'd like to have a trade association. We've got all these problems. We don't know what to do about them." Somebody said, "Why don't we look in the yellow pages and find a professional high-class organization that could help us?"

Our company was right next door. It was called H.P. Dolan and Associates. It sounded professional, like there were all kinds of people, but I was the "associates." Harry Dolan at that time was out of the office, so Gene Jones and Bill McGinley walked in, and I'm sure when they saw this young-looking kid—though I was 30 years old—they thought, "What are we doing here?"

I'd made a flip chart showing things we had done for the six associations we were working for, and they were all manufacturing associations, so they all had needs for standards and technical work and improving the technology and all that. Then they needed market data, and they needed all kinds of things, but we'd done them all. So they saw my chart flipping, and they said, "Come on over to the Palmer House, and we'll talk to you about what you might be able to do."

Click here to read the full interview.

Six reasons why outsourcing CAM Engineering can be a great idea for you:

- On-Demand Capacity
- Improved Automation
- Fast Turnaround
- Reduced Costs
- Improve Quality
- Build Redundancy

...and here is the delivered value:

	In-House	With Entelechy
Availability	48 weeks	52 weeks, 24/7
Overhead Cost	>30%	0%
Scalability	Limited	Unlimited
Redundancy	Variable	100% Bulletproof
Operational Efficiency	Status Quo	Continual Improvement
Total Cost	Fixed	Significantly lower

"In our company, the CAM department was the bottleneck. As a result of our working with Entelechy, we can now accept orders that we had to refuse in the past."

-Thomas Hofmann, CEO/Owner

HOFMANN LEITERPLATTEN

Click here to check out our risk-free Quick Start program»

We deliver the highest quality PCB CAM and Mechanical CAD engineering services to customers around the world. We can help you beat your competition by teaming up with us.

www.entelechyglobal.com

Supply Lines
Highlights

The Near and Far Future for Orbotech and Inspection

Orbotech's PCB Division President Arik Gordon and I spoke in detail about the company's newest developments in automated optical shaping (AOS), Orbotech's unique culture and commitment to R&D, and what he expects to see in the near future for the inspection industry.

Nano Dimension Supplies 3D Printer to Israeli PCB Design Bureau

Nano Dimension Ltd. announced today that its wholly owned subsidiary, Nano Dimension Technologies Ltd., has supplied its flagship DragonFly 2020 3D Printer to a PCB design bureau located in Israel.

Rogers' John Ranieri Discusses 92ML Conductive Epoxy Materials for Power Electronics

John Ranieri, business development manager for Rogers Corporation, sat down for an interview with me at IPC APEX EXPO in San Diego. He discussed Rogers' 92ML™ series of thermally conductive epoxy materials, and some of the challenges facing technologists in the power electronics market.

RTW IPC APEX EXPO: Arlon's Partnership with Doosan Brings Benefits All Around

The recent distribution agreement between Arlon EMD and Doosan Electro-Materials enables the supply and technical support of Doosan's flexible laminates and high-Tg, FR-4, and halogen-free materials into North America to complement Arlon's established range of polyimide and specialty materials for the military, avionics and space market segments.

RTW IPC APEX EXPO: Taiyo Discusses Option for PCB Heat Dissipation—Thermally Conductive Solder Resist

Conventional solder resists are relatively poor conductors of heat, but dense PCB assemblies generate heat that needs to be dissipated by all means possible. Don Monn, business development and European sales manager for Taiyo America, introduces a ceramic-filled formulation that increases thermal conductivity by a factor of 10 or more.

RTW IPC APEX EXPO: The Power of Synergies with MacDermid Enthone and Alpha Assembly Solutions

Don Cullen, global director of marketing communications with MacDermid Enthone, and Tom Hunsinger, VP global marketing with Alpha Assembly Solutions explain the structure of MacDermid Performance Solutions, which combines the former MacDermid, Enthone and Alpha Assembly Materials businesses to provide PCB and EMS industries with enhanced innovation and service throughout the supply chain.

Ventec Launches VT-5A2: Next Generation, Best-in-Class High Tg Thin-Core and Pre-Preg Material

Ventec International is adding to its extensive thermally conductive laminate and pre-preg range with the launch of the VT-5A2, a next generation best-in-class, high Tg thin-core and pre-preg material.

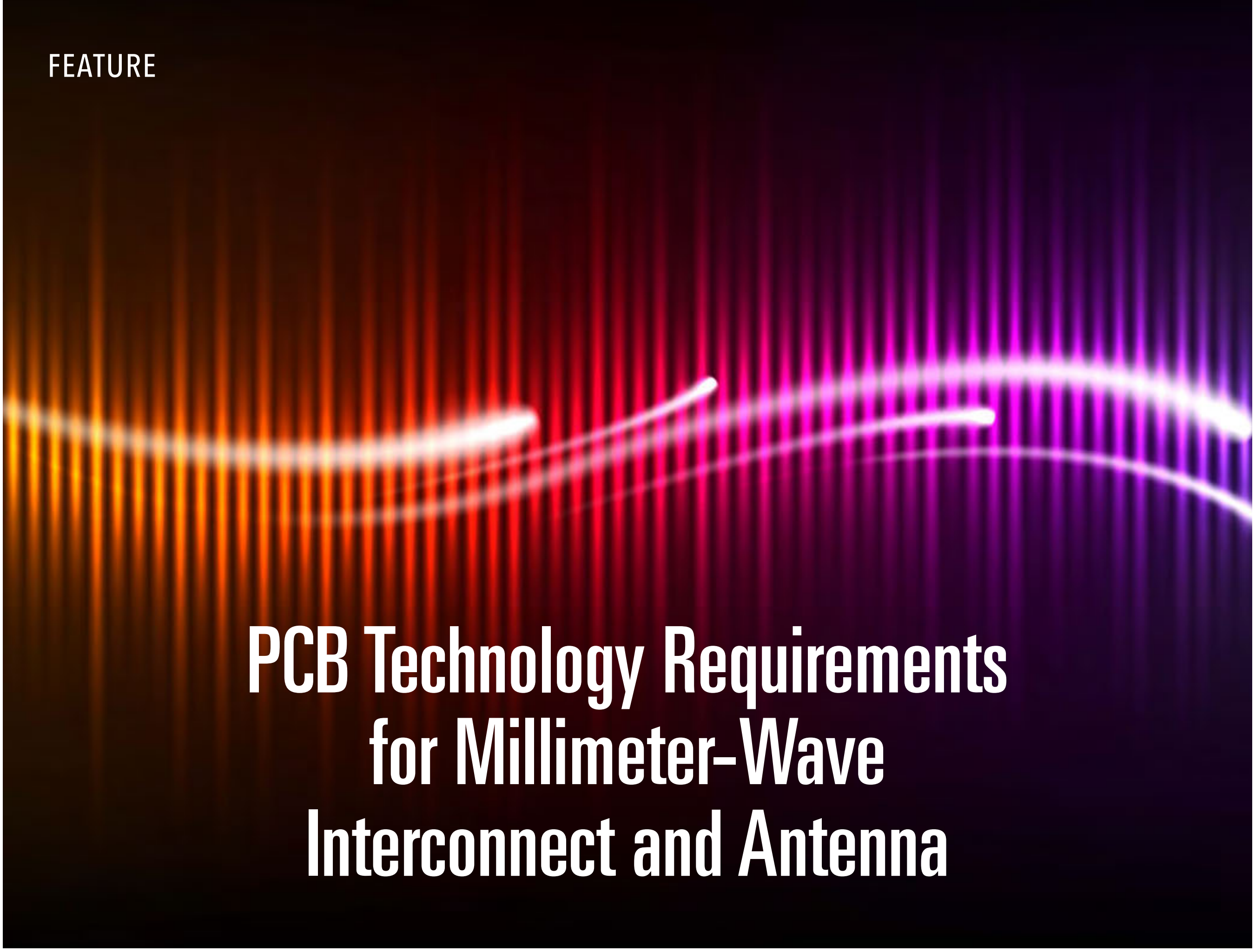
Let's Talk Testing: How Strong is Your Foundation?

In my December 2016 column, we discussed the idea of supplier surveillance and that one should put into place some type of doublecheck to ensure that you are getting exactly what you've asked for, designed, ordered, etc. To take that idea a step further and to circle it back to the main industry we are discussing here…

RTW CPCA Show 2017: ESI Discusses Latest Innovations in Laser Drilling

At the recent CPCA Show 2017 in Shanghai, China, Mike Jennings, director of marketing for flex and interconnect products at Electro Scientific Industries Inc. (ESI), highlights their expertise in laser drilling, as well as being the first roll-to-roll capable UV laser drill provider.

FEATURE



PCB Technology Requirements for Millimeter-Wave Interconnect and Antenna

by Jim Francey and Terry Bateman
OPTIPRINT AG

Introduction

Since its inception in 1985, Optiprint has specialized in fabricating PCB products for radio frequency (RF) and microwave (MW) applications. In recent years, there has been commercial exploitation of so-called millimeter-wave (mmW) frequencies. Generally speaking, this commenced with automotive radar; however, increasingly the telecommunications sector is offering radio products operating in V-band (57–66 GHz) and E-band (71–76 GHz and 81–86 GHz) portion of the radio spectrum[1]. The attraction is the comparatively high volume of data that can be transmitted wirelessly to cope with a demand for bandwidth, driven by growth in mobile data traffic for portable devices and machine-to-machine communications. The expectation is that mmW radio architectures will be deployed in future "5th generation" cellular mobile" (5G) networks and to ease "spectrum congestion" in current 4G and earlier configurations.

In 2013, Optiprint joined a European collaborative project called "MiWaveS"[2], a three-year project to develop key technologies for mmW wireless access and backhaul in future 5G heterogeneous cellular mobile networks. Optiprint's role in MiWaveS was to support the collaborative partners in the design and manufacture of PCBs for local access and backhaul radio transceivers and antennas. This article describes the PCB technology requirements of fabricating PCB articles designed for the distribution and propagation of mmW signals with emphasis on the work done to support MiWaveS project.

Technology Overview

The PCB, often referred to as an organic substrate, represents an economically attractive and mature technology for mmW hardware interconnect and antenna given the ubiquity of PCB and PCB assembly manufacturing capability. Interestingly, the MiWaveS project also involved LTCC ceramic substrate technology; however, a review of that is outside the scope of this article. From a PCB manufacturing perspective, the needs for distributing and propagating

signals in millimeter wavelengths have a direct influence on the choice and thickness of substrate, PCB feature (and feature-to-feature) *positional* accuracy and feature *dimensional* accuracy. The requirements for matching manufacturing and metrology capacities are discussed in this article.

Match Needs

Raw Material Selection

Microstrip, stripline and co-planar waveguide transmission line technologies are all deployed in mmW PCB design. Increasingly, designers are using substrate integrated waveguide (SIW) and this was true of circuitry used in MiWaveS. SIW sees a rectangular waveguide created within the dielectric by adding a top metal over the ground plane and *fencing* the structure with rows of plated vias on either side. A sketch depicting the SIW PCB feature configuration is depicted in Figure 1. Benefits of SIW are potentially lower losses than with microstrip and coplanar waveguides since dielectric losses are typically lower than conductor losses at millimeter waves. The via fence needs to be dense enough to prevent field leakage and signal loss from the waveguide to the substrate. Many traditional waveguide components such as power dividers, signal couplers, filters and antennas can be realized by SIW technology. Component performance approaches conventional air-filled waveguide performance and has the advantage of low radiation leakage and interference compared to microstrip and coplanar circuits.

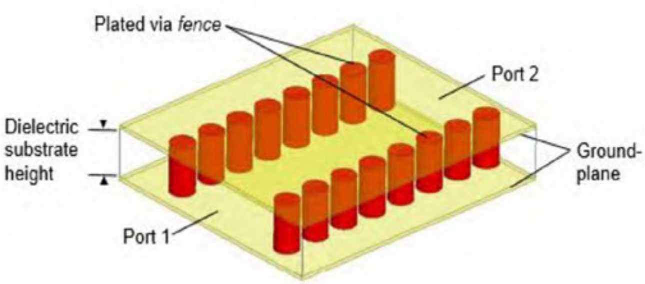


Figure 1: Sketch depicting SIW configuration; ground plane either side of dielectric with PTH (via) fence.

A defining requirement for raw material selection is minimizing loss (dielectric loss, conductor loss). Much has been published regarding raw materials and loss[4]. Several low-loss materials were used in MiWaveS and in some instances combined with FR-4 to form so-called mixed-dielectric multilayers (FR-4-based layers being used to satisfy the digital function of the designs with consideration for the long-term economic aspects). However, liquid crystal polymer (LCP), a low-loss thermoplastic base material, was identified at the outset for the mmW functions. LCP is a good candidate for mmW multilayer PCB structures; it has a stable dielectric constant through the frequency range, exhibits low moisture absorption, and has comparatively low loss. Rogers Corporation offer a non-woven-based copper-clad laminate and matching bond-ply[3]. The combination of laminate and bond-ply simplifies the design process inasmuch it provides opportunity for homogenous dielectric properties. A mechanical benefit of such a combination is the opportunity to maximize MLB planarity (flatness). The challenge from a fabrication perspective (with LCP) however is coping with material movement:

- Typically, mmW MLB dielectric separations are comparatively thin. For transmission, the dielectric spacing (signal to ground plane) is governed by wavelength. In MiWaveS 100 µm thick laminates and bond-plies were deployed. The combination of thin substrate without woven-glass reinforcement has a negative effect on dimensional stability. Innerlayers change dimensionally during processing (etching and so forth). Typically, they shrink in both X and Y planes; the degree of retained metal of course has an influence on the degree of shrinkage.
- Being a thermoplastic, the materials soften during thermal excursion, MLB lamination induces further mechanical distortion, often localized.
- Further dimensional change occurs during outer-layer processing.

Since positional alignment of drilled/plated features to printed feature is a critical attribute (some mmW designs required positional accuracy in the order ± 20 µm) there is the need to gather accurate X/Y measurement data and compensate dimension change in the CAM data. Measurement and compensation must be repeated at outer-layer formation. The corollary is the dimensional change must be measured and compensated over the course of multilayer board (MLB) manufacture. Experience showed that, despite refining the CAM data, LCP-based MLB exhibit discrete dimensional stability variation. Back-end machining, say, for cavity formation, must make use of localized optical targets (fiducials) to satisfy positional accuracy requirements. Laser-based metrology and laser direct imaging (LDI) are mandatory capabilities.

Circuit Requirements

Consider that each aspect of the circuitry must be defined in relation to minimizing signal degradation (loss). Transmission line tolerance is a key factor. In MiWaveS typically ±10% was specified. For features <150 µm, this means ±15 µm which challenges PCB manufacturing capabilities for multilayer RF boards. Millimeter wave circuits on a PCB use very narrow line widths around 100 µm or even 75 µm. A single microstrip or coplanar line impedance itself does not change very rapidly due to geometry variations but problems can arise with flip-chip component pads, filter circuits and antenna center frequency change due to under- or over-etching. The line mismatches are also cascaded that can exacerbate problems due to standing waves between circuit blocks. Repeatability of the etching tolerance is also important for optimization of mmW circuits.

An attribute of low-loss materials is the use of low-profile copper-foil; this helps the etch process, which is isotropic in nature. Naturally the aspects of a subtractive process versus semi-additive (or fully-additive) have a major bearing on feature resolution capability. Regardless, the processor must have the opportunity to deploy liquid photoresist (i.e., <10 µm thickness) and the right level of etching control.

As mentioned in the Technology Overview section earlier, feature-to-feature accuracy is an important factor for managing transmission losses. It is not uncommon in mmW type work to have blind or buried vias placed within 20 µm location alignment to an underlying feature (pad for example). This is complicated in achieving the requirement over an 18" x 12" (457 mm x 305 mm) manufacturing panel and on materials with inconsistent dimensional stability. In such a requirement, innerlayers are bonded sequentially. Optical targets in the underlying layer are spot-faced and LDI is deployed and optimized to define the over-lying layer features. Additional targets can be added for localized/critical positional accuracy requirement. Figure 2 shows an image of a LCP MLB that deployed this technique.

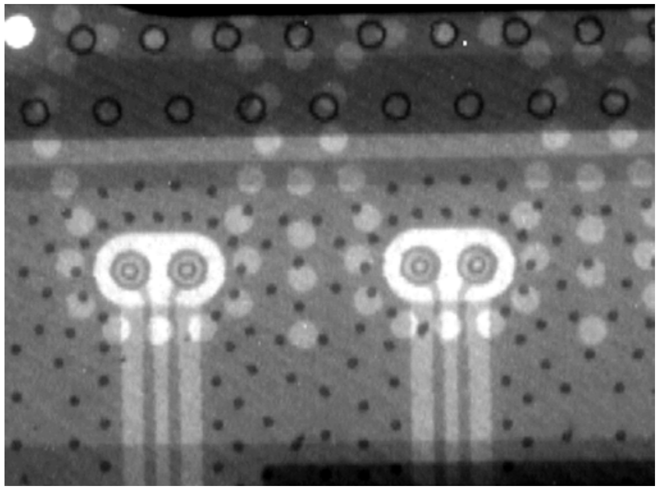


Figure 2: X-ray image of laser-drilled plated via in sequentially laminated LCP MLB located using localized optical alignment and LDI.

In terms of componentry, the mmW industry is benefiting from packaged devices (e.g., QFN and BGA). This is an evolving process. An example of packaging developed recently for the mmW industry is the embedded wafer level ball grid array (eWLB) package, developed and used by Infineon Technologies[5]. These packaged components are available up to 86 GHz (BGT80). Flip-chipping of MMIC dies is also a promising technology for high performance mmW interconnects. Flip-chip bumps or pillars are typically less than 100 µm in height and have low parasitic inductance. However, there are problems with flip-chipped high-power circuits due to thermal issues. A multitude of bumps would need to be dedicated for thermal transfer from the die to PCB. For some MMIC devices like very high-power amplifiers (PA), designers have no option but to use bare die. These are invariably gold-wire (or preferably ribbon) bonded (to provide interconnect) and typically 50–100 µm thick. Similarly, managing signal loss and wire inductance are key to performance and limiting the length of the gold wire (or ribbon) is an important consideration in mmW PCB assemblies viz. the shorter the connection, the lower the losses, and inductance. Ribbon bondwires have superior performance but in most cases two or three parallel single bondwires are good enough.

An established practice is to recess the dies within cavities that are either mechanically milled or laser-ablated. A ground plane of copper will form the floor of the cavity. The ground plane is required by the MMIC for both low impedance electrical grounding and for good thermal coupling from the die. The thermal dissipation of a single PA mounted on a PCB cavity can be several watts in an area <10 mm2 which needs very efficient cooling through the PCB laminate. In such instances, thermal via and embedded coins are features that can satisfy the thermal management aspects. In a 100 µm thick copper-clad laminate there is the convenience to remove the dielectric and allow the MMIC device (with wire-bond pads atop) to be flush (or near flush) with connecting bond-pads on the PCB. As its apparent the proximity of MMIC bond-pad to PCB bond-pad is a key factor for short bond-wires. The use of laser ablation works well in this aspect as positional accuracy of it is typically better than that of mechanically milling. In MiWaveS work the gap between PCB bond-pad and cavity wall was typically ≤25 µm. Consider too mechanical milling requires process tolerance in Z-plane and burring is prevalent. Figure 3 shows an image of a laser-ablated MMIC cavity with the PCB bondwire pads meeting the top of the cavity wall.

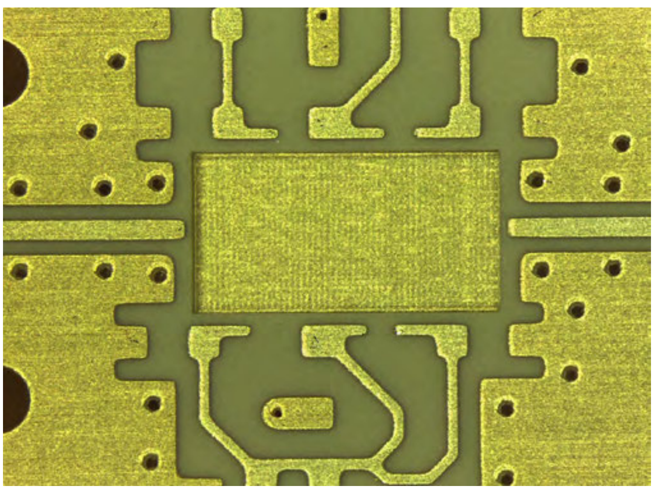


Figure 3: Micrograph of laser-machined MMIC cavity in 100 µm LCP dielectric depicting circuitry and bondwire pads defined in layer 1 and exposed cavity floor in layer 2 (ground).

Waveguide transitions are a key feature of mmW PCBs. Often the mating waveguide (in a transceiver assembly the waveguide will lead to the antenna) will mechanically locate with side 2 of the PCB and the RF energy is fed by a mechanically milled conduit. An etched resonator on side 1 completes the transition. In MiWaveS mechanical depth-milling was used to form the cavity in the bonded PCB; an end-mill was used to machine within ~50 µm of the side one resonator. Often the walls of the cavities are plated and that adds to the complexity of manufacture. In such circumstances two depth-milling steps are required to reveal a non-metalized opening to the side 1 resonator. The Z-axis depth-milling capability required being ±35 µm. Figure 4 shows images of a depth-milled cavity from top and bottom perspectives.

In circumstances where plated vias require "capping" the accepted practice of via-filling (with epoxy-based pastes) is impractical because mechanical planarization can mechanically distort the non-reinforced base materials. The sequential plating steps can also hamper conductor definition because of the overall copper thickness result. Galvanic copper via-filling is the only practical route. Here the via geometries (height versus diameter) require careful consideration to maximize the copper filling process. This is a process not unique to mmW PCB product but is a trend prompted by the availability of mmW packaged devices, particularly BGA types.

Plating and Finish Requirements

It is generally accepted in the PCB industry that the panel plating process, whereby all surfaces of a drilled panel are copper-plated, re-

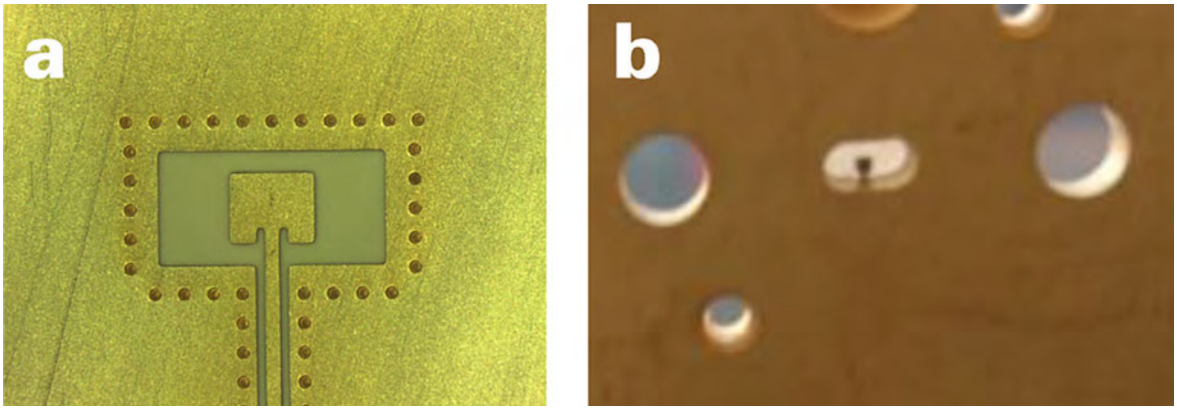


Figure 4: Micrograph (a) shows etched resonator on side 1 and (b) shows depth-milled cavity on side 2, machined into dielectric and within ~50 µm of side 1 resonator.

sults in a more uniform copper deposit thickness in comparison to pattern-plating process. The latter is sometimes regarded as semi-additive whereas the panel-plate process is *subtractive* in the formation of conductors. Uniformity of copper thickness results in more consistent electrical performance (e.g., line width variation). As mentioned earlier, copper etching is an isotropic process and the industry practice of etching-down copper was deployed in MiWaveS to meet dimensional tolerance needs.

Much of the PCB work in MiWaveS required both SMT and gold wire-bond. Autocatalytic silver/immersion gold (ASIG) and immersion silver/immersion gold (ISIG) are two silver-based finishes that were used. Both finishes are universal (i.e., they support both SMT and gold wire bond). Electroless nickel/electroless palladium/immersion gold (ENEPIG) was a *universal finish* candidate but, being nickel-based, losses are higher.

Conclusions

The work done by Optiprint AG in support of MiWaveS substantiates that PCB technology can satisfy the engineering requirements for mmW circuitry providing the manufacturing capabilities can match the positional accuracy, feature tolerance and surface finish requirements.

Acknowledgment

The research leading to this paper has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n°619563 (MiWaveS).

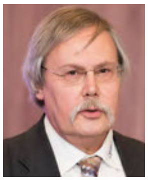
The authors would like to thank Professor Ronan Sauleau, Université de Rennes 1 and Dr. Jussi Säily, VTT Technical Research Centre of Finland Ltd for their valuable inputs. **PCB**

References

1. ETSI White Paper: E-Band and V-Band—Survey on status of worldwide regulation.
2. MiWaveS.
3. Rogers Corporation LCP product page.
4. John Coonrod, Managing Circuit Materials at mmWave Frequencies, published in Microwave Journal.
5. Wikipedia, Embedded Wafer Level Ball Grid Array.

This paper was originally presented at the EIPC Winter Conference in Salzburg, Austria, February 2–3, 2017, and published in the proceedings.

Jim Francey is sales manager for Northern Europe with Optiprint AG in Berneck, Switzerland.



Terry Bateman is project manager with Optiprint AG in Berneck, Switzerland.

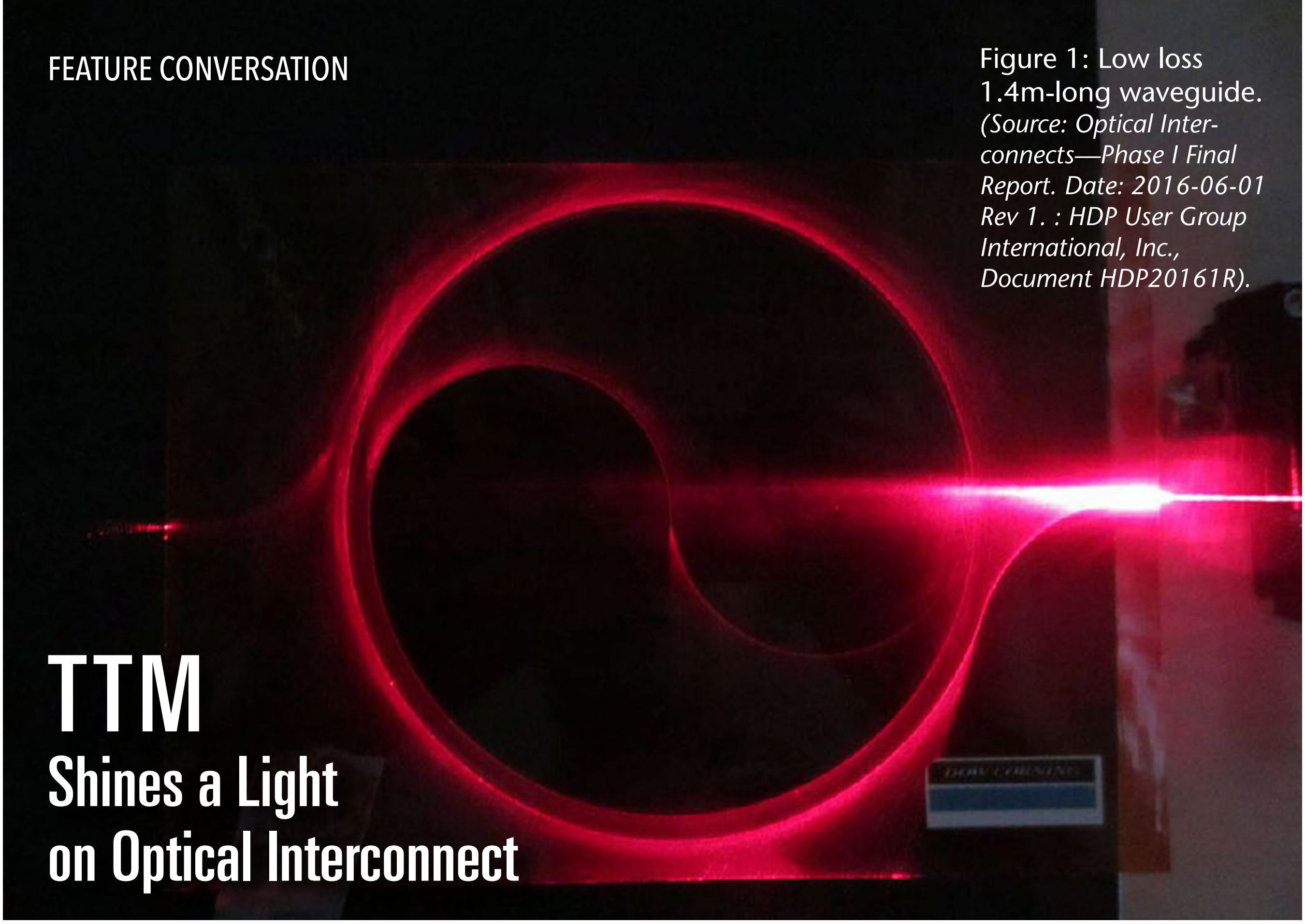


Figure 1: Low loss 1.4m-long waveguide. *(Source: Optical Interconnects—Phase I Final Report. Date: 2016-06-01 Rev 1. : HDP User Group International, Inc., Document HDP20161R).*

TTM Shines a Light on Optical Interconnect

by I-Connect007

Are embedded optics on PCBs set to make a breakthrough in the upcoming years? According to Dr. Craig Davidson, VP of Corporate Technology at TTM, it might be closer than you'd expect. In a recent interview with the I-Connect007 team, Craig outlines TTM's current pursuit of high-volume manufacturing lines able to deliver embedded optical interconnect, what that would mean for the PCB industry, and why he thinks there will be manufacturing production capability by 2020.

Barry Matties: Craig, for context, tell us a little bit about the optical side of TTM and what you guys are doing there.

Craig Davidson: Sure. We're engaged already with the optical groups of many large customers. As you probably know, there are optical products today that do not include onboard optical interconnect or inboard optical interconnect, but rather optical cables to the edge of the board. These include fiber connectors and transceivers embedded in connectors. TTM certainly supports networking companies with these kinds of products formally classified as optical.

What we're really taking about here is the future as we bring optical signals on board, onto the printed circuit board directly embedded in the board for optical packages, line cards or backplanes.

Matties: Yes.

Davidson: The basic capability has been around for decades. I first got involved in it back in the year 2000 when there was a big push for onboard optical interconnect and just about every printed circuit board fabricator at the time was doing something around embedding fibers into boards. Many PCB fabricators have these kinds of processes. It's relatively simple to do but it's not a very happy solution.

You still have problems with 90° bends, for example, and the z-axis in the board, and you certainly have continuing difficulties associated with connectorizing the fibers. Also, importantly, is registration—making sure the fibers actually end up where they need to be. That›s a very difficult task. So those types of problems haven›t really been solved for

a long time. The TTM team in Europe has been working on this for a long time now. And you interviewed Marika Immonen on our team back in 2015, I believe. TTM now has technology we can offer that will allow embedded waveguides in boards. This includes polymer waveguides either buried inside a board or built-up on the board surface and with in-plane or 90° connectors. We›re working jointly with several consortia and individual companies to demonstrate this technology.

Craig Davidson

So that's a brief history of where we have been and at least a little preview of what we can offer. TTM has a long experience of fabricating multimode waveguides for short-reach datacom applications. Now as silicon photonics at OEMs is pushing through, we are scaling technology to support their single-mode roadmaps. There we pursue both polymer- and glass-based waveguides. Polymers are very versatile, low cost and easy to fabricate, whereas glass provides low loss at the longer wavelengths and optical compliance with fibers. Single mode waveguides are looked at to provide complex routing between chips or to serve as "bridges" between sub-micron silicon waveguide and 9-micron fiber. In single mode, accuracy and registration both in waveguide fabrication and termination is critical.

***Matties:** And really the impetus behind this is the speed barrier, right?*

Davidson: Yes, it absolutely is. We're now in production with 25-gigabit backplanes, and by that I mean per channel, so it's some of the fastest boards out there these days. We know that companies are already working on product for the 50-gigabit node. The generation after that is also being developed now and will be around 100 gigabit per channel. I think it's those speeds that people are most focused on for these optical interconnects.

We know that even 25 gigabit is difficult to manufacture because of the tolerances required. The 50-gigabit node will be very difficult to manufacture, again because of the losses. Low-loss materials are required and the tolerances on the copper and dielectric geometries in all dimensions are going to be very demanding for even the 50 Gb. The consensus from our customers seems to be that with the 100-gigabit node we really will have to be thinking pretty hard about moving to optical interconnect onboard as more traditional PCB fabrication techniques may not be capable of the tolerances required.

***Matties:** Now, with regard to high-speed materials and the traditional coppers, haven't they broken barriers that have been somewhat surprising to the industry? Barriers that technologists had previously predicted would never be breached with copper?*

Davidson: Yes, I think that's true. I remember hearing "Oh, geez, we need flip-chip next year or we're out of business." Or in 2000, they said, "If we don't have embedded optical in a year or two, we're out of business." None of those things came to pass. It's remarkable how robust existing technology is and it's always so much easier to make incremental improvements to what exists than to implement a whole new type of technology.

This 100-Gb barrier might be a little bit different because it does not rely just on opinion regarding what future manufacturing technology will be able to deliver but on fundamental calculations of losses associated with current materials. Other factors may delay the requirement of embedded optical. That could be software solutions such as error correction or additional functionality such as on-board repeaters. But the physical solutions come with severe power and thermal dissipation requirements.

Nevertheless, embedded optical is a focus for us and our customers. In fact, we have manufacturing techniques now that we're ready to introduce into pilot and volume production. We want to be able to deliver optical interconnect at reasonable costs and at these kinds of performance levels. TTM's goal is to ensure we have the technology if it's needed and in that time frame.

***Matties:** Now, with regard to your technology, is this already being used in any practical, commercial application or is it all design and experiment at this point?*

Davidson: Well, we're past the experimental stage. We have a stable manufacturing process now. Of course, we continue development of new materials and the maturation of our manufacturing processes. We provide pilot-level quantities with good yield. The industry focus has been on proving out the overall technology with evaluations and demonstrators. We are engaged with many companies and consortia to do demonstrators assessing how optical interconnect technology could be used in package substrates, line cards and backplanes and measure the benefits.

TTM has built many demonstrators for companies—mostly through joint development activities either one-on-one, bilateral types of development, or through the many consortia of which we are members or with which we cooperate closely, for example PhoxTrot in Europe and AIM Photonics here in the U.S. They have designed demonstrators to determine how best to employ these tools and determine design parameters. We're building functional demonstrators for companies that include routers, switches, other types of networking devices, and storage applications. Cloud storage arrays have different requirements and configurations than a network line card, as an example.

***Matties:** Now, with regard to manufacturing and your techniques, you mentioned that TTM has an optical line. Is this manufacturing equipment that you've partnered with suppliers to produce or is this internal development to create the manufacturing process?*

Davidson: We're using existing PCB fabrication technologies including material deposition, imaging, patterning, etc. I don't think at this point we have to design or develop any unique tools but rather utilize our innovative approaches to fabrication and incorporate light transmission materials—for example, polymer waveguides. These tend to be photoactive materials. We can deposit and define using typical phototools with high precision. But it's something that the industry understands and is recognized by our customers which reduces risk and raises confidence. We have already done up to two embedded optical layers on a 20-layer backplane as one of the demonstrators. This is a demonstration of real product containing all regular copper layers and functions and it is quite a complex product to build.

***Matties:** That's quite the undertaking.*

Davidson: Yes, it is. It's quite exciting and not a revolution from a technology point of view. We can deliver the tolerances required and continue to evaluate some of the newer optical materials that are available to us now. We've been evaluating the polymer waveguide materials that are offered by different companies. And now the new glass waveguide materials are also

"We are already using these embedded glass waveguides for the higher-performance applications."

being offered. We are already using these embedded glass waveguides for the higher-performance applications. Quite interesting.

***Matties:** I bet. For other fabricators, I assume you are licensing this process; when they embrace the process, it doesn't sound like a lot of capital investment, but more process knowledge and training.*

Davidson: Yes. I'd say that is mostly true. We know how to set up a manufacturing line to do this. Obviously, because of the geometries and materials, cleanliness is important. So, we're just making sure that for a volume line, we've got sufficient cleanliness at the appropriate process step. But yes, we know how to build a volume line to do this today. We're pretty confident.

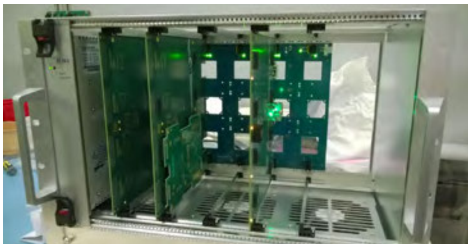


Figure 2: System enclosure with joint HDP OE2/PhoxTrot eco-system demonstrator.

Now we're waiting for the business. We remain close to our customers. The industry is now looking at different ways to employ embedded optical and you probably also know that companies have different approaches to their system architecture. Some companies make very heavy use of big backplanes; others not so much. Some use smaller mid-planes. Some use harnesses instead of backplanes. They all have slightly different architectures and they are working the benefits of optical interconnect into their designs. The result will be, I think, different solutions and different product. We are gaining a lot of experience with these different approaches and solutions.

We're waiting for a little more maturity in the industry to see how they're going to do this. We've been quite open with our customers. As soon as you have a design, even a pre-production type of design, we're ready to go work with you on it and make sure that we can put it in play. Right now, most of the industry is focused on test vehicles and demonstrators but they are quite sophisticated, by the way. They are functional and almost products unto themselves.

Matties: ***When do you see this becoming more mainstream, where it's market-accepted and product-proven in the real world? How long a time frame?***

Davidson: Well, that's a really good question. We're asked internally and externally all the time.

Matties: ***I bet you are [laughs].***

Davidson: Our forecast comes from our customers and potential customers. But we are focused on the 100-gigabit per channel node, which is predicted to be in full production sometime in 2020–2022. There is no commercial product yet. As far as the process technology is concerned, we're expecting that in the year 2020 we may need to be in production. We are planning the expansion of our pilot lines and low volume lines now to understand the real business case for this. We want to be ready to go when companies have real products they want to put into production.

Matties: ***Primarily this is tied to the server farms, the big server markets, communications—there's a real need for speed there, of course. Do you see this reaching, say, the automotive industry with the need for speed around autonomous vehicles?***

Davidson: I think it's certainly going to penetrate the infrastructure type of product—the big switches and hubs and other infrastructure product that's going to be needed to support autonomous driving. True autonomous driving probably isn't going to happen until the 5G node is fully deployed. Things like latency in our Internet connections today needs to be quite a bit better for full autonomous. I don't see optical interconnect going into a car first. I see it mostly right now penetrating the types of infrastructure products that we already produce. It'll take a little while longer before anything needs to be done inside a car—at least as to high speed requirements. As you know, we're also one of the largest automotive suppliers in the industry with a strong share in safety critical applications. So, we're very familiar with the qualification requirements and reliability requirements of the auto industry. The time it takes to qualify new materials and processes is quite extensive in the auto industry. I don't see them adopting this as a leader; maybe a fast follower as needed.

Having said that, the automotive guys are subject to some things today that they were not before. They are buying commercial semiconductors that are fast and in big, complicated high IO packages. I see them advancing along the density curve—from where they were yes-

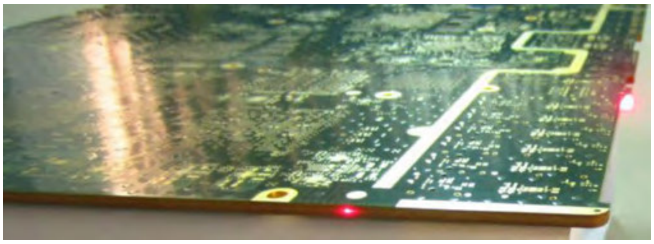


Figure 3: 20-layer optical line card with embedded polymer waveguides (20L+1Opt).

terday and where they are today—faster than most other industries have. They have to buy the latest chips and those chips are complicated and dense. We see them adopting HDI faster probably than most other industries have. Maybe the same will occur with optical interconnect once it is available.

***Matties:** I would think that you're going see that with companies like Nissan, which is one that comes to mind that's really driving automotive technology and electronics. I would think that these guys would be knocking on your door sooner rather than later just because it seems that the electronics is the advantage that they have in every vehicle, aside from the standard seat and steering wheel luxuries. It's really the differentiator.*

Davidson: Yeah. They really do need speed in the Internet connection and the information back-and-forth with the car, and that's all going to be done wirelessly, of course.

***Matties:** This is great. Does anyone else have any questions for Craig?*

***Andy Shaughnessy:** From what I know about optics, it seems like it's not perfect, but it seems like a whole lot better method for transmitting a signal than copper. From what I understand, there are almost no resonance problems, a lot of the EMC and signal integrity problems go away, and you can make optics 10 times the density of HDI copper. If we could ever get it standardized, designers are really praying for it.*

Davidson: Yes, I think you're right. The benefits are there, for sure, and I think there's a big flywheel that has to be spun up in terms of understanding how to use this technology, having PCB designers who are familiar enough with it that can actually integrate electrical and optical on the same board. These kinds of skills aren't all that prevalent out there. And something we are also considering as we ramp this technology and evaluate new materials is looking at reliability. TTM already is a high-reliability supplier including aerospace and defense and the safety-critical automotive. Even in our telecom customers, when we build a backplane for them, they're worried about the reliability of that backplane. Line cards can more easily be swapped out if something goes wrong, but a backplane…no. Just as in today's designs, the designers' understanding of this technology will also be important to reliability.

As of now, we haven't seen reliability issues. Most of the early work has been done to prove out the technology and assess its capabilities. Now TTM is looking at some of the reliability aspects, including the materials and the manufacturing techniques. We're fairly confident about it. The industry is still not able to offer it in volume as a solution including second sourcing and having designers who are familiar with the manufacturing techniques and the design space to be able to effectively use it.

***Patty Goldman:** I'm wondering if most of this development is being done here in North America and what sort of interest there is in foreign markets like in Europe and in China?*

Davidson: TTM is a global corporation and the Corporate Technology group within TTM is also global. We have people located around the world including Asia, Europe, and North America. This particular development activity reflects the organization with project members from all geographical locations. We fabricate boards with embedded optical interconnect with participation from our global technology team and involving many of our sites around the world. This also represents a broadening of our internal experience base and gives more confidence to our customers.

The customer base we are working with today in optical interconnect product are also truly international and located again in Asia, Europe, and North America—everywhere that you see companies engaged in networking, telecom, and storage systems.

Steven Las Marias: Craig, with the proliferation of optical boards, do you think it will require a different set of manufacturing or assembly expertise or techniques?

Davidson: Yes, I do. The early work in this space was subject to many issues, not the least of which was registration and making sure you know the precise location of the fiber. This has a major impact on assembly. You probably know that the connectors have to be lined up with the waveguides requiring a lot of precision and even active positioning perhaps. That is, putting an optical signal through the board to optimize component and connector positioning during the assembly operation. In some of the higher speed optical, we're talking about a few microns of registration accuracy required. That's quite a change for most of the assembly operations. Our embedded wave guides, as opposed to fibers, reduce this overall problem, but new approaches to assembly are required. For the consortia work in which we have participated parts were sent to the connector companies because they have the tools to do this type of connector alignment and assembly. That's obviously not a very happy solution for volume manufacturing.

So the industry needs appropriate volume assembly solutions. It's also very dependent on the type of connectors you're going to be using and the board technology. TTM is heavily involved with the connector companies. I didn't really point that out before, but in all of the demonstrators and prototypes, we're heavily involved with all the connector companies, and are aware of their new connector technologies and connector designs coming to meet this requirement. It is a challenge to put these connectors on and make sure that they're within a few microns of where they need to be. If you could do that without active alignment by using new assembly approaches that would be interesting.

It's also an area that TTM is looking at as we also have assembly capabilities in-house.

Matties: I think there's a whole list of new connectors that have to be developed to be compatible with this technology as well. It's not just items off the shelf. They have to design and develop new technology for this specifically, right?

Davidson: Yes, there are connectors now like today's cable connection; you just plug it into the receptors on the board. But as we begin to integrate optics into the board, we clearly need new sets of connectors. The connector companies are developing them and we are evaluating them. It's also true that in the evaluations the connectors are a significant part of the losses in the system. Connectors represent a discontinuity—electrical or optical—so I guess you'd be surprised if they weren't also a loss problem in optical systems as well. We're quite happy with the performance of the embedded optical waveguides we have in our boards, but we know that there needs to be improvements in the connectors and at that interface to keep loss at a minimum. So, yes, a very important part.

These technologies play together in a very systems-oriented solution, I think, including design which also plays a prominent role. Our ability to embed waveguides in the right configurations is a major part of the solution. When you start thinking about it all, all the components must be ready for a manufacturing production capability by 2020. There's not much time to put it all in place and prove it out and make sure it's integrated and with a supply chain that's ready to go.

Matties: It's a large undertaking for sure, and I know when we first started talking about it with Marika in 2015, TTM was thinking three to four years. To me that seemed like a long time, but when you start looking at the entire infrastructure that needs to be developed and supported, it's not long at all. It goes by very fast.

Davidson: Yeah, not long at all. In fact, it's quite exciting and very interesting for sure.

Matties: I bet.

Davidson: In the 1980s and '90s, companies were more vertically integrated. They had their own board shop, wafer fab, and did all the assembly on their own designs. We could put together a program that was very vertically integrated and make it work on a short time scale. Today, of course, not so much. It's quite difficult to put together the integrated solutions necessary. Global companies like TTM that have many of the required capabilities and a culture of internal cooperation are in a good position to help fill those gaps.

Figure 4: PhoxDem09.04MPX – 18L+2 opt embedded WG layers.

***Matties:** Yes. I would think with the global footprint and the supply chain it's very difficult. Is there anything that we haven't talked about that we should be sharing with the industry?*

Davidson: Oh, let's see. Well, I guess the only comment I have is that many companies don't understand what it takes to qualify new materials and processes. That's very true outside of the optics space, for example with high-speed materials. This has been an issue now with the industry for the last decade or so. So many new materials are being introduced and it's difficult to characterize them fully for all the variations of PCB configurations including straight up lam, multi-lamination, different types of via constructs, different copper weights and copper profiles, different glass styles and for different applications. It is really quite a challenge. Companies sometimes forget the work involved and the risk they take when introducing new materials to their products. TTM also has a very extensive materials program to look at all these aspects of performance and provide experience and data to customers.

Having said that, the proliferation of materials gives us many now to choose from when before there may really have been only one or two in key performance categories.

***Matties:** We've heard about the material process, the approval process and how lengthy it can be—a multi-year process in some cases. Do you see ways of streamlining this process that the industry should be considering?*

Davidson: Yes, and we do participate in leveraged activities where we can to help with this work. TTM, for example, is a member of HDPUG (the High-Density Packaging Users Group) and we are a big supporter of HDPUG. Through HDPUG, we can evaluate many new materials. If you go through the literature, HDPUG periodically publishes results. They have done a lot of really good work in terms of lead-free compatibility and CAF performance over the years with the newer high-speed materials. We take advantage by working with these consortia and leveraged activities whenever possible, so that helps.

Some companies understand how difficult this is and have very aggressive and rigorous materials qualification programs.

That's certainly true of the automotive customers. Many have internally qualified—with their suppliers' help—their own materials list. But there are many customers that really don't have that expertise internally. But they can take advantage of our extensive materials test database and process expertise. Obviously, today, there are designers that have never been in a printed circuit board fabrication facility. They just go through a catalog, pick a material that seems right and use it. Many times, that's not the right way to go.

***Shaughnessy:** That's most of my readers, Craig. I think half of my designer readers have never been in a board shop, and then for the few that have it's been 25 years.*

Davidson: Yeah. I totally get it. We have outreach programs within TTM, run by our applications engineering team that's out in the field all the time. They are doing lunch and learns and PCB-101 fabrication seminars for companies and otherwise lending fabrication expertise.

***Matties:** Well, Craig, we certainly appreciate your time today and we know you're a busy man and we thank you for your insight for sure.*

Davidson: Sure, no problem. I enjoyed it. Thank you. **PCB**

Electronics Industry News
Market Highlights

Top 10 Advanced Materials and Technologies

The Top 10 Advanced Materials & Technologies in Electronics Market includes high growth materials & technologies in the electronics domains such as G. fast chipset, quantum dots, graphene, 3D IC & 2.5D IC packaging, organic electronics, flexible battery, carbon nanotubes, biochip, silicon carbide in semiconductor, and smart glass.

Plastic Electrode Stretches Like Rubber but Carries Electricity Like Wires

The brain is soft and electronics are stiff, which can make combining the two challenging, such as when neuroscientists implant electrodes to measure brain activity and perhaps deliver tiny jolts of electricity for pain relief or other purposes.

Battery Production Goes Industrie 4.0

A battery that can be charged in seconds, has a large capacity and lasts ten to twelve years? Certainly, many have wanted such a thing. Now the FastStorageBW II project, which includes Fraunhofer, is working on making it a reality. Fraunhofer researchers are using pre-production to optimize large-scale production and ensure it follows the principles of Industrie 4.0 from the outset.

Updatable Chips for a Safer Internet of Things

Whether it's Industrie 4.0, self-driving cars or smart home solutions, connected machines and high-value goods need security mechanisms that can be updated.

Rural Divide the Last Big Challenge to Smartphone Ownership

As the mobile industry gathers this week at the Mobile World Congress in Barcelona to discuss the latest and greatest in the smartphone industry, IDC thinks product maturity is not the only challenge the smartphone industry faces.

Wearables Market Grows 16.9% in Q4

The worldwide wearables market reached a new all-time high as shipments reached 33.9 million units in the fourth quarter of 2016 (4Q16), growing 16.9% year over year. Shipments for the entire year grew 25% as new vendors entered the market and previous champions refreshed their product lineups.

Textile-Based Wearable Electronics and Fashion Displays

Articles such as clothes, watches, shoes, and accessories are essential to people around the world. However, going beyond the basic roles and purposes of these items, the concept of "wearability" is rapidly evolving to include computing power and the ability to connect to the internet. In other words, information, communication, and technology (ICT) are beginning to be integrated into wearables.

CIOs in China Preparing for a Digital Ecosystem Surge

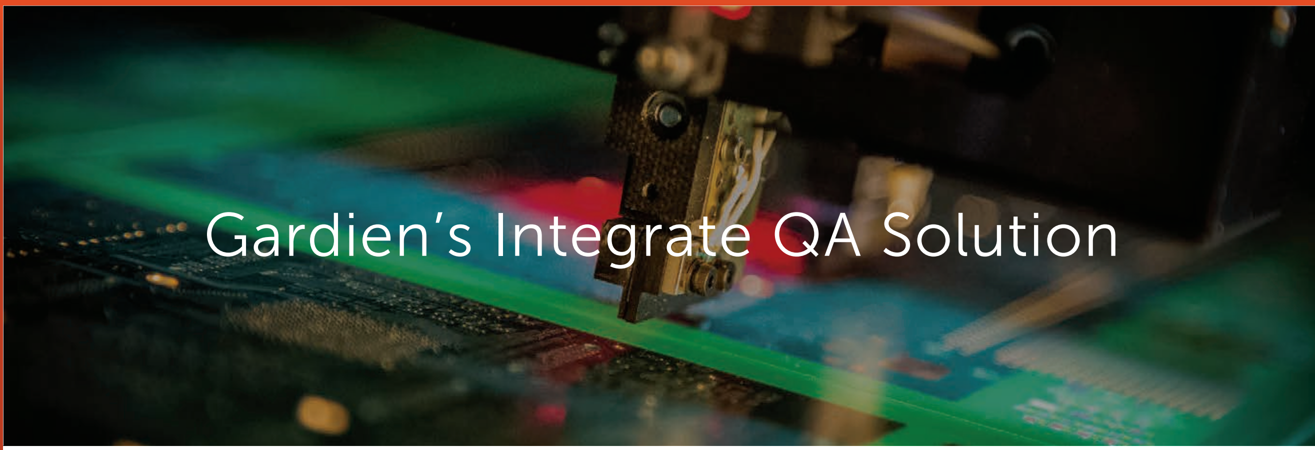
CIOs in China are investing their fast-growing IT budgets in digitalization, according to Gartner, Inc. Gartner's annual global survey of CIOs found that the great success of digital-born companies in China, such as Alibaba and Tencent, is encouraging more Chinese enterprises to build or participate in digital ecosystems.

Increasing Usage of Data Centers to Increase Annual Global Server Shipments by 3.8% for 2017

The growing user base of smart handheld devices and the expansion of Internet-based services for these devices have generated enormous demand for cloud computing and cloud storage businesses in the recent period.

Smartphone Volumes Expected to Rebound in 2017

While growth is expected to remain in the low single digits, IDC predicts shipment volumes to grow 4.2% in 2017 and 4.4% in 2018 with a compound annual growth rate (CAGR) of 3.8% over the 2016–2021 forecast. Shipments are forecast to reach 1.53 billion units in 2017 and grow to 1.77 billion in 2021.



Gardien's Integrate QA Solution

WHAT IS INTEGRATE?

Integrate is a new approach to bare board PCB quality assurance. We address and are responsible for 100% of your tail end QA needs, whether it's AOI, testing, final inspection, or a combination of all three. We can provide the service in one of our service centers or fully integrate within your facility.

WHAT MAKES IT DIFFERENT?

Partnership pricing. Payment is based on product that actually passes quality assurance, not on panels produced or tested. Our success is built entirely on how successful we can help you become.

3900 jobs tooled per month

18100 orders processed per month

24,500,000 boards processed per month

Find out if our Integrate solution is right for you!

www.gardien.com/why-integrate

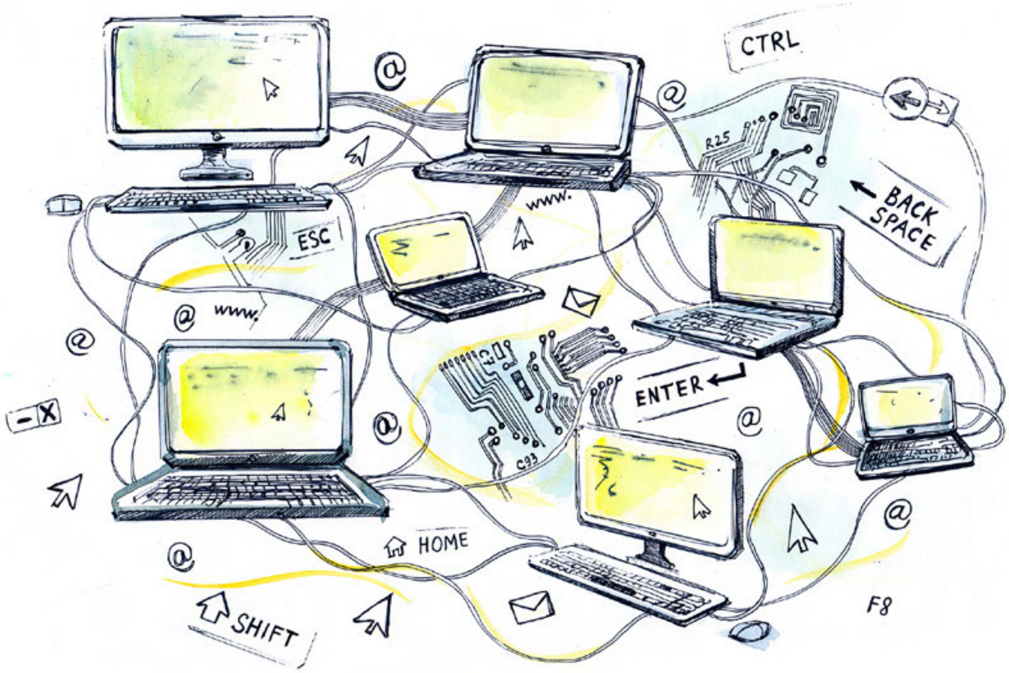
Go With the Flow

by Todd Kolmodin
GARDIEN SERVICES

In today's testing theatre, the flow of information from the OEMs and manufacturers to the independent contractors is mission critical. Missing information can cause delays, incorrect processing and ultimately scrap or end user rejection of the product. The buzz term being used a lot today is "flow-down." It pretty much describes itself: It is the flow of information down the supply chain. So let's go with the flow, shall we? We will break it down in the flow required for correct electrical testing of an unpopulated printed wiring board.

1. The OEM designs the latest must-have innovation for the market. Time is critical to get this product built, tested and on the shelves so that little Johnny will not be disappointed on his upcoming birthday. Now, the design engineers have painstakingly designed in all the impedance, IC footprints, material requirements, impedance/inductance and resistive components, and have written it in their design specification document. Since this is a new product and top secret the document is then saved at their top secret secure location (along with the notorious 11 herbs and spices).

2. The OEM procurement department now receives the build request from the engineers and proceeds to shop vendors for manufacturing. They may send out many RFQs and each time they need to be specific on what they want manufactured. Here is the first major flow-down example: When the RFQ goes out they must be very specific on what they wish to receive. Information here are the general manufacturing requirements (IPC-6011, IPC-6012) but also the specifics that may be outlined in the top-secret design specification document the engineers created in section 1. What are the special requirements for characteristic impedance, dielectric breakdown, continuity and isolation? What is the performance class expectation? Does this board need to pass military performance specifications?



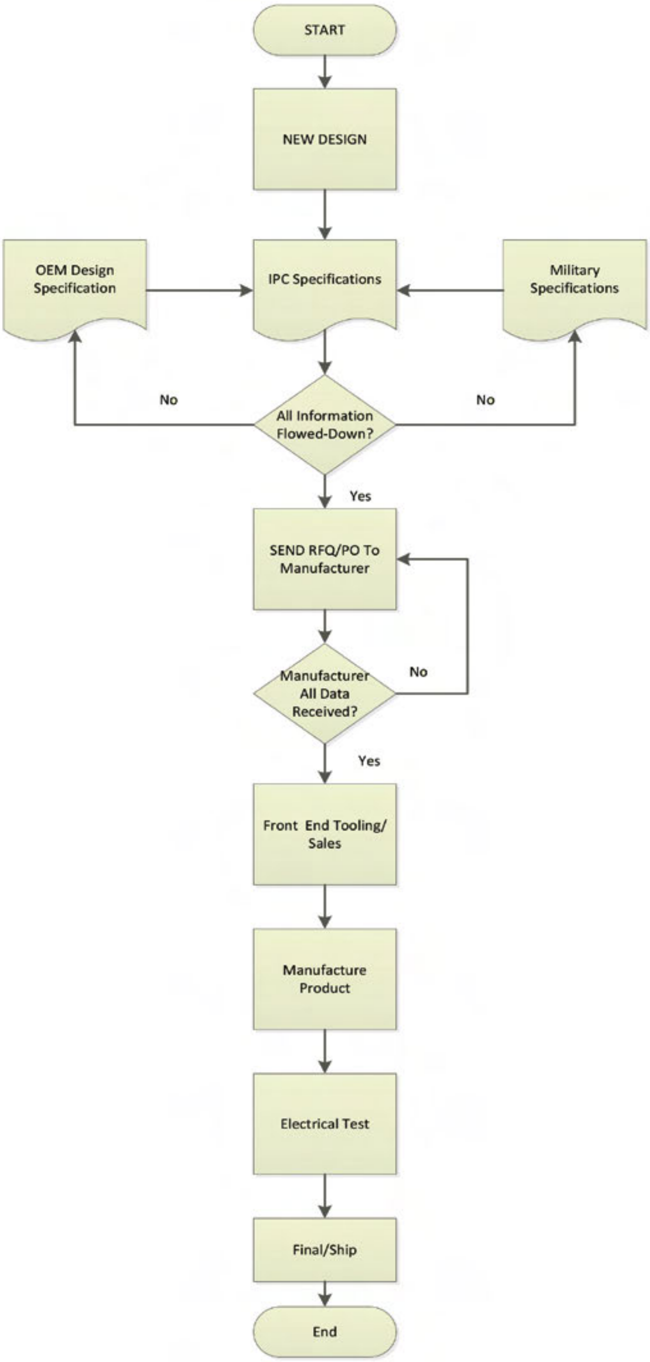


Figure 1: Flow Down.

(Mil-PRF-31032, 55110 or 50884 as examples.) These all need to be specified up front for the proper quotation to be generated.

3. Now that a suitable manufacturer has been selected the OEM issues a procurement document (PO) and the final design package. This now goes through the tooling process at the manufacturer. It is critical here that all specific information outlined in steps 1 and 2 are flowed down in the manufacturing order that will run the course of the manufacturing floor. It is important to remember it is difficult as the flow-down increases in steps that it will be more difficult and time-consuming to retrace steps to find important information that is missing in your current area. This can lead to delays and mistakes. So the information from the PO design specification and industry/military specifications need to be flowed-down.

4. Now that the flow-down has worked as it should, the product reaches electrical test and is ready for screening. If proper flow-down has been achieved the technicians will have the important information available for processing:

A. Part number
B. PO number
C. Order number
D. Date code
E. Performance class requirement
F. Voltage, continuity and isolation requirement
G. Indirect vs direct testing directive
H. Serialization requirement
I. Military requirement (if applicable)
J. Dielectric breakdown requirement

5. When ET is complete and the product goes to final inspection prior to shipping the flow-down information can be reconciled to the original PO and design specifications. The requirements have been flowed-down through the entire process so no required information is lacking. The product ships on time and little Johnny from step 1 (remember him?) receives his birthday gift on time and in perfect condition and working order. **PCB**

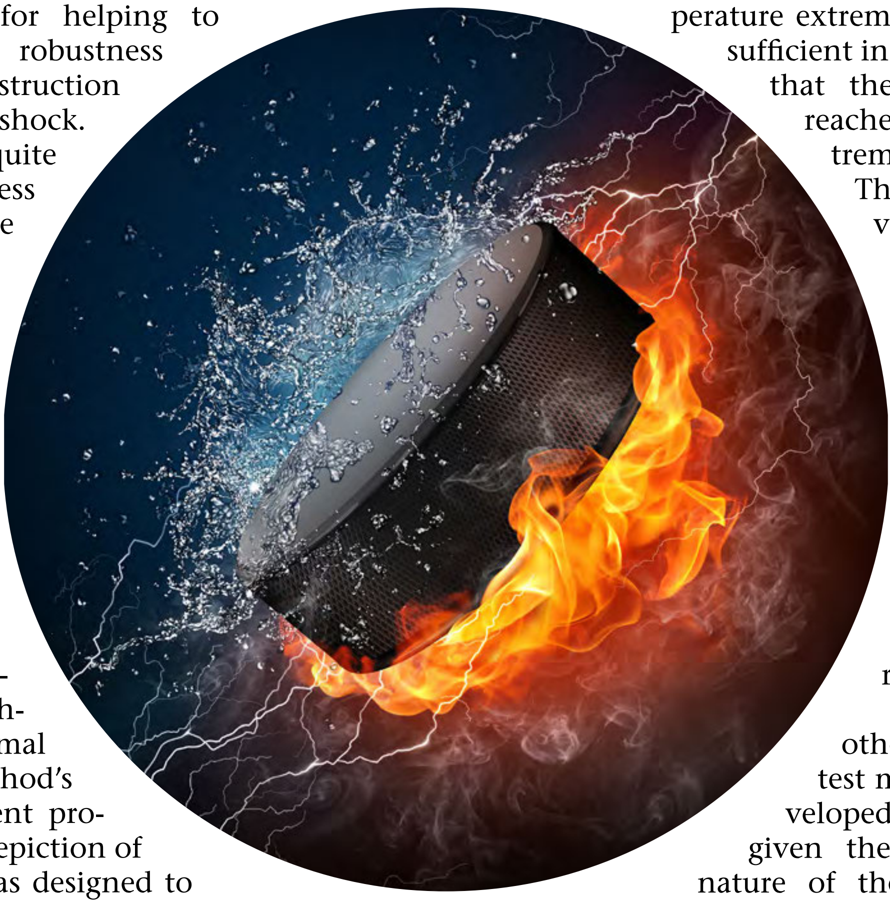
Todd Kolmodin is the vice president of quality for Gardien Services USA, and an expert in electrical test and reliability issues. To read past columns, or to contact Kolmodin, click here.

You're in for a (Thermal) Shock!

by Keith M. Sellers
NTS-BALTIMORE

Printed circuit board history stretches back to the early 1900s, with real promise shown in the industry after World War II. Through the 1940s, 1950s, and 1960s, PCB construction really started to progress when fiberboard and wood were replaced with resins and laminates, and rivets replaced early plated through-holes. As the industry grew, IPC, the worldwide printed circuit board trade association, had its first meeting in the late 1950s.

It was around this same time that the idea of testing printed circuit boards became a real discussion topic, and one of the first tests explored for helping to determine the robustness of a PCB's construction was thermal shock. The premise is quite simple: apply stress and strain to the PCB via exposure to hot and cold temperature extremes.



One of the first methods developed for this type of testing, but geared more towards any type of test sample, was MIL-STD-202, method 107—Thermal Shock[1]. The method's purpose statement provides a perfect depiction of what the test was designed to do: "This test is conducted for the purpose of determining the resistance of a part to exposures at extremes of high and low temperatures, and to the shock of alternate exposures to these extremes, such as would be experienced when equipment or parts are transferred to and from heated shelters in arctic areas."

Further inspection of the test document describes thermal shock testing with the use of both environmental chambers as well as liquid baths. For the latter topic, the method even provides some guidance as to what type of fluid can be used, as water is obviously not a suitable fluid for all the temperature test conditions that are listed. Also in the document is a table which provides some knowledge about dwell times. The dwell time is the duration that the test specimen is exposed to a given temperature extreme and should be sufficient in length to ensure that the test specimen reaches the desired extreme temperature. The table itself provides some guidance on this topic relating the dwell time to the test sample's weight. I would highly recommend perusing this table to educate yourself on the industry-accepted durations.

Over time, other thermal shock test methods were developed, but ultimately, given the uncomplicated nature of the test, they all ended up being incredibly similar. Circling back to IPC, interested committee volunteers also took it upon themselves to develop some thermal shock test methods that are directly related to PCB construction. Two of the


UCE
WET PROCESS LINE
Etchers
Scrubbers
Developers
PTH
Oxide Replacement
THIN CORE HANDLING • PC CONTROL • RELIABLE • LOW COST
CLICK TO VIEW OUR UCE WET PROCESS LINE
The leading European PCB Equipment and Parts Supplier
www.vikingtest.com
sales@vikingtest.com
Viking

more common test methods are: IPC-TM-650, method 2.6.7—Thermal Shock & Continuity, Printed Board[2] and IPC-TM-650, method 2.6.7.2—Thermal Shock, Continuity and Microsection, Printed Board[3]. Each of these methods, and others developed by committee members within the IPC-TM-650 test methods manual, pair the thermal shock exposure with some type of analytical testing to allow for an evaluation of the PCB's ability to withstand the stress.

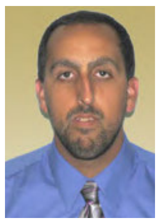
Anyone who has performed or contracted thermal shock testing knows that the process can be drawn out. As mentioned earlier, the exposure is certainly not complicated; however, the laws of thermodynamics can only be "pushed" so much as thermal mass and heat transfer limitations can greatly lengthen a given thermal shock test.

As an improvement on this drawn-out test protocol, a technology referred to as HATS (highly accelerated thermal shock) was developed. The idea behind the advancement was to speed up the traditional thermal shock test by decreasing the time needed for the test samples to reach the desired temperature extremes. Specially designed test coupons are needed, which could be a deterrent for those that would prefer to test their actual product; however, they are necessary for the equipment's setup and, ultimately, to achieve the faster test time.

In the end, the idea of thermal shock testing is not new and the exposures themselves are all fairly similar across all the various test methodologies. Further, advancement in the test theory has been minimal over the years given its simplistic nature, other than the development of HATS testing which also has its detractors. Ultimately, the "during" or "pre/post" exposure evaluation is the truly critical part of this realm of testing. Being able to detect, locate, and then understand any failure that you've experienced as the result of the testing—that is of real benefit to the tester. And this sentiment holds not just for PCB test samples, but for any type of test specimen that is exposed to thermal shock testing. If there is no metric that your test sample is being held accountable to, then why did you perform the test to begin with? **PCB**

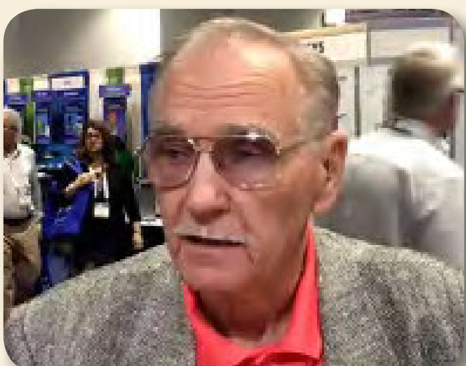
References

1. Department of Defense Test Method Standard: MIL-STD-202
2. IPC-TM-650 Test Method 2.6.7A
3. IPC-TM-650 Test Method 2.6.7.2B



Keith M. Sellers is operations manager with NTS in Baltimore, Maryland. To read past columns or to contact Sellers, click here.

RTW IPC APEX EXPO: HDPUG's Jack Fisher Discusses Updates on Optoelectronics Project



Conventional copper electronic interconnect faces fundamental obstacles that prevent it from meeting increasing bandwidth demands. Optical PCB technology had been researched for several years, but significant issues remain before it can be commercialized. The HDPUG Optoelectronics project set out to demonstrate that optical waveguides incorporated within a backplane could benefit the system's interconnect topology. HDPUG facilitator Jack Fisher explains that a demonstrator has now been built and is currently under test at a number of leading OEMs.

Click here to view the interview.


Universal
Direct Image Solder Mask
Established in production on a wide variety of direct image machines including:
• Chime Ball Technology
• Ledia
• Limata
• Miva
• Orbotech
Diamond™, Nuvogo™ & Paragon™
• Schmoll Maschinen
www.electrapolymers.com
ELECTRA
EMP110 DI
Liquid Photoimageable Soldermask for Direct Imaging.
"The exposure speed of the EMP110 DI coloured soldermask versus the fine feature capability was perfect for our production needs"
Intec tiv, Slovenia - Schmoll MDI
"Electra EMP110 DI has been widely accepted by Amphenol Invotec's blue chip customer base and going forward Amphenol Invotec will look to EMP110 DI to be the soldermask of choice"
Amphenol Invotec, UK - Ucamco Ledia SD-53
"Electra's optimised soldermask exceeded expectation in quality, cosmetics and speed on the Nuvogo™ 800 DI system at Print Electronics."
Print Electronics, Israel - Orbotech Nuvogo™
"Electra EMP110 DI solder mask passed all requirements of our extensive testing process, including Cogra's fine line requirements and fast exposure speed to meet our quick turnaround production"
Cogra Pro AB, Sweden – Miva 2605L Duo
"The versatility and reliability of the EMP110 DI to run on our 3 direct imaging machines gives us the flexibility needed for our specialist PCB's"
Stevenage Circuits Ltd, UK – Limata UV-R, Orbotech Nuvogo™ and Paragon™
"Cipsa circuits extensively tested and approved Electra EMP110 Direct Image soldermask for use with the Nuvogo 780 system, thanks to its fast exposure and fine resolution capabilities."
Cipsa Circuits, Spain - Orbotech Nuvogo™

Copper-to-Copper Peeling

by Michael Carano
RBP CHEMICAL TECHNOLOGY

Introduction

Yes, it is annoying, even critical. Your customer returns product to you complaining about poor adhesion of plated copper to the surface. So what is the genesis of this defect? Is it electroless copper peeling from base laminate copper? Or is it electrolytic copper peeling from the electroless copper? One can experience copper peelers in pattern plating, panel plating or in electroless copper. Peeling can be seen on the conductors, within the PTH or in the microvias. Thermal excursions will exacerbate the problem as thermal stresses will increase the opportunity for one layer of copper to separate from another. As is often the case, separation of the copper from the post interconnect (aka interconnect defect) is considered peeling. However, I have presented ICD issues in previous columns, so this month the focus is on copper-to-copper peelers.

Electroless Copper Peeling

First, one must consider achieving good electroless copper-to-copper foil adhesion. One must start with a copper foil surface that is free from oxides, soil greases and other organic materials. In addition, a micro-etching solution, whether it be persulfate or peroxide-sulfuric acid-based, should be used to ensure a clean and active copper surface that will provide sufficient surface roughness to promote and enhance adhesion of the copper to the surface. Not to be forgotten is the need to get solid bond of the electroless copper to the innerlayer copper (post innerconnect) and to the capture pad of a blind via.

In previous columns, I described several reasons that electroless copper could separate from the foil copper, copper interconnect and/or copper capture pad. One such cause is the use of a particular type of cleaner-conditioner

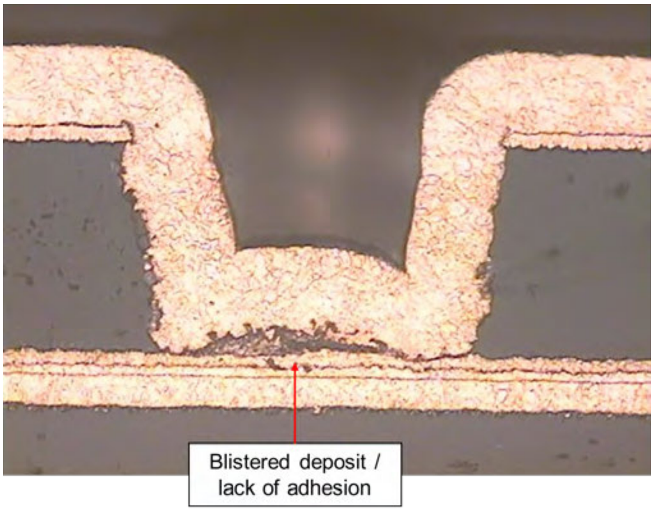


Figure 1: Plated copper blistering from capture pad. (Source IPC-9121)

prior to the electroless copper deposition process. Some of these chemicals, while helping to promote strong palladium catalyst adsorption to the surface, may also leave a surfactant-like film on the copper. This film in turn will act as an adhesion barrier, causing the copper plated deposit to peel from the foil copper. One suggestion is to carefully evaluate any cleaner-conditioner to ensure compatibility with the electroless copper.

There are other possibilities that would lead to this type of adhesion failure. One such failure mechanism is related to resin smear remaining on the capture pad of a blind via. Figure 1 shows significant blistering of the copper from the blind via capture pad most likely due to resin. One way to fix this issue is to design the laser process to ablate the resin material down to the capture pad. Even with this scenario, the concern with UV YAG is that once the beam reaches the copper pad, the energy is "stepped down" to minimize further attack on the copper pad. This can lead to resin and ablated byproducts to remain on parts of the pad. In turn this provides a mechanism for adhesion failure. Any remaining resin material can act as a fulcrum, forcing the plated copper to peel.

Pattern Plating Copper-to-Copper Peeling

There are many reasons for electrolytic copper to peel or fail to adhere to the electroless copper deposit. However, one must understand the process in general. For example, is this a panel plating process or pattern plating? Are we looking at a flash (low thickness electrolytic) copper separation or is the issue related to a full thickness of plated copper? This is important to keep in perspective as one troubleshoots the defect.

With respect to pattern plating, one of the most common reasons for copper-to-copper peel is photoresist residues that were not completely removed during the developing process step.

There are many reasons for this—but none of them are excuses! If the defect is clearly electrolytic copper peeling from electroless copper, and the fabricator is employing pattern plating, the first order of business is to examine the surface preparation and developing operations. This includes surface prep, resist lamination, exposure and development.

Surface prep

At this point, with thin coating of fragile electroless copper on the surface and in the via, one must not over-prep the surface for fear of creating a void in the thin deposit. It is suggested that to widen the process window to prevent voiding from etching, a very thin electroless copper deposit can be followed with an electrolytic copper flash plate. Typical thickness of 100–150 microinches would add protection from the possibility of etch voids. This step is performed immediately after electroless plating and prior to resist coating and imaging.

As an aside, this author prefers an electroless copper process that delivers 40–60 microinches. In this case, there is no need for flash plate. In addition, one can be more aggressive in the pat-

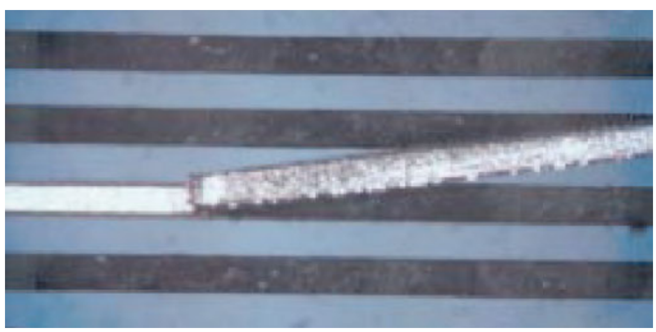


Figure 2: Copper-to-copper peelers.

tern plate micro-etch to ensure optimum plating adhesion.

Developing

Another possible source of copper-to-copper peelers has its genesis in the resist developing process. These are:

- Over-developing
- Under-developing
- Poor rinsing after developing
- Excessive hold time between resist lamination and develop

With respect to overdeveloping, check the temperature of developing as well as the pH level in the developer solution. Higher pH and temperatures can lead to overdeveloping. This in turn leads to the potential for the exposed resist to leach from the side walls and onto the surfaces to be plated. In addition, one can manage the breakpoint of developing to occur further along in the chamber.

Under-developing will result in resist residues and adhesion promoters remaining on the copper surface. Again, adjust the breakpoint to insure sufficient removal of the unexposed resist. Adjust developer pH and operating temperature per suppliers' recommendations.

At the end of the day, chemical processing of printed circuit boards requires good rinsing with a high quantity of high-quality water. The alkaline nature of resist developing solutions requires warm water rinses as alkaline residues do not rinse very well. A good rule to follow to achieve adequate rinsing is the rinse chamber length should be at least 50% of the developer chamber length. Counterflow rinsing with two, if not three, rinse chambers using incoming tap water is also recommended. Counterflow rinsing will help reduce the pH of the first water rinse. Typically, the first rinse will have the highest pH due to dragout from the developer chamber.

Finally, do not underestimate the hold time between lamination and developing. Excessive hold times (usually 12–14 hours or more) will lead to resist lock-in. This results in difficult to remove resist further increasing the tendency to cause copper-to-copper adhesion failures. If this is the case, a more aggressive acidic cleaner is required.

Summary

Follow good shop practices in terms of surface preparation, electroless copper plating thickness and resist developing parameters. Optimal surface preparation utilizing cleaners and micro-etches is critical to eliminating copper-to-copper peeling. In addition, over- and under-developing create their own set of process constraints. Pay very close attention to developer pH, operating temperature and break point.

Finally, rinsing after develop with warm tap water is necessary to remove alkaline residues lurking on the resist sidewalls and traces. PCB

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

100 Days In: President Trump and a Better Manufacturing Policy

by John Mitchell
IPC—ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

On the campaign trail and since coming to office, Donald Trump promised to bring manufacturing jobs back to the United States.

Since coming to office, he has followed through on this pledge by announcing his Manufacturing Jobs Initiative[1], which will draw on input from a council of more than two dozen U.S. executives and CEOs. He has also directed agencies to support the expansion of manufacturing through reducing regulations.

While these were welcome early measures, there is a world of difference between simply announcing an advisory council and reviewing regulations, vs. pursuing more meaningful measures that will truly advance the industry.

This month's column will focus on three concrete policy initiatives the Trump Administration should consider to truly help strengthen manufacturing in the United States. The lessons—in broad strokes—are just as applicable to governments worldwide as well.

One hundred days into his presidency, President Trump must begin to face the reality that the vast majority of the 5 million U.S. manufacturing jobs lost since 2000 can be attributed not to offshoring, but to automation.

In fact, a 2015 study by researchers at Ball State University, "The Myth and Reality of Manufacturing in America"[2] found, "Almost 88% of job losses in manufacturing in recent years can be attributed to productivity growth…" chiefly "…automation and information technology advances." U.S. manufacturing output today is as at an all-time high, but the industry has far fewer workers because productivity has doubled since 1994.

Photo: Gage Skidmore, Wikicommons

This increase in productivity and automation is not limited to the United States, but is part of a seismic shift affecting our electronics industry worldwide. Today's manufacturing relies on high-skilled labor, digital tools, and customized automation that increases outputs and reduces costs. Thus, the first step to advancing U.S. manufacturing is to create a policy framework that fosters today's manufacturing industry.

Specifically, the Trump administration should focus on three areas:

- **Apprenticeships**—Increased apprenticeship programs for manufacturing workers.
- **Early STEM Education**—Promote STEM education in primary and secondary schools.
- **Federal Research Funding**—Increase federal support for research, development and commercialization of advanced technology through public-private partnerships.

Apprenticeships

Recent surveys have shown that more than 80% of manufacturing executives believe there is a talent shortage in the United States. Similar statements are heard around the globe. Openings for U.S. manufacturing jobs last year averaged 353,000 per month, up from 311,000 in 2015 and 122,000 in 2009.

A viable solution to this talent shortage is to establish a robust program of apprenticeships, funded and led by public-private partnerships. This model works well in Germany, where companies including Siemens and Bosch use apprenticeships to train their workers in advanced engineering and manufacturing.

Such apprenticeship programs exist in the United States, but on a much smaller scale. ApprenticeshipUSA[3] is a public-private partnership aiming to ramp up this neglected sector of education. Surely the executive producer of "The Apprentice" should support business-led apprenticeship programs.

The U.S. Department of Labor reports that 87% of apprentices in the United States receive employment offers following their training programs[4]. Further, workers who complete apprenticeships earn $50,000 per year on average[5], or higher than the median U.S. annual wage of $44,720.

Early STEM Education

But support for widespread vocational apprenticeship programs will require more than just political support and funding. A wider understanding of advanced manufacturing today and the advanced skills required to work in those industries would help de-stigmatize U.S. vocational education, which many view as a last resort for those students not adequately equipped for traditional college.

This could start with a broader focus in building foundational STEM skills in early childhood education. Without a robust pipeline of students prepared to pursue advanced STEM education in vocational schools or universities, there won't be talent available for the jobs we're trying to create.

As Ball State professors Dr. Michael Hicks and Srikant Devaraj conclude in their study, "The Myth and Reality of Manufacturing in America":

> *The nation and individual states should actively support education reforms at the secondary and tertiary level that prepare students for employment opportunities in manufacturing, which will be large due to job turnover among the baby boom share of the manufacturing labor force. …Human capital interventions should also begin at the pre-K level, focusing on skills that enable acquisition of the mathematical and cognitive skills required of the modern manufacturing workforce[2].*

Federal Funding

If President Trump truly wants to return manufacturing jobs to the United States, his first focus should be on investment in research and development of new technologies that will keep America at the forefront of advanced manufacturing.

The Obama administration and Congress made a valuable contribution by establishing Manufacturing USA[6], formally known as the National Network for Manufacturing Innovation. Established with bipartisan congressional support in 2014, and led by the National Institute of Standards and Technology, Manufacturing USA brings together industry, academia and government in a network of public-private partnerships designed to accelerate manufacturing innovation.

For example, my organization—IPC, representing the electronics industry—is active in NextFlex[7], a consortium of companies, laboratories, and government agencies that work together to foster the growth of the flexible electronics supply chain. Unlike traditional rigid circuit boards, flexible circuits embedded in fabric or film will pave the way to innovations such as medical implants that conform to bones and organs; lighter communications gear built into military uniforms; and solar cells on a roll of plastic.

Other Manufacturing USA institutes are focusing on hot areas such as 3D printing, lightweight materials, and advanced semiconductors. Taken together, these organizations will unleash wave after wave of innovation and growth in the manufacturing sector.

Thus, the Trump administration would do well to continue advocating for public-private partnerships, and urge Congress to spare Manufacturing USA from budget cuts.

Conclusion

To truly increase the number of American manufacturing jobs, President Trump should support increased investment in research and development for advanced manufacturing, promote and fund STEM education in primary and secondary schools, and build stronger apprenticeship programs. It is this type of investment—in human capital and technology—that will truly help make American manufacturing great again.

Special Note

It is time for the PCB manufacturing industry to present a united front and make our voices heard. On May 1–3 top executives from leading electronics companies plan to do just that as they gather in the nation's capital for IMPACT Washington, D.C. 2017. Join us as we advocate for a better public policy framework for our industry. For more information on this event, please visit our website. **PCB**

References

1. President Trump Announces Manufacturing Jobs Initiative
2. Ball State University, The Myth and Reality of Manufacturing in America
3. ApprenticeshipUSA
4. U.S. Dept. of Labor: ApprentiticeshipUSA
5. U.S. Dept. of Labor: Apprenticeship Quick Facts
6. Manufacturing USA
7. NextFlex

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

MilAero007 Highlights

Gary Ferrari Earns Dieter Bergman IPC Fellowship Award

In recognition of his ongoing leadership in developing and promoting IPC standards on a global basis, IPC bestowed the Dieter Bergman IPC Fellowship Award upon Gary Ferrari of FTG Circuits.

Imagineering CEO Khurrum Dhanji Discusses New AS9100 Guidebook

I have had many conversations with Imagineering President and CFO Parvin Dhanji, and CEO Khurrum Dhanji, and I always come away very impressed with their dedication to their community, associates and their customers. That's why it was no surprise to me that they teamed with I-Connect007 to publish this long overdue guide to AS9100.

Opinion: Robots and AI Could Soon Have Feelings, Hopes and Rights ... We Must Prepare for the Reckoning

Is artificial intelligence a benign and liberating influence on our lives—or should we fear an impending rise of the machines? And what rights should robots share with humans? Christopher Markou, a PhD candidate at the Faculty of Law, suggests an urgent need to start considering the answers.

Beware the Killer Robots

Autonomous weapons have moved from science fiction to become a clear and present danger. But there is still time to stop them. In July 2015, thousands of researchers working in artificial intelligence (AI) and robotics united to issue an open letter calling for a pre-emptive ban on such weapons.

IPC Volunteers Honored for Contributions to Electronics Industry at IPC APEX EXPO

IPC—Association Connecting Electronics Industries presented Committee Leadership, Distinguished Committee Service and Special Recognition Awards at IPC APEX EXPO at the San Diego Convention Center. The awards were presented to individuals who made significant contributions to IPC and the industry by lending their time and expertise through IPC committee service.

American Standard Circuits' John Rupp Certified as Quality Lead Auditor for AS9100D

American Standard Circuits CEO Anaya Vardya has announced that the company's Quality Systems Manager, John Rupp, has earned his certification as a quality lead auditor for AS9100D.

PCB Maker IMI Installs Micro-Vu Excel Measuring System

IMI Inc. announced today that they have acquired and installed a Micro-Vu Excel 661 UCL Measuring System. This sophisticated machine will complement IMI's current Micro-Vu inspection system and overall inspection, test and measurement capability.

NASA Taking First Steps Toward High-speed Space 'Internet'

The Laser Communications Relay Demonstration (LCRD) will help NASA understand the best ways to operate laser communications systems. They could enable much higher data rates for connections between spacecraft and Earth, such as scientific data downlink and astronaut communications.

Electronics Industry Experiences Technology's Turning Point at IPC APEX EXPO 2017

From revolutionary advancements displayed on the show floor to expert insights conveyed in technical conference sessions and professional development courses, IPC APEX EXPO 2017 provided the learning and connections that helped 4,169 attendees from 39 countries prepare for the future.

Next Generation of Nuclear Robots Will Go Where None Have Gone Before

The cost of cleaning up the UK's existing nuclear facilities has been estimated to be between £95 billion and £219 billion over the next 120 years or so. The harsh conditions within these facilities means that human access is highly restricted and much of the work will need to be completed by robots.

Nasty News Releases

by Barry Lee Cohen
LAUNCH COMMUNICATIONS

Since leaving my corporate digs a year ago and launching my "new wonderful[1]," I've had the pleasure to evaluate, enjoy and envy insightful communications by some of the world's best technology companies. From new appointments and facilities, to recent product innovations and event announcements, I admire the professionalism and relevance of these news releases that populate my inbox.

Yet, for every well-crafted news release, there seems to be an avalanche of announcements that are confusing, grammatically gross, and less than awe inspiring. It's alarming that companies with the absolute best intentions to inform, arouse curiosity, and excite are inadvertently casting a dark shadow on how their brand is being perceived by their targeted readership.

The news release is well underestimated in importance. In this digital world where content is king[2], a news release is deemed "old school" or little more than a device to support search engine optimization (SEO). Strategic message development, thoughtful composition, and optimizing the overall benefits of a news release are often relegated to a quick and dirty "just get 'er done" document.

If you've read this far, I expect you're feeling more than a little guilty. Me too! Besides my Jewish heritage that innately predisposes me to guilt, I admit to being a party to more than one nasty news release. The following is a partial listing of best practices to rid us of the nasties.

Blast Off

• **News Release 101—The Basics:** Hire professionals to write your news releases. They possess the knowledge and passion—yes, passion—to favorably showcase your company. If this is not deemed feasible, the primary author should make it a priority to understand and learn how to execute the Five Ws[3]. This includes the necessity to reference sources. One of the best investments I ever made was purchasing an *Associated Press (AP) Style Book* for my first undergraduate journalism course. The AP and other credible style guides are reissued regularly

New ON IPC EDGE

IPC Provides ESD Certification For Trainers and Operators

Why is ESD certification important?

- Dual certification program from IPC and EOS/ESD Association, Inc.
- Third-Party Certification verifies technical competence and problem-solving ability
- Third-Party Certification facilitates uniform ESD control
- Certification confirms that high standards are met
- In compliance with ANSI/ESD S20.20
- In compliance with training requirements for MIL-Spec.-1686
- In compliance with IEC61340-5-1
- Fills a training gap within the electronics industry

Learning Objectives

- Covers basic ESD theory/physics
- Covers advanced theory for trainers
- Provides strategies to protect increasingly sensitive components
- Provides technical requirements for operator training
- Operators learn basic theory from the online course
- Operator-led classroom training by certified trainers

ESD certification can be found on IPC EDGE, the industry's leading online education portal: edge.ipc.org.

Contact ipcmail@ipc.org with your questions.

IPC EDGE Online Education and Training for the Electronics Industry

IPC EDGE

to accommodate new standards, accepted vocabulary, best practices and digital platforms. These guides help to ensure your news release is properly formatted and communicates essential content correctly.

• **Hitting Headlines:** You're expending the resources to publicize a major accomplishment or new service. Don't be bland about it! Your headline should include a key benefit that is meaningful to your readership. The headline is critical to encouraging editors to consider your story for publication and enticing your customers and prospects to read the release itself. Note: Sub-headlines should also be considered to support the headline and sell the story.

• **Why Should I Care?** This is the very first question that should be addressed before composing any news release. The "I" refers to your targeted readership. The news release should focus upon facts that are truthful, understandable and relevant to your markets and customers. Don't dilute your message with secondary subject matter. What if the news is applicable yet has a unique relevancy to more than one market or customer type? In some select cases, composing a separate news release with a different emphasis is highly beneficial. However, multi-releases must be carefully managed to safeguard your media and customer distributions against redundancy and furrowed eyebrows.

• **Consider Quotes:** Quotes from senior management or an authority on the subject matter add further credibility. It also contributes to creating thought leadership. However, puffery dulls the message, as does being overly commercial. Any quotes should introduce or further detail the key message and value proposition of your opening paragraphs.

• **Pictures Are Perfect:** Photos, infographics or other images should be included and increase readership. If you're stating statistics, make them stand out with a graphic. Given that the news release will be repurposed to differing degrees for other print and digital materials, such imagery is often easily transferable and informative for these complementary tactics.

• **Number Crunching Counts:** Backing up your claims with data engages readers to keep reading! Percentages, ranges, and hard numbers all should be considered as part of your news release.

• **Cut the Corporate Commercials:** Of course, you should include information about your company, but don't overdo it. Some companies feel the necessity to elaborate on corporate divisions within the main release content. These mini-commercials are sometimes introduced to appease the corporate brass or there is a very shaky assumption that it increases SEO. Instead, it potentially distracts readers who may become confused, tune out and stop reading altogether. Save the corporate background for the closing "About" section, also known as boilerplate.

• **Social Sharing:** After publishing the news release on your website and distributing to targeted media, a brief announcement *linking* the news release to your company's social media channels is highly beneficial. When applicable, also link the news release to relevant corporate blog articles. As previously stated, this drives visitors to your website and supports SEO. Furthermore, encourage team members to share these postings on their own channels. If you're introducing a study or guide, landing pages are often recommended to allow you to obtain visitors' contact information prior to literature download.

• **Call to Action:** Make sure to provide a dedicated email address for readers to request further information. The email address should be vigilantly managed by someone with the knowledge to respond to or forward inquiries for a timely response.

• **Proofread:** You think you're finished with your masterpiece. Your adrenalin is pumping. You're aching with excitement to click that mouse and announce to the world your wonderful news. While counting down to blast-off, less than heroic flaws in grammar and terrible typos are suddenly discovered. Abort launch! Although you've proofread the release a dozen times, it's always important to have another set of eyes review the news release for grammar, typos, and overall comprehension.

No matter how relevant, a news release with gross grammar, flawed formatting and other errors translates as being sloppy, rushed, and unprofessional. It reflects badly on your company's brand. Don't let nasty news releases repel readers. Consider these best practices to compel customers and prospects to learn how your company creates value. **PCB**

References

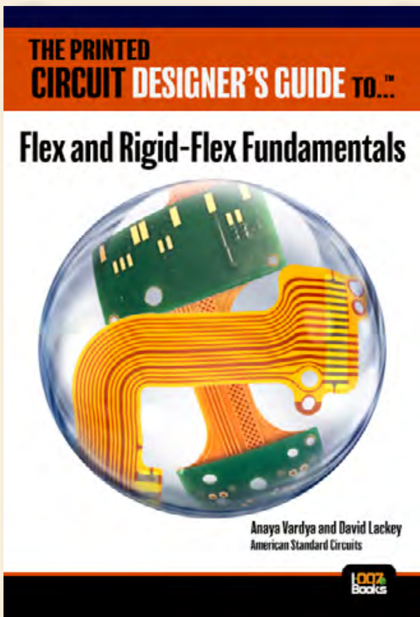
1. *The Launch of a Lifetime: Catching up with Barry Lee Cohen.*
2. Sumner Redstone, circa 1995.
3. Wikipedia, The Five Ws.

Barry Lee Cohen is president and managing director of Launch Communications. To read past columns or to contact Cohen, click here.

I-Connect007 Launches New Micro eBook in Design Series for Flex and Rigid-Flex

I-Connect007 is excited to announce the release of a new offering in our micro eBook series: *The Printed Circuit Designer's Guide to…Flex and Rigid-Flex Fundamentals.*

The Printed Circuit Designer's Guide to… is an ongoing series of micro eBooks specifically dedicated to the education of PCB designers. This book series will become the gold standard for people seeking the most relevant information available.



The latest title in this new line of eBooks, *The Printed Circuit Designer's Guide to… Flex and Rigid-Flex Fundamentals,* is authored by Anaya Vardya and David Lackey of American Standard Circuits. This micro eBook provides both new and seasoned circuit designers with valuable, important information that will help to assure first-pass success in getting their products to market.

"We have found that when we are working with companies who need flex and rigid-flex PCBs, the best course of action is to work closely in partnership with them to make sure we give them the very best value in flex and rigid-flex PCBs," said Lackey. "We want to make sure our customers get exactly what they need for their end-products."

Added Vardya, "This guidebook is based on the many conversations we have had with our customer partners helping them to gain a better and more complete understand of this technology. We also consider this American Standard Circuits' gift to the industry. This unique guidebook will be available to everyone through a free download on our eBook website."

This eBook has something for everyone; in addition to guidance on key callouts, design considerations and material sets for optimum manufacturability, there are plenty of dos and don'ts for fabricators, cost drivers for OEMs, and key information on data package requirements for contract manufacturers.

To download this book for free, click here.

Executive Agent for PCB and Electronic Interconnect Technology PrCB Trust Accreditation

By Steve Vetter, NAVAL SURFACE WARFARE CENTER—CRANE DIVISION;
Richard Snogren, BRISTLECONE LLC;
and John Timler, Ph.D., SAIC

Abstract

Within the Department of Defense (DoD) supply chain, trust and trusted have become widely used terms and concepts. Department of Defense Instruction (DoDI) 5000.02, Operation of the Defense Acquisition System, and DoDI 5200.39, Critical Program Information Identification and Protection Within Research, Development, Test, and Evaluation, establish the requirements for the Program Protection Plan (PPP) to manage risks to advanced technology and mission-critical systems' functionality throughout the acquisition lifecycle[1-2]. DoDI 5200.44, Protection of Mission Critical Functions to Achieve Trusted Systems and Networks defines the protection of mission critical functions to achieve trusted systems and specifically calls out printed circuit boards (PrCBs) as a component of these systems[3].

The Executive Agent for Printed Circuit Boards and Interconnect Technology (PrCB EA) has been chartered to develop a trusted network of PrCB supply chains, including design, manufacture, and assembly, and therefore is creating the PrCB Trust Accreditation. The PrCB EA has established that in the DoD supply chain for national security systems, trusted status is assigned to a supplier of PrCB related products and/or services when that supplier has consistently demonstrated the ability to meet specified requirements for quality, supply chain management, chain of custody (CoC), and security.

This paper describes the drivers of PrCB Trust Accreditation for the design, manufacture, and assembly of PrCBs and PrCB subsystems. The methodology used to establish the accreditation system and the status of that system are also discussed. This accreditation leverages existing process structures developed and fielded by Defense Logistics Agency (MIL-PRF-31032/55110), Defense Microelectronics Activity (DMEA) (Trusted Supplier Program), and the Association Connecting Electronics Industries (IPC) specifications and standards[4-7]. The accreditation places an emphasis on integrity assurance, where historic emphasis targeted quality and reliability.


Get the spark you need
to tune up your sales team.
When an engine doesn't fire on all cylinders, performance is limited. The same goes for your sales team. We provide the spark to get your sales to the next level ...and beyond.
We've helped dozens of companies big and small improve their bottom line.
db MANAGEMENT GROUP
Learn how we can help YOU
207-649-0879
danbbeaulie@aol.com

Insights into the structure of the proposed process methodologies, how the existing structures will be leveraged during the transition toward full implementation, what a potential ideal end-state might look like, and status for the effort are provided.

Introduction

To strengthen the U.S. PrCB industrial base and DoD supply chain for national security systems, the PrCB EA is developing and implementing a PrCB Trust Accreditation process for PrCB manufacturers and service providers. The motivation for this initiative comes from the National Research Council's 2008 Report to Congress[8] and is further based on DoDI 5200.44[3]. In addition to establishing a trusted DoD electronics supply chain, the initiative aims to provide cost savings to both DoD and industry through a standard trust accreditation process that leverages compliance with relevant commercial standards, eliminates redundant audit functions, and increases competition for DoD work.

As technology progresses and DoD systems become further reliant on electronics, the trust accreditation process will be critical for securing the DoD PrCB industrial base going forward, especially in the context of cloud computing and the internet of things where information security and system security have become even more entangled. In the scope of the above rational, trusted status is assigned to a supplier of PrCB related products and/or services when that supplier has consistently demonstrated the ability to meet specified requirements for quality, supply chain management, CoC, and security.

PrCBs and assemblies provide the mechanical infrastructure and electrical interconnects that serve as the foundation of all electronic systems. Key PPP elements are quality, availability, security, and CoC—all of which directly impact program schedules, life-cycle cost, performance, and reliability. DoDI 5000.02 and DoDI 5200.39 establish the requirements for PPPs to manage risks to advanced technology and mission-critical system functionality throughout the acquisition lifecycle[1-2].

The Defense Acquisition Guidebook (DAG) chapter 13 section 13.2 states the purpose of the PPP is "...to ensure that programs adequately protect their technology, components, and information throughout all phases of the acquisition process including design, development, delivery and sustainment"[9].

DMEA developed the Trusted Foundry Program to satisfy the requirement of DoDI 5200.44 policy for integrated circuits and field-programmable gate arrays (FPGA) which requires programs to "employ protections that manage risk in the supply chain for components or subcomponent products and services (e.g., integrated circuits, FPGA, PrCBs) when they are identifiable (to the supplier) as having a DoD end-use"[3]. To satisfy the same policy requirement, the PrCB EA has developed a PrCB Trust Accreditation process for the design, manufacture, and assembly of PrCBs. The purpose of this accreditation is to support Program Offices in the development of their PPP where PrCBs have been identified as a Critical Technology. The accreditation may also be used in any circumstance where the reliability of PrCB system components has significant impact on program risk.

"The purpose of this accreditation is to support Program Offices in the development of their PPP where PrCBs have been identified as a Critical Technology."

To establish a common basis of terms, the DoD Directive 5101.18E for the PrCB EA has defined the following terms:

Interconnect Technology: Technology associated with all physical connections that provide mechanical, chemical, electrical, optical, sonic, or thermal linkages between a pairing of individual components, integrated circuits, electronic subassemblies, or the application environment.

Printed Circuit Board (PrCB): The foundation for all electronic equipment which both mechanically supports and provides electrical connections between electronic components using conductive traces, usually etched from copper sheets laminated onto a non-conductive substrate. The acronym "PCB" is used interchangeably with PrCB in industry.

Trustworthiness: The inherent confidence in a particular item as it pertains to quality, reliability, availability, integrity, and technology protection. With reliance on global sources of supply growing across the spectrum of electronic products, confidence in system availability and performance is becoming increasingly difficult. Characteristics of trust range from anti-counterfeit on the supply-end of the lifecycle, to anti-tamper on the protection-end[10].

Within the trustworthiness definition, the context of, "trusted PrCB suppliers" are those that:

1. Deliver products and services that meet the technical performance criteria called out in the relevant procurement contract (quality)
2. Ensure that any threats related to disruption in supply are understood and managed (supply chain management)
3. Provide assured control for data, finished products and in-process material (CoC)
4. Secure their products and services from unauthorized access with a focus on preventing illicit modification, tampering, reverse engineering, exposure of functionality or evaluation of vulnerabilities (security)

The PrCB Trust Accreditation requirement is based on these four elements as they apply to the design, manufacture, and assembly of PrCBs.

Methodology

The DAG describes the PPP as "…the Department's holistic approach for delivering trusted systems and ensures that programs adequately protect their technology, components, and information"[9].

DoDI 5200.39 defines Critical Program Information (CPI) as "Elements or components of a research, development, and acquisition program that, if compromised, could cause significant degradation in mission effectiveness; shorten the expected combat-effective life of the system; reduce technological advantage; significantly alter program direction; or enable an adversary to defeat, counter, copy, or reverse engineer the technology or capability"[2].

DoDI 5200.44 states that "CPI based technologies must be protected from compromise in the development environment and on fielded systems. CPI may include classified information but it may also include Controlled Unclassified Information…. In some cases, (dependent on the Program Manager's determination) a commercial-off-the-shelf technology can be designated CPI if the commercial-off-the-shelf element is determined to fulfill a critical function within the system and the risk of manipulation needs mitigation. CPI requires protection to prevent unauthorized or inadvertent disclosure, destruction, transfer, alteration, reverse engineering, or loss (often referred to as 'compromise')"[3].

It should be clear that information related to PrCB design, manufacture, and assembly may become more commonly determined as CPI given the increasingly complex and highly integrated composition of electronics systems. Therefore, in order to satisfy the requirements defined in DoDI 5200.44 for the "protection of mission critical functions to achieve trusted systems and networks" as related to PrCBs, the PrCB EA has developed the PrCB Trust Accreditation process[3]. The accreditation is based on the successful demonstration of the four trust elements as supported by objective evidence. The accreditation will be based on submission and review of objective evidence to the accreditation authority and a site audit to verify systems and procedures are in place and actively used.

Trust Accreditation

The trust accreditation approach is derived from the DMEA Trusted Foundry program[6]. This program has been active for several years and has been adopted in DoD policy and utilized by Program Offices as needed based on CPI. The scope of the trust definition was modified to better suit the PrCB supply chain. The PrCB supply chain is less affected by classified information and more impacted by controlled unclassified information. Trust as defined in the scope of the PrCB accreditation, consists of four elements, quality, supply chain management, CoC, and access controls.

The requirements for trust accredited PrCB sources starts in the DoD Program Office as illustrated in decision tree shown in Figure 1. Classification is determined once a decision is made that a PrCB is CPI. CPI is the output of the criticality analysis initially performed at a high level by the Program Office early in the product development phase. As the product design becomes more mature, and as the program progresses into engineering and manufacturing phases, the maintenance of the criticality analysis and assignment of CPI may transition to the contractor.

To mitigate the burden of additional requirements being imposed on the supply chain, efforts were made to utilize pre-existing standards and certifications as much as possible to satisfy the requirement. The accreditation process provides all major roles in the PrCB supply chain from PrCB layout design, to bare PrCB manufacturing, through PrCB assembly. The general accreditation flow is common to all roles, but each role may be affected by different requirements as it relates to the four trust elements.

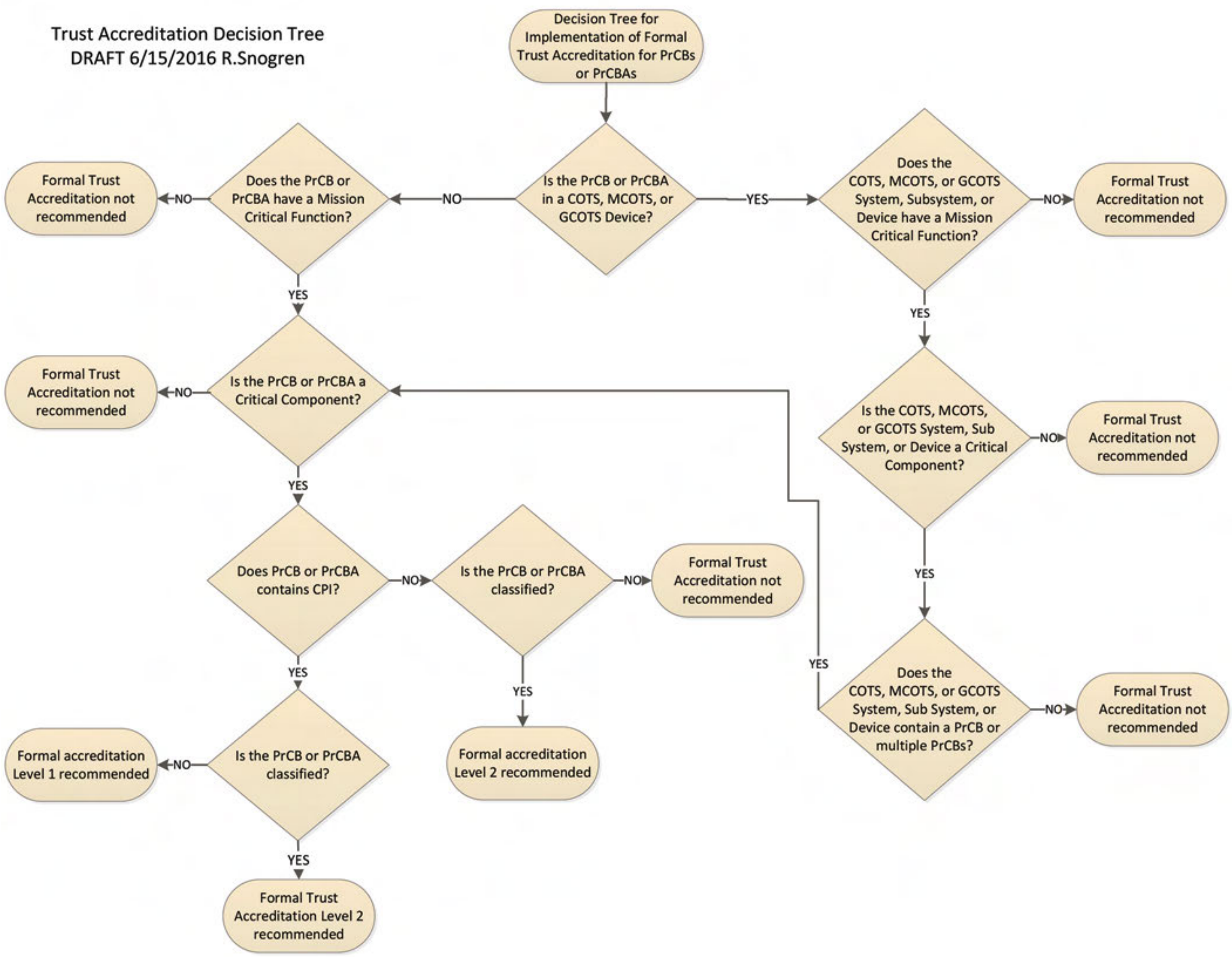


Figure 1: Decision Tree for implementation of Formal Trust Accreditation.

Trust Element	Design	Manufacture	Assembly
Quality	Required: ISO-9100 or AS-9100 Technology Specific: IPC-2221, IPC-2222, IPC-2223, IPC-2225, or IPC-2226	Required: Active Listing on QML-31032 with technology specific slash sheet or AS 9100 certification and at least one of the following technology specific certifications: QPL-55110, QPL-50884, IPC-6011, IPC-6012, IPC-6013, IPC-6014, IPC-6015, IPC-6016, IPC-6017, IPC-6018	Required: IPC-A-610 Required: ISO-9100 or AS-9100
CoC	Required: Develop and maintain a CoC documentation system ensuring and tracking physical security of PrCB data or hardware elements from facility entry to facility exit Required: Maintain a training program for all employees that supports implementation and maintenance of the CoC documentation system		
Supply Chain Management	Required: Develop and maintain a supply chain risk management control plan		
Security Category 1 (supports classified work)	Required: Meet all relevant Defense Security Service requirements – DoD 5220.22-M		
Security Category 2	Required: International Traffic in Arms Regulations (ITAR) registration Required: Maintain compliance with the Export Administration Regulations Required: IPC-1071 Level 3 or compliant to National Institute of Standards and Technology NIST 800-171 or compliant to PrCB EA security requirements		

Table 1: Alloy temperature details.

Table 1 summarizes the applicable requirements and certification options and combinations for the three supply chain roles by trust element. Individual companies may seek trust accreditation (bottom up) or, alternatively, the Prime DoD contractor can contractually impose PrCB EA developed accreditation requirements on their in-house or sub-tier contractors requiring trust accreditation (top down).

Accreditation Process

Bottom Up

Individual contractors may become trust accredited, which is referred to as the "bottom up" process as illustrated in Figure 2. The contractor (applicant) may initiate an application for PrCB Trust Accreditation to the accreditation authority. The application is evaluated and

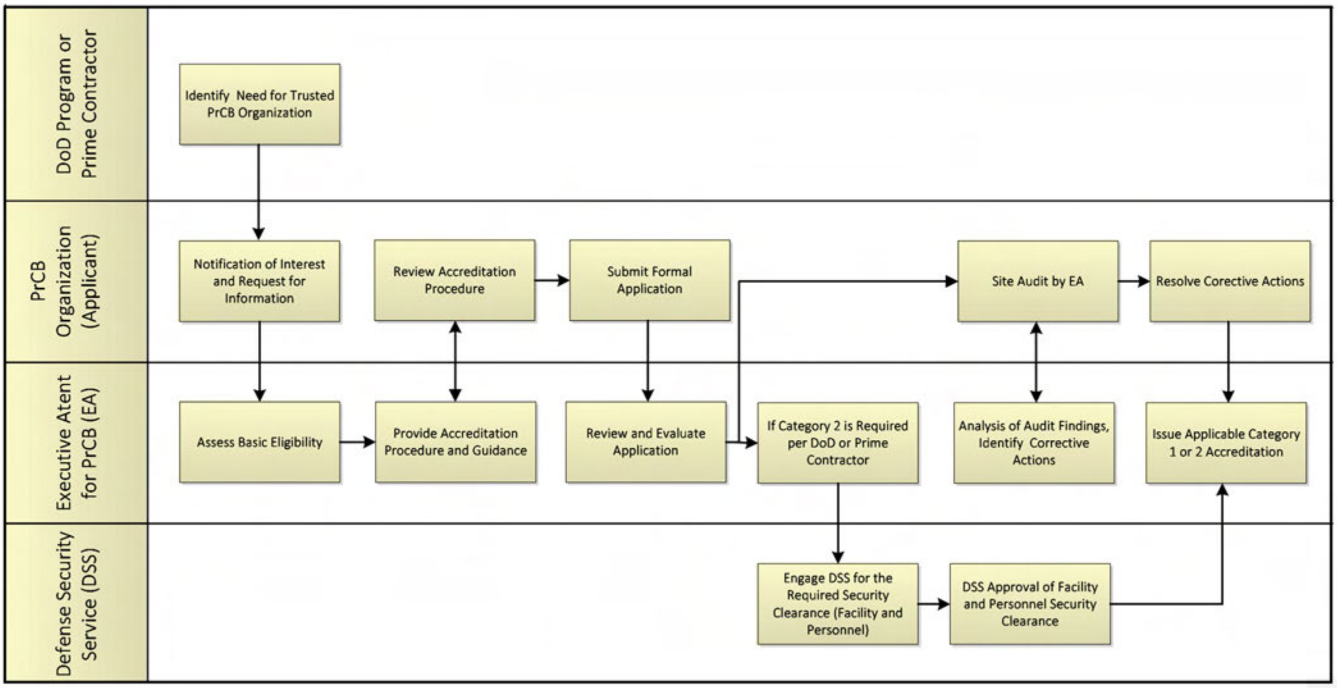


Figure 2: PrCB organization (design, manufacture, assembly) trust accreditation process flow.

based on the specific programmatic need, the flow will follow Level 1 for classified accreditation or Level 2 for unclassified accreditation. In the Level 1 flow, the application is transferred to the Defense Security Service for further action. The Level 2 flow begins with a site audit to ensure the operation of the facility complies with the accreditation requirements. The applicant will also provide objective evidence for review by the accrediting authority to demonstrate that policies, systems, and training are in place and actively utilized.

The trust accreditation is site-specific, since the accreditation requirements entail physical and information system security elements, and many of the certifications packaged to create the accreditation are site specific. At the completion of the audit, the accrediting authority will provide a debriefing of observations and audit findings to the applicant.

The accrediting authority will issue a formal letter within thirty days after completion of the audit, notifying the applicant of either approval, conditional approval with required corrective actions, or disapproval with reasons identified. If the applicant has conditional approval, the corrective actions shall be submitted to the accrediting authority within thirty days after receipt of formal notification of failure, or the application will be canceled. The accrediting authority will issue an official letter of accreditation within thirty days after completion of the audit, and/or verification of satisfactory closure of all corrective actions. Accreditation is valid for three years from the date of approval unless revoked with cause.

The addition, modification, or reduction of PrCB technology capabilities will be documented by an update of the accreditation status through submission of the appropriate objective evidence. The accrediting authority will notify the PrCB design organization of acceptance or rejection of the additional capabilities.

Accreditation may be revoked with cause by the accrediting authority for any of the following reasons:

1. Loss of ITAR registration or failure to keep registration current
2. Loss or failure to maintain AS-9100 or equivalent certification
3. Failure to perform and pass the annual PrCB design organization's internal audit, within the 90-day period prior to

the accreditation anniversary date. Self-identified deficiencies and corrections are acceptable

4. Failure to submit the report of the annual PrCB design, manufacture, or assembly organization's internal audit within thirty days after completion
5. Failure to notify the PrCB EA within thirty days after significant change to management, ownership, process capability, or loss of certification to IPC-1071

An accredited organization will need to conduct annual internal self-audits. Self-audits will be in accordance with a check list of items provided by the accreditation authority. The organization will record and maintain audit results and document any corrective actions necessary, to ensure sustainment of technical capability. The self-audit is intended to be an annual activity within 90 days prior to the accreditation anniversary date. A self-audit report will be submitted to the accrediting authority within 30 days of its completion for review and approval. Failure to submit the annual summary of internal audit activities may result in loss of accreditation.

Top Down

The PrCB EA recognizes that prime contractors may have existing internal systems and internally developed supplier approval processes which are ingrained in their supply chain management system. To minimize duplicative effort, a top down accreditation process was developed. In the top down process, it will be the responsibility of the Prime Contractor to ensure implementation of all accreditation requirements and procedures to their own captive design, manufacture, and assembly organizations, and to all levels of subcontractors, sub-tier contractors, and service providers. There are many combinations and levels of contracting PrCB development and sources within the supply chain for PrCB-related products (Figure 3).

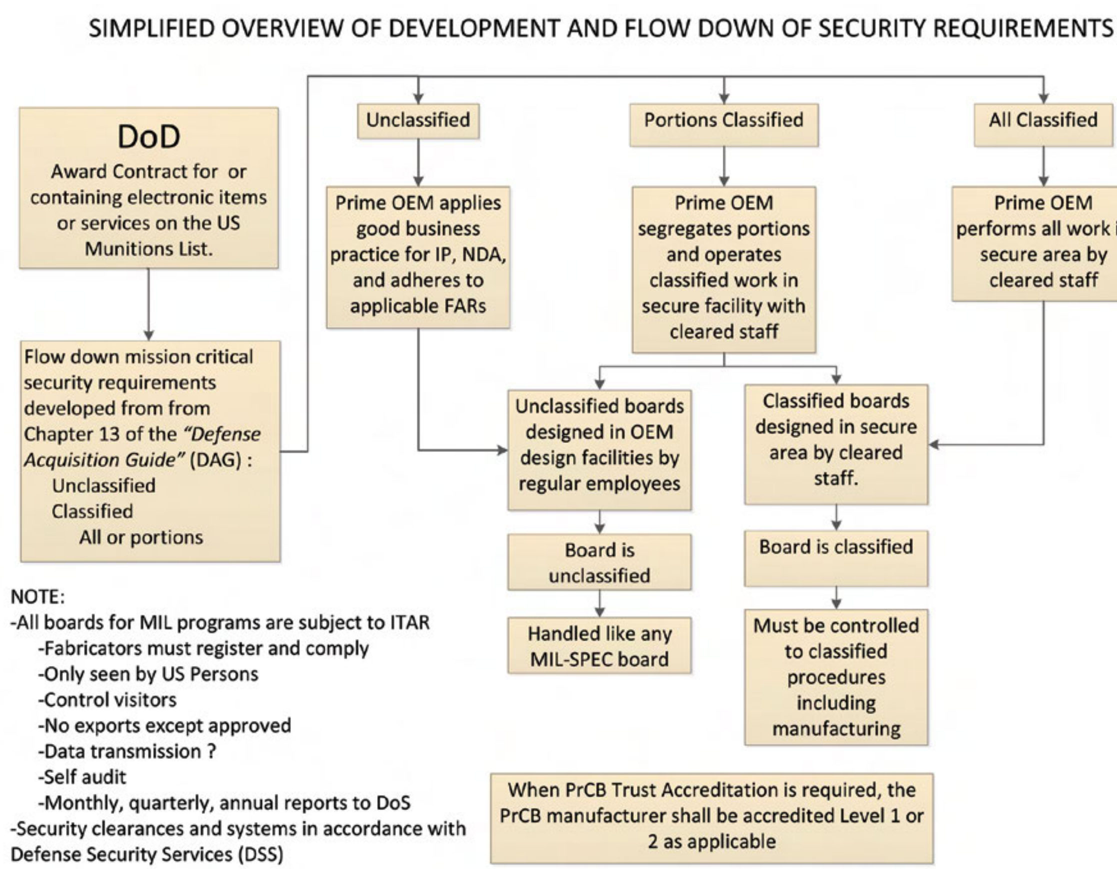


Figure 3: Supply chain for PrCB-related products.

Top down accreditation will begin with a review of the prime contractor's accreditation policies and procedures by the accrediting authority. The accrediting authority will ensure that the Prime Contractor's policies meet the PrCB Trust Accreditation requirements. Therefore, with little or no change to the prime contractor's supply chain management system, a trust accreditation may be ensured.

Implementation

Implementation of the PrCB Trust Accreditation consists of two parallel activities. First is the establishment of the accreditation authority. The accreditation authority may be realized in one of the following scenarios:

1. The PrCB EA will create a government auditing and accreditation capability
2. The PrCB EA will utilize the audit capability of another government entity and provide subject matter expertise and final accreditation approval oversight
3. The PrCB EA will contract the audit function to a private sector entity and provide subject matter expertise and final accreditation approval oversight

The first scenario will require standing up a completely new audit function. This scenario provides for optimum control of policy and process implementation. It is expected that this scenario would be the costliest and time consuming.

The second and third scenarios likely will provide the most efficient path to implementation. Utilizing existing capabilities which already have the experience and knowledge to execute audits is a significant savings over building the capability from scratch. It is recognized that increases in budget and staffing would be necessary to accommodate the increased workload. In either case, the PrCB EA (or other government entity) will have the final approval oversight.

The second parallel activity is the adoption of the PrCB Trust Accreditation into DoD policy. As with the DMEA Trusted Foundry program, the PrCB Trust Accreditation process will need to be incorporated into acquisition policy. This will require language in the Defense Federal Acquisition Regulation which instructs contract officers to flow down PrCB Trust Accreditation requirements language through the contract. Training throughout the DoD Program Office and acquisition communities on what a trusted PrCB is and when the accreditation requirement should be invoked will also be necessary.

These parallel activities will occur over the next six to 12 months with an anticipated roll out by the end of 2017.

Results of Data

The PrCB EA has made efforts to gain feedback from the industry concerning the implementation of the PrCB Trust Accreditation. Two vehicles have been utilized to communicate the purpose, need, and details of the accreditation: (1) a small sample of 25 PrCB design, manufacture, and assembly suppliers solicited to review the requirement and provide feedback and (2) a standard form provided to facilitate compilation of the feedback, with a focus on requirements causing undue burden. There has been about 50% response to the informal solicitation with two negative comments. The comments specifically addressed additional requirements being levied on the supply base. More specifically, there were particular industry certifications that were not possessed. To address these concerns, generic requirements were developed and incorporated as options to the trust accreditation which will maintain the intent of the certification compliance.

To achieve a wider communication of the accreditation, the PrCB Trust Accreditation requirement was presented to an IPC invitation only session at both SMTA/Fall and IPC/APEX conferences. Lively conversations were stimulated regarding additional requirements. As a result of this feedback, the top down process was formulated.

Conclusion

The DoD mandate for trust in the PrCB supply chain is mirrored in DoDI 5200.44, which states: "Employ protections that manage risk in the supply chain for components or subcomponent products and services (e.g., integrated circuits, FPGAs, PrCBs) when they are identifiable (to the supplier) as having a DoD end-use"[3]. In response to congressional and DoD directives, the PrCB EA proposed pursuing a trust accreditation program for PrCB suppliers.

A standard trust accreditation process for DoD PrCB suppliers will result in cost savings for both industry and DoD by leveraging pre-compliance with industry standards, eliminating redundant audit functions, and increasing competition for DoD work. Recent market growth in the PrCB industry has been accompanied by globalization of production capabilities along with a declining domestic industrial base and DoD market share. Even when a U.S. based firm accepts an order, it is typical for all or some of the production to take place in a foreign facility. This environment has an increasingly limited view into suppliers' quality processes and access controls. There is an unquantified risk to the reliability, safety, and security of the PrCB related products and services being delivered for national security systems.

"There is an unquantified risk to the reliability, safety, and security of the PrCB related products and services being delivered for national security systems."

To mitigate risk, each prime or government program currently conducts independent audit functions on their supply base. This is highly redundant, as board shops with multiple DoD customers may be subject to multiple independent audits with the associated overhead costs. This also limits healthy competition, as the barrier to entry is higher for manufacturers that focus on commercial products and do not want to incur the audit-driven costs associated with winning DoD work. The PrCB Trust Accreditation standardizes requirements for working with the DoD, thus eliminating the necessity for program-specific audits. It also promotes competition by recognizing the value of both military and commercial accreditations in quality and security to lower the barrier to entry for nontraditional DoD suppliers.

With technology progression and increased reliance of military systems on electronics, information security has acquired a new level of importance. There is a need for a trust accreditation process to ensure that board shops delivering DoD products have taken adequate steps to protect DoD proprietary information and prevent unauthorized access. As new technologies emerge, the lines between software, firmware, and hardware will continue to blur. On the hardware side, integrated circuits and PrCB technologies continue to progress, and the distinctions between the two industrial bases have become less pronounced with 3D packaging of integrated circuits and the embedding of active components into PrCBs. In this atmosphere of rapid advancement, it is critical that the DoD has an industrial presence to maintain awareness of domestic capability and evaluate the security risk posed by modern technologies and industrial base globalization. Products and services obtained from trusted suppliers must meet known standards for quality, CoC, and security. The return on investment for the additional upfront costs of procuring premium products and services from a trusted supplier comes in the form of increased system-level reliability, safety, and security. **PCB**

References

1. Department of Defense, "DoD Instruction 5000.02 Operation of the Defense Acquisition System," 7 January 2015.
2. Department of Defense, "DoD Instruction 5200.39 Critical Program Information Identification and Protection Within Research, Development, Test, and Evaluation," 28 May 2015.
3. Department of Defense, "DoD Instruction 5200.44 Protection of Mission Critical Functions to Achieve Trusted Systems and Networks," November 5, 2012.
4. Department of Defense, "Performance Specifciation MIL-PRF-31032 Printed Circuit Board/Printed Wiring Board, General Specification for," May 16 2016.

5. Department of Defense, "Specification Standard MIL-PRF 55110 Printed Wiring Board, Rigid, General Specification for," August 2, 2007.

6. Defense Microelectronics Activity, 2002.

7. IPC Association Connecting Electronic Industries, 2016.

8. National Research Council, "Report to Congress," 2008.

9. Defense Acquisition University, "Program Protection," in Defense Acquisition Guidebook, November 8, 2012, p. Chapter 13.

10. Department of Defense, "DoD Directive 5101.18E DoD Executive Agent for Printed Circuit Board and Interconnect Technology," June 12, 2016.

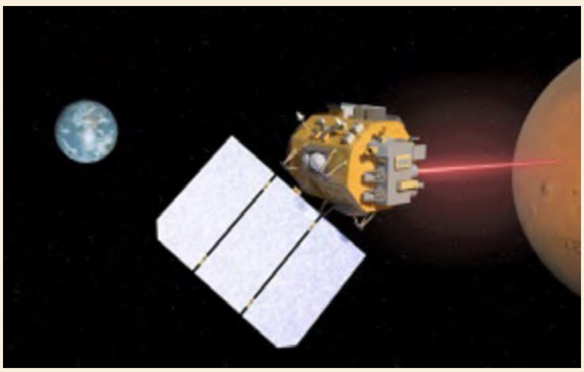
This paper was originally presented at SMTA International in Rosemont, IL, USA, and published in the proceedings.

1. Steve Vetter is electronics engineer with NSWC Crane.

2. Richard Snogren is technology consultant at Bristlecone, LLC.

3. John Timler is solution architect with SAIC.

NASA Taking First Steps Toward High-speed Space 'Internet'



NASA is developing a trailblazing, long-term technology demonstration of what could become the high-speed internet of the sky.

The Laser Communications Relay Demonstration (LCRD) will help NASA understand the best ways to operate laser communications systems. They could enable much higher data rates for connections between spacecraft and Earth, such as scientific data downlink and astronaut communications.

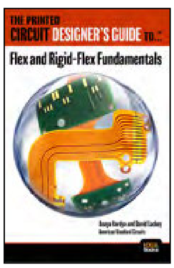
"LCRD is the next step in implementing NASA's vision of using optical communications for both near-Earth and deep space missions," said Steve Jurczyk, associate administrator of NASA's Space Technology Mission Directorate, which leads the LCRD project. "This technology has the potential to revolutionize space communications, and we are excited to partner with the Human Exploration and Operations Mission Directorate's Space Communications and Navigation program office, MIT Lincoln Labs and the U.S. Air Force on this effort."

Laser communications, also known as optical communications, encodes data onto a beam of light, which is then transmitted between spacecraft and eventually to Earth terminals. This technology offers data rates that are 10 to 100 times better than current radio-frequency (RF) communications systems. Just as important, laser communication systems can be much smaller than radio systems, allowing the spacecraft communication systems to have lower size, weight and power requirements. Such capability will become critically important as humans embark on long journeys to the moon, Mars and beyond.

The mission builds upon the Lunar Laser Communications Demonstration (LLCD), a very successful pathfinder mission that flew aboard the Lunar Atmosphere Dust and Environment Explorer in 2013. While LLCD was first to demonstrate high-data-rate laser communications beyond low-Earth orbit, LCRD will demonstrate the technology's operational longevity and reliability. The mission will also test LCRD's capabilities within many different environmental conditions and operational scenarios.

Recent Highlights from PCB007

1 I-Connect007 Launches New Micro eBook Series on Design for Flex and Rigid-Flex



I-Connect007 is excited to announce the release of a new book in our micro eBook series: *The Printed Circuit Designer's Guide to…Flex and Rigid-Flex Fundamentals.* This micro eBook provides both new and seasoned flex circuit designers with valuable information that will help to assure first-pass success in getting products to market.

2 Weiner's World—February 2017

IPC APEX EXPO 2017 was the best in five or more years. The 60th annual meeting drew a crowd. The meetings were good and the mood was upbeat. Reports from the show floor indicated new orders from Asia as well as the Americas, and news of increasing business. IPC membership was up in all its regions to more than 4,000.

3 Eagle Electronics: Success through 'Building Everything'

During a recent visit to Chicago, Editors Andy Shaughnessy and Patty Goldman stopped by Eagle Electronics just outside of Chicago. Chief Operating Officer Brett McCoy gave them a tour of the facility, spoke about the company's plans for the future, and why Eagle is bucking the niche market trend and manufacturing a wide variety of PCBs.

4 Vertical Conductive Structures–a New Dimension in High-Density Printed Circuit Interconnect

From our previous conversations, I knew that Joan Tourné was working on a novel high-density interconnection concept. Having eagerly awaited the chance to discuss the technology in detail, I was delighted when he contacted me to confirm that his IP had been secured and that he could now talk openly about VeCS, the Vertical Conductive Structure.

5 RTW IPC APEX EXPO: Candor Industries' Unique Capabilities Through an Alternative PCB Manufacturing Process

Sunny Patel, Technical Sales Manager with Candor Industries, tells Guest Editor Kelly Dack about their unique manufacturing method that not only improves PCB process turnaround time, but also yields much tighter design constraint quality.

6 RTW IPC APEX EXPO: Lenthor Engineering Updates Rigid-Flex Capabilities

Lenthor's CFO Oscar Akbar and EMS Manager Matt Kan share ideas with Guest Editor Kelly Dack on the growing flex market and Lenthor's strategy to grow with it.

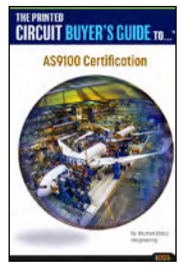
7 All About Flex: Considering a Flexible Heater?

Custom flexible heaters are available in an infinite variety of sizes, shapes and materials. The most common flexible materials are polyimide and silicone rubber. While silicone rubber has traditionally been thought of as the higher temperature flexible heater option…

8 EuroTech: Reporting on the Institute of Circuit Technology Spring Seminar

There has long been debate over the exact location of the geographical centre of England, but the village of Meriden has traditionally laid claim to the title, and it offered an appropriate Midlands venue for the Institute of Circuit Technology 2017 Spring Seminar, which followed the Annual General Meeting of the Institute.

9 Imagineering Authors The Printed Circuit Buyer's Guide to… AS9100 Certification



Imagineering, Inc. recently released their valuable new resource, "The Printed Circuit Buyer's Guide to… AS9100 Certification." Authored by CEO Khurrum Dhanji, "The Printed Circuit Buyer's Guide to…AS9100 Certification" is the first book in an ongoing series of micro eBooks specifically dedicated to the education of the PCB design, fabrication and assembly industry.

10 Standard of Excellence: Staying Prepared with Operations

Handling the operations of a PCB company these days is a challenge, to say the least. When I started in 1979, we were building single-sided, double-sided, four-layer multilayers, and the occasional six-layer if you really had your act together. We were using FR-4 materials sprinkled in with an occasional polyimide build.

For the latest PCB news and information, visit: PCB007.com

Events

For IPC Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar of Events, click here.

For the complete PCB007 Calendar of Events, click here.

14th Electronic Circuits World Convention (WECC)
April 25–27, 2017
Goyang City, South Korea

KPCA Show 2017
April 25–27, 2017
Goyang City, South Korea

NEPCON China 2017
April 25–27, 2017
Shanghai, China

IPC Reliability Forum: Manufacturing High Performance Products
April 26–27, 2017
Chicago, Illinois, USA

IMPACT Washington D.C. 2017
May 1–3, 2017
Washington, D.C. USA

What's New in Electronics Live!
May 9–10, 2017
Birmingham, UK

Thailand PCB Expo 2017
May 11–13, 2017
Bangkok, Thailand

JPCA Show 2017
June 7–9, 2017
Tokyo, Japan

IPC Reliability Forum: Emerging Technologies
June 27–28, 2017
Düsseldorf, Germany

SMTA International 2017 Conference and Exhibition
September 17–21, 2017
Rosemont, Illinois, USA

electronicAsia
October 13–16, 2017
Hong Kong

IPC Flexible Circuits: HDI Forum
October 17–19, 2017
Minneapolis, Minnesota, USA

TPCA Show 2017
October 25–27, 2017
Taipei, Taiwan

productronica 2017
November 14–17, 2017
Munich, Germany

HKPCA/IPC International Printed Circuit & South China Fair
December 6–8, 2017
Shenzhen, China

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

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

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

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

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

MAGAZINE PRODUCTION CREW:
PRODUCTION MANAGER: **MIKE RADOGNA**
mike@iconnect007.com

MAGAZINE LAYOUT: **RON MEOGROSSI**

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

INNOVATIVE TECHNOLOGY: **BRYSON MATTIES**

COVER: **SHELLY STEIN**

I-Connect007 Presents the pcb magazine

The PCB Magazine® is published by BR Publishing, Inc., PO Box 50, Seaside, OR 97138

April 2017, Volume 7, Number 4 • The PCB Magazine© is published monthly, by BR Publishing, Inc.

ADVERTISER INDEX

Coming Soon to *The PCB Magazine:*

MAY:
Help Wanted!
The challenges of finding, hiring and retaining talent in our industry

JUNE:
Embedded Components
Perspectives on freeing up board real estate

JULY:
The State of MilAero
Update on the military industry