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August 2015

an I-Connect007 publication

THE WAR ON FAILURE

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November 4
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Professional development courses for engineering staff and managers:
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- Best Practices in Assembly
- Advanced PCB Troubleshooting
- SMT Problem Solving

December 2–4
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Shenzhen, China

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San Jose, CA, USA

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August Featured Content

WAR ON PROCESS FAILURE

This month, *The PCB Magazine* is taking on failure, and a few industry experts are on hand to back us up! Topics range from the power of systems when combating failure and how supplier improvement drives product improvement, to avoiding circuit failure in high-rel applications and the copper plating process.

PCB007 PRESENTS

AUGUST 2015
VOLUME 5
NUMBER 8

THE DEFINITIVE INTERACTIVE MAGAZINE DEDICATED TO THE GLOBAL PCB INDUSTRY

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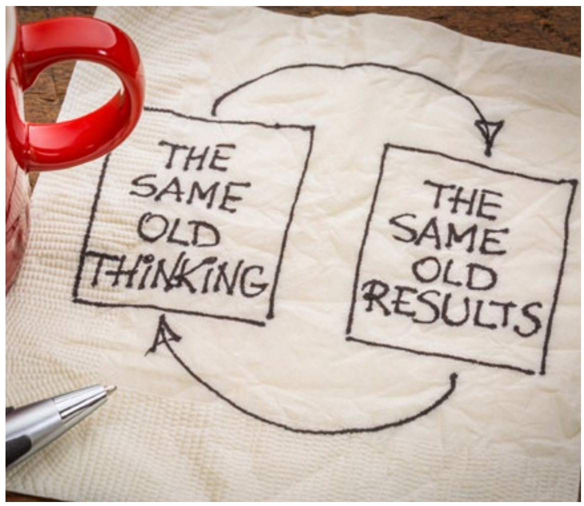

HIGHLIGHTS

EXTRAS

The War on Process Failure

by Patty Goldman
I-CONNECT007

Who out there thought of it as a war? Is it? Well, we think it is—and a never-ending one at that. In fact, we thought it significant enough to devote all three of our August issues to the subject, because no matter how good you are or how great things are running, Murphy's Law is right there, ready to take you down a peg or two—or worse. Think about it. You get one thing fixed or in line and something else pops up, just like the proverbial alligators in the swamp. And then, just as you have a handle on everything, specs change, controls tighten, a new customer comes on board, and there you are back at it again.

The subject of process failure turns out to be quite broad and affects essentially everyone in our industry, from the raw material suppliers to the circuit designer to the PCB processor to the assembly folks and on to the OEM. We all have a hand in it, both causing and solving problems and benefiting from solutions. Oh my!

We of course started with a survey to our general readership, which is rather broad. As expected, the survey takers covered the full spectrum, from supplier to OEM; even consultants chimed in (Table 1).

Company manufacturing volume was pretty evenly distributed between low, medium and high, with a few non-manufacturers. We also asked fabricators and assemblers where in their operation the most scrap was produced and surprisingly, it seems that every manufacturing area was prone to scrap. No areas stood out as especially scrap-prone.

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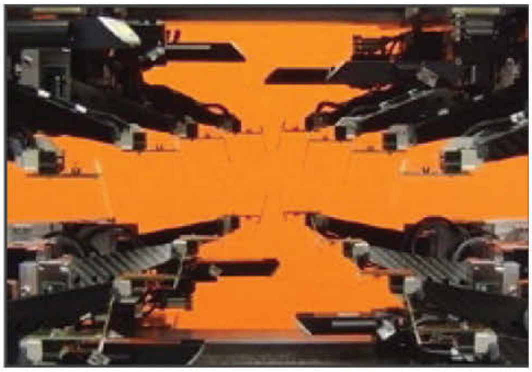

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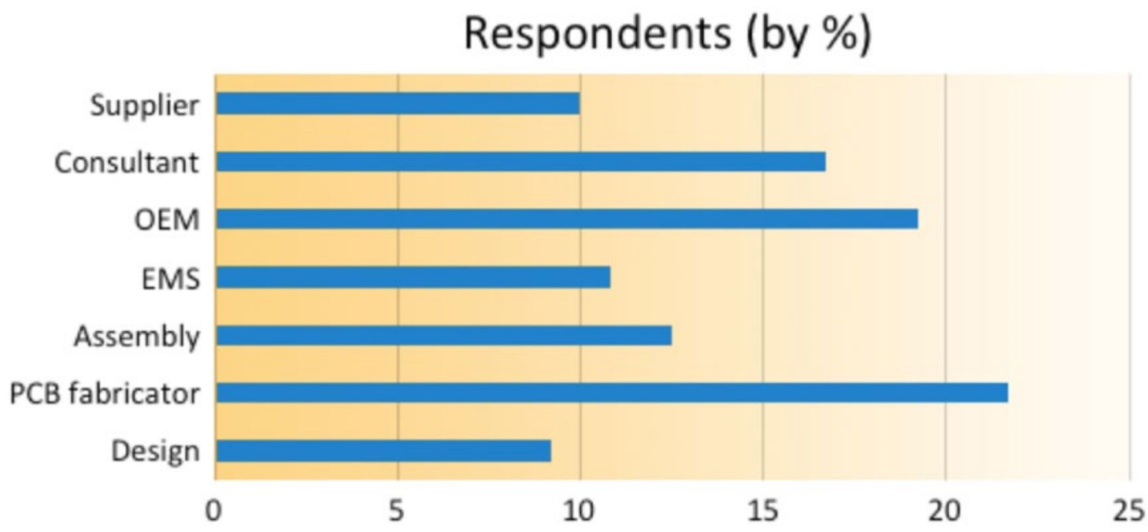

Table 1.

This Month's Line-Up

As you'll learn in Dave Dibble's article, the problems and concerns were the same for everybody. Dave not only analyzes the survey results but provides answers to the top four areas of concern using his systems approach. Much to learn here!

Next, we have Steve Williams interviewing operations and supply expert Fane Friberg. Together, they discuss how important driving supplier improvement is to driving product improvement. And lest you think they mean raw materials suppliers—no, they mean you; no matter who you are, you are both supplier and producer (think about it). It's not all discussion; there is plenty of basic, how-to info included, too.

For our engineering folks, we have an excellent article from Stan Heltzel at the European Space Agency that was first presented at IPC APEX EXPO 2015. Heltzel discusses circuit failure in high-reliability PCBs in detail. This highly technical paper presents good evidence and reasoning for the need to improve not only our processes but also our industry specifications, in order to keep abreast of current high-rel requirements.

Bob Tarzwell then gives a great mini-troubleshooting guide for the copper plating process. There is nothing like a detailed refresher to get one out on the line and asking, "Why do we do that?" or "Why don't we do that?"

Rounding it out is our Flex Talk columnist Tara Dunn with a somewhat international viewpoint. She discusses the ins and outs and pitfalls of transitioning from a domestic prototype to offshore production, highlighting considerations such as supplier selection and potential material variation.

As I mentioned earlier, all three of our August issues have the same "War on Failure" focus, so don't forget to check out the other two. Or better yet, subscribe and they'll come right to your inbox each month. It's always good to see what the other parts of our industry are reading and thinking!

See you next month, when we take a look under the hood at "Cars: A Driving Force in the Electronics Industry." **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. She has worked actively with IPC since 1981 and served as TAEC chairman, and is also the co-author of numerous technical papers. To contact Goldman, click here.

The War on Failure

by David Dibble
NEW AGREEMENTS INC.

We have completed our I-Connect007 Survey: The War on Failure. We surveyed companies in the following businesses asking questions about their greatest areas of concern in key areas around quality and process control:

- Design
- PCB fabrication
- Assembly
- EMS
- OEMs
- Consultants
- Suppliers

We were somewhat surprised that across the various businesses the major issues boiled down to four:

1. Poor process control (46%)
2. Poor training of employees around quality (40%)
3. Inability to quickly identify where and how waste is being created (37%)
4. Poor technical support from suppliers (31%)

As might be expected, these companies most wanted answers to the following questions (Table 1).

In this article, we will attempt to provide answers to these questions. Please note that po-

How to have better process control?		45.9%
How to train employees about quality?		39.8%
How to quickly identify where and how the waste is being produced?		36.7%
How to improve supplier technical support?		30.6%

Table 1.

tential solutions to these problems are not going to be more of what is no longer working for you. While the quality programs of the past have brought us to this point in the evolution of our businesses, we clearly need more. In the war on failure, we must move beyond traditional thinking and problem-solving techniques to something new.

Let's set the stage for what appears to be the root causes for our continuing struggles to create consistently great businesses and high-quality products and services at ever lower cost.

Everything is Systems

Science has shown us that everything in the physical universe is made of systems and subsystems from the largest features such as clusters of galaxies to the smallest at the quantum level. All systems are connected and work synergistically. That is, until the human mind gets into the act, such as in the workplace. In the workplace, people, for the most part, create their own systems for doing the work, the vast majority of which are informal. People, including leaders and managers, simply do whatever they feel is best, many times sub-optimizing other processes and people down the line. This isn't bad or good. It's simply the way we've been domesticated to be in the workplace.

Quality guru W. Edwards Deming told us that 94% of the results (quality or not) we experience in the workplace are a function of the systems in which people work, not the efforts of people. How many leaders and managers are aware of this fact and, more importantly, how many leaders and managers lead and manage in a systems-based way? Not many! Instead, most leaders and managers look to people as the source of problems and solutions, with the thinking being: *If we can get people to behave differently, we can solve problems and get better results*. The problem with this thinking is that in most cases it's simply not true and therefore can't be optimized or made sustainable. Einstein reminds us that we can't solve our problems with the same level of consciousness used to create them. We must expand our consciousness to include systems thinking. As leaders and managers, when we begin to think in systems, the entire world of work changes—dramatically; we see things more as they are rather than how we believe them to be. We begin to see

the systems that are creating the less than optimal results we want to change. I'm reminded of something I heard long ago, but no longer know the source of: "It's not what we don't know that is hurting our businesses; it's what we know that isn't so."

How Systems Change

Ilya Prigogine won a Nobel Prize in 1977 for his Law of Dissipative Structures, which describes what happens to systems that resist change in a changing environment. In short, systems that resist change in a changing environment add complexity and so require more energy inputs to fuel that complexity. However, the system can dissipate only the original amount of energy and so becomes perturbed or stressed. As the system continues to resist change, stresses build up until the system rapidly moves into a state Prigogine called "reorder." Reorder starts with a move into a chaotic state and then, over time, the energy reforms into a completely different system that can handle both incoming and dissipating energy. It is important to note that the new system is not a bigger or changed version of the old system. It's completely new.

"Understanding the nature of systems and how the mind works, we soon see that the degree of change, both in physical systems and systems of the mind, is proportional to the energy present at the time of the change. In the case of physical systems, the energy is stress (dysfunction). In the case of the mind, the energy is emotional energy."

Stresses in Systems are Passed on to People

Over 35 years of applying the Law of Dissipative Structures in our systems improvement work in many types of organizations, we made a startling and I believe game-changing discovery. The stresses that build in the change-resisting systems are passed on to the people who must work in those systems. Not only that, the stresses are passed system to system and hence spread throughout the organization and on to customers and suppliers. The further one gets away from the original source of stress (a given system), the less effect. However, the stresses will be felt to some extent throughout the organization. This fact aligns with Bell's Theorem, which tells us of the connectedness of all systems in the physical universe. But the stresses don't stop there.

As the system's stresses (physical energy) are passed on to people, the energy is usually transduced to fear-based thoughts that are held in the mind as stress. Each of these thoughts has an emotional component that individuals identify in some way as stress, unhappiness, frustration and, toward the "reorder" stage, potential for acute disengagement and even burnout. Of course, employees take these stresses home where they are passed on to family members in some way.

The Mind is a System, Too

The mind is a system, too. The great Buckminster Fuller goes even further in stating that, "Every thought is a system." Because thinking is systematic, we can use many of our systems improvement tools to shift paradigms and expand thinking. This is critically important because sustainability of quality systems is only ensured when both physical systems and mindsets are optimized. In essence, systems and thinking are equally important parts of an integrated whole.

Understanding the nature of systems and how the mind works, we soon see that the degree of change, both in physical systems and systems of the mind, is proportional to the energy present at the time of the change. In the case of physical systems, the energy is stress (dysfunction). In the case of the mind, the energy is emotional energy. Look for yourself. In all of the instances of great change in your life, the events are circumscribed by significant emotional content. No emotion—no change.

There is light at the end of the tunnel for proactive leaders and managers in the workplace. The stresses that have been building up in status quo systems in the workplace can be used to speed change. Similarly, the emotional

stresses that have been building in the minds of leaders, managers and employees can be used to speed changes in thinking and shifting paradigms. However, for the necessary changes to be sustainable, physical systems and systems thinking must be seen as an integrated whole. When we commit to optimizing our systems, becoming systems thinkers and serving our employees, quality and predictability go through the roof while costs plummet. Highest quality with lowest costs makes one the ultimate competitor, yes?

The Four Reasons Most Quality Programs are Underperforming

After more than 30 years of familiarity with quality programs such as Deming's, which morphed into TQM and on to Six Sigma, Lean, Lean Sigma and others, one thing can be said with some conviction: Most quality programs over the 3–4 decades that have been implemented are underperforming or outright failing in Western culture companies. Even where they have been somewhat successful, lack of sustainability is rampant. Our research indicates that there are four primary reasons why Western companies fall so short on realizing the benefits of the quality systems optimization:

1. Programs Mentality: In most organizations, process improvement initiatives such as Six Sigma, Lean, or Lean Sigma are seen as "programs." The problem with programs is that they come and go, many times as a flavor of the month. Systems thinking, systems-based leadership and management, and systems-based organizational improvement are not programs. They are a way of *being* in the workplace. Toyota doesn't have a quality program. It has a quality, systems-based culture and a way of *being* that creates ever-improving quality naturally. The reason Six Sigma, Lean, Lean Sigma or Toyota's ways of being haven't translated well to most Western companies is because we've tried to jam quality improvement concepts and tools into legacy mindsets. These programs have not taken into account the critical nature of the paradigm shifts necessary to make these programs into a way of being in the workplace.

2. Lack of User-Friendly Tools: Although I taught basic SPC tools to my clients, I noticed that many people's eyes glazed over with fear or concern when faced with learning to use these tools. This was especially true of non-technical workers and managers who hadn't signed up to become systems improvement experts. Leaders too, in many cases, showed little desire to learn or use the tools. For some, English was a second language, making learning more difficult still. People do not learn well or easily when in fear. We found in order for people to learn, use, and eventually *own* the tools, we had to reformat the tools, making them simple, user friendly and even fun. Remember, if your front lines are not using the tools on a daily basis, you're not systems-based. You are people-based and asking for the fires you put out yesterday to be burning brightly sometime in the near future.

3. No Paradigm Shifts: There are two equally important parts of sustainable systems-based cultural change: systems improvement and expanding our existing paradigms. Six Sigma, Lean and the like focus on tools and process, but whiff on the critical nature of paradigm shifts, particularly at the levels of leadership and management. Systems thinking is a significant paradigm shift, an expanded way of


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thinking, a more accurate way of thinking and viewing the world. It's the same for improving systems. We have to begin to think differently and expand our mind and skillsets to make systems improvement work sustainable. We found in many cases, these paradigm shifts must take place *before* significant sustainable systems work can be done.

4. Leaders Who Won't Grow: Systems thinking is like learning a foreign language. Without knowing this language, leaders have little idea of the source of problems in the organization or how to resolve those issues. In addition, with 90+% of the problems being a function of the systems, not the people who work in those systems, a leader or manager misses the opportunity and responsibility to set up his or her people to be optimally successful in their jobs, surely a top function of more conscious/skilled leaders or managers. Instead, most non-systems thinking leaders and managers use what I call the "more-better-different" strategy. They do what's no longer working more, better, or differently—expecting a different result. We will talk a little more about the more-better-different problem below.

The Power of Systems Thinking

It's important to remember that quality isn't something we do—it's something we become. It's a way of being in the workplace. It's the way work is done. Quality is a mindset more than program. It's systems thinking from the boardroom to the stockroom. The transformation of the mind toward systems thinking can be accelerated using the stresses in the mind as fuel.

Systems thinking is a skill set much like learning a foreign language. In the beginning, to make sense of it, we translate systems thinking back into our old way of thinking. As we become more fluent, we have to do less and less translation until we begin to think in a systems-based way. As a leader or manager, your entire world will open up in profound ways when you begin to see your workplace reality as it is, an ongoing dance of systems and subsystems that are driving whatever results are being produced. In the process, previously invisible systems will begin to become visible. Being that 90+% of the problems you face in your business are a function of these systems, can you begin to see how systems thinking obsoletes much of what we have been domesticated to believe about leadership and management?

There are undoubtedly other factors contributing to the critical condition of most quality initiatives. However, if we begin to address these four issues, it appears we will be well on our way to creating sustainably better products, services and businesses. Let's take a look at the four concerns most on your minds and what we might be able to do alleviate them.

Let's start with the biggest question: **How may we create better process control?**

As stated earlier, everything in your business is systems and subsystems including systems of process control. Those systems are creating approximately 94% of the less than optimal results that you'd like to improve—sustainably. We have to improve the systems and grow the people—simple as that. It's simple to say, but not so simple to implement, yes?

Systems, even when formally created, often morph into the informal. In addition to being informal (workers putting their own twist on to how the work is done), the systems are for practical purposes, *invisible*. To make a system visible and identify the critical 20% of the variables producing 80% of the problems, we must put the systems "on the wall." The on-the-wall process normally uses flip charts to gather data about systems and the flip charts are displayed literally on a wall where everyone sees the same thing. The 'on the wall' process can also be done electronically, but this is not recommended for early stage implementations.

The data that goes on the wall (on flip charts) is collected using a number of quite unique and simple, yet powerful tools listed below. A note of caution: If you are new to the proper use of these tools, you will want to bring in an experienced facilitator to get your systems improvement efforts started correctly and your people trained properly. If you get the first 15% of any system right, the rest will follow. However, if you don't get the first 15% right, you will never be able to fully optimize your systems.

The New Agreements tools you will be using:

1. Disruptive Discovery
2. Systems Distillation
3. 80/20: Identify the Critical 20%
4. Taking Right Action & Accountability
5. Measuring & Monitoring the Critical 20%

Disruptive Discovery

This process is based upon the Law of Dissipative Structures described above. As stresses in physical systems are passed on to the people who work in those systems, the energy of stresses changes from physical energy to emotional energy in the form of stress, frustration, worry and other negative emotions. Disruptive discovery looks at the emotional stresses in workers to determine which systems are most stressed and where a company will get its greatest ROI in doing systems improvement work. The process is quite fast, simple and highly reliable. The process will also tell leadership and management where people are most and least engaged in their work and with the company.

This process can be used with large groups all the way down to individuals. We have quite effectively used the process with groups as large as 500 and it appears there is no real

limit to group size. Here is how the process works.

Bring the people together who are actually working in the systems you wish to evaluate. Have flip charts and scribes at the front of the room to record people's responses to the question, "Do you have any problems, concerns, or frustrations in your job or with the company?" As people respond one at a time, write down their exact words, the problem, concern or frustration on a flip chart. Keep going until everyone in the group cannot think of any additional stresses in his or her work life. You will know you are done when the room goes *dead quiet,* usually between ten and 25 minutes depending upon the size of the group. When you have collected this data (stresses passed from systems to the people who must work in those systems) you are ready to move on to the next tool, systems distillation.

Systems Distillation

After disruptive discovery, the data must be *distilled*. Systems distillation is a simple process of categorizing emotional stresses into like type groupings. The power of distillation comes from the principle that the human mind values thoughts in two ways: 1) those with high emotional content, and 2) those that are similar or tend to repeat. Distillation looks at these two aspects of the data. Wherever we find high

emotional content or significant repetition in the emotional stresses within a group, we will find the systems transferring the most stress to the most people and thus, a good early candidate for systems optimization.

Usually with smaller groups, we will distill the data using different colored markers to designate similar groupings. The group must make the choices of what category a given stress will fall into. With larger groups, a manageable size distillation team is formed out of the original large group to do the distillation process. Once the data has been categorized, the team will give each category a name. Now we're ready to move to the next tool, 80/20.

Critical 20% Analysis

Systems distillation is also highly reliable in identifying the critical 20% of the variables within a system upon which one must focus to receive 80% of the benefits of systems optimization. This tool is based in Pareto analysis, but with a few important twists. In addition to looking at systems optimization, we highly recommend to leaders that 80/20 be run for each employee of the company from CEO to stockroom, around roles and responsibilities. Forget job descriptions. Everyone should have their own critical 20% and only work on that critical 20%. Forget the trivial many. Only work on something if it is or becomes a part of the critical 20%.

As a systems improvement facilitator, ask the group to choose only one category/problem/system from the systems distillation list, the one they most want to fix or optimize. Then ask the group for the second most important category, then the third, and so on, until all categories have been given a priority. Normally, the categories ranked 1, 2, or possibly 3 will be the Critical 20%. This ranking is then taken to leadership to make a decision where to start in doing systems optimization. In general, we want to choose something that comes early in the overall process and isn't so big that people can't experience success in less than 90 days, with initial victories in 2–4 weeks. If a system is still too large to get a 90-day handle on, run disruptive discovery, systems distillation and 80/20 again or until you have broken the larger system into manageable subsystems. Don't try to do too much. It's much better to have a smaller but meaningful victory for the team than risk disillusionment working on something too big for too long without seeing measurable results.

Avoid the Problem-Solving Trap

As a facilitator, there is one trap with the group that must be avoided at all costs—problem solving too soon. It is guaranteed that members of the group will want to jump into solving problems prior to having everything on the wall. If the group is allowed to jump to problem solving too soon, the systems improvement team will degenerate into a committee meeting and systems improvement will grind to a halt. Do not let the team get into problem solving before all the data has been put on the wall and the root causes of systems problems identified.

Taking Right Action

Rapid progress is achieved through Right Action. Right Actions are small actions taken on

a regular basis for which a person or persons is responsible and accountable—who will do what by when. On a process improvement team, it is imperative that the team be a working team and that everyone on the team has some right action for which they are responsible and accountable. If a person cannot keep his or her word in completing action items, he or she must leave the team.

Measuring and Monitoring

David Chambers, W. Edwards Deming's right-hand man and probably the country's most esteemed statistician, said it best, "Focus on what you measure and how you measure. If you get these right, everything else will follow. If you don't get these right, it's impossible to improve and control a system or process." In other words, it's impossible to create quality systems unless we know what to measure and how to measure. This is an area where many well-meaning quality advocates fall down. Leaders should also realize that the only things that are important to an organization are those things that are measured. We can disregard what leaders say about the company's vision, mission and values when these culture/operational critical aspects of the organization are not measured in some way. It's the same for quality and customer satisfaction, including internal customer satisfaction. These things must be measured, correctly answering the question, *what and how are we measuring?* At some point, you will want to have control charts for your critical 20% variable measurements so you will know when a process or system has changed in some way. It's much better to catch problems early as opposed to later and, worst of all, when they show up in the field or with your customers.

"Focus on what you measure and how you measure. If you get these right, everything else will follow. If you don't get these right, it's impossible to improve and control a system or process. In other words, it's impossible to create quality systems unless we know what to measure and how to measure. This is an area where many well-meaning quality advocates fall down."

Now let's look at the second question: **How do we train employees about quality?**

As stated above, two significant obstacles to training employees in quality are: 1. a program mentality and 2) tools that are difficult to teach and apply for both front-line workers and managers. I might add a third that might be even more important: Is the leader willing to grow and change, too? It's mindboggling how many leaders are unwilling or unable to look in the mirror and see that unless he or she is willing to grow beyond what has brought the company to its present state, little can be done to improve the organization. This is because the mindset of top management shapes the mindset or culture of the company. When top management has a robust quality/systems mindset, we transcend program mentality and begin to move the company into a quality state of being. Without this shift in thinking, we're more or less stuck wherever we are or with incremental improvement only.

In looking at how best to train employees about quality, one strategy has proved by far to be most effective—teach them to improve the systems in which they work. As I stated, a process improvement team is a working team. It is also a learning team. In the process of improving systems, employees learn to use the tools and even facilitate. They are turned loose to contribute to the process, apply the principles and be accountable. We learn the most when we teach. Once trained in a real work situation, the team, with some support, moves on to resolving its next critical 20% issue. Average people can easily become extraordinary in process improvement in only a couple of months of actually doing this work using the indicated methodology and tools.

Let's look at question three: **How do we quickly identify where and how the waste is being produced?**

This question is answered naturally when using the systems improvement tools described above. In particular, we know that usually 20% of the sources of waste will contribute 80% to total waste. For example, when we make a system visible and identify the critical 20% of the variables driving 80% of the throughput of the system, it is usually quite evident where the critical 20% of the waste is coming from. Fix the critical 20% and we cut 80% of the waste. Then, work on the new critical 20% within the system(s) and so on.

Finally, we'll examine question four: **How do we improve supplier technical support?**

Again, the question is systems related. Whatever system you have in place now for supplier technical support, either formal or informal, is producing less than stellar supplier technical support. If you want better support, you have to change the system. Start by making your existing system visible using the disruptive discovery and systems distillation processes. Once the system is on the wall and visible, identify the critical 20% and optimize those parts of the system. However, if the system is too dysfunctional, it may be better to start with a blank canvas and create the system anew. To do this, run the processes described above asking the question, how should this work to sustainably produce optimum supplier technical support? You'll find that 20% of the variables will deliver 80% of the results you want. Identify the critical 20% and build your system about those variables.

Sustainable Results: What's Possible with the Strong Support of Systems-Thinking Leaders

A $30 million company that lost $9 million in fiscal 2013 moved to a $1.1 million profit in 11 months with no layoffs. This is a bit of an anomaly in that an entire team of leaders and managers had already been trained in the use of the described model and tools when this company collapsed. Once the previous CEO and his hires were removed by the board in 2013 and replaced by a systems thinking CEO we had trained, the results speak for themselves—probably unprecedented in the history of this industry.

A 650-person company reduced turnover from 27% to 4.3% in 14 months. It is well known that excessive turnover of employees is one of the largest, mostly hidden costs and disrupters in any business. We found that the leading causes of employee defections (in most businesses) are poor systems that do not set the employee up for success, and poor, non-systems-based leadership or management. With Forbes reporting 70% of the U.S. workforce disengaged, it appears our legacy leadership and management models are, in many cases, obsolete. With tens of millions of Millennials coming into the workforce who are clearly not responding to old leadership and management models, the war on failure is also a war on legacy non-systems-based leadership and management models.

A small company (24 people) was ranked in the bottom 5% in customer satisfaction when compared to 270 competitors nationwide. In 12 months, the company enjoyed a move into the 96th percentile in customer satisfaction when compared to its competitors. In the process, the company moved from years of losses

to an $80,000 profit. We found that the critical 20% of the systems that were causing most of the poor performance included: an antiquated and totally ineffective scheduling system, a non-systems-based director who was allowing employees to do whatever they felt best—creating impenetrable silos, severe sub-optimization problems, and an almost complete lack of focus on systems for serving the customers, including internal customers.

In a larger company ($1 billion in sales with a 2% pre-tax profit) we were, over six months, able to save the company in excess of $1 million. However, in that same six months, we identified systems changes that would have created approximately $10 million in additional benefits that could have, within a 24–30 month period, been accruing to the company annually. Unfortunately, leadership was unwilling to grow and elected to not pursue the changes that could have increased the bottom line of the company by 50%. Here we see the mindset of top management ultimately determining the depth, speed and sustainability of systems-based organizational improvement.

"Leaders and managers try to do more of what's no longer working, try to do what's no longer working better, or try to do what's no longer working differently. This strategy normally accelerates the dysfunction or demise of the systems because non-systems-based changes usually add to the stresses and variability inherent in legacy systems."

More-Better-Different: The Hidden Trap for Leaders and Managers in a Changing Environment

As indicated earlier, one of the common mistakes leaders and managers make in dealing with stressed systems is a strategy we call, "more-better-different." Leaders and managers try to do *more* of what's no longer working, try to do what's no longer working *better,* or try to do what's no longer working *differently.* This strategy normally accelerates the dysfunction or demise of the systems because non-systems-based changes usually *add* to the stresses and variability inherent in legacy systems. Instead, realize that when improving systems, *we don't know what to do.* If we knew, we'd have already made the correct changes. This is why it's imperative that we become proficient in systems thinking and the systems improvement tools listed above. This way of thinking and use of the tools make the systems visible and tell us as leaders, managers and front-line staff what are the correct actions to take and what and how to measure. This is the essence of sustainable quality systems and ultimately, the long-term success of the organization.

The war on failure is really a war on poor systems and non-systems-based thinking of leadership and management. To some extent, it is also a war on leaders and managers who don't value people or don't know how to set up their people to be most successful in their jobs. Without knowledge of systems and systems improvement, how can any leader or manager know how to set up his or her people for success, quickly and sustainably solve problems, or manage anything! They can't—at least not well. Non-systems-based leaders and managers do their best, but their best is far from optimum. It doesn't have to be that way. There is a whole new way of leading and managing, a whole new way of being in the workplace that wins the war on failure through quality systems and tools, systems thinking and a willingness to grow beyond more-better-different and the deadly status quo. **PCB**

David Dibble is a keynote speaker, trainer, consultant, executive coach, and systems thinker. For more than 25 years he has consulted and trained in the workplace, with a focus on his systems-based *Four New Agreements for Leaders and Manager.* To reach Dibble, click here.

Fighting the War on Failure with Supplier Analytics: *An Interview with Fane Friberg*

by Steve Williams
THE RIGHT APPROACH CONSULTING (TRA[C])

I had the opportunity to sit down with operations and supply chain expert Fane Friberg recently to talk about how a company can only be as good as its supply base, and how driving supplier improvement directly impacts product improvement.

***Steve Williams:** Hi, Fane. Thanks for taking the time to sit down with me and talk about a subject near and dear to both our hearts—supplier development. You have been a senior operations and supply chain executive for some of the biggest companies in our industry, including Plexus, GE Oil & Gas, Avnet, GE Aircraft and Goodrich, as well as turning around a number of smaller manufacturing organizations. I understand you have recently started your own company, Cephas. Can you tell me a little about it?*

Fane Friberg: Cephas is a supply chain consulting group that strives to optimize the value proposition for the companies it engages with. It's a slant on the theory of constraints (ToC), introduced by Eliyahu M. Goldratt in his 1984 book, The Goal. What is it today that needs attention to resolve pain points, processes, and challenges, and then to design solutions that address exactly those things.


Fane Friberg

To have a standard platform that drives a competitive advantage, the manufacturing operations team (inclusive of those suppliers that provide business value) must have a proven methodology to realize profound impact and sustainable results. This includes:

- Analytics
- Alerts
- Advice
- Action

Cephas sets out to optimize the supply chain and information bifurcation theory, which is a well-established mathematical framework that explains and models how a small, smooth change in a system can cause a sudden, dramatic change overall.

***Williams:* Since I have been teaching Goldratt's ToC for the past 10 years, let's dive deeper into your particular slant on this theory. How can this methodology be flowed down to drive improvement in supplier performance?**

Friberg: Let me use an example, with delivery as the constraint that needs to be evaluated (or "exploited" in ToC vernacular). Using some simple analytics of on-time delivery (OTD), what has the supplier performance been over 1 year, 6 month, 1 quarter, and the last five deliveries? Keeping in mind the critical factor with OTD is to the customer's dock, not shipment from the supplier's dock. Sounds simple, but over 75% of companies miss this correlation. Looking at percentage and also span (when late and how late), subordinate everything else. From this there are three quick takeaways:

1. If the supplier is late equal to or less than transportation time, chances are they are working to the customer's PO date as a ship-date and not the customer's dock date. There is a quick fix!
2. If the supplier is consistently late a consistent number of days, check your MRP system to validate that the supplier lead-time in your MRP system is consistent with the committed and demonstrated lead-time in the supplier's system. Could be another quick fix!
3. If the supplier is consistently late and the part is on the critical path of your indented BOM, your committed lead time to your customer is suspect. Chances you are making up the delta by expediting, working overtime, paying a premium for an alternate supplier to replace late or problem parts, or paying for expedited freight to your customer. This results in margin shrink!

***Williams:* So, Fane, the focus of this issue of The PCB Magazine is the War on Process Failure; when you and I first talked about this, you mentioned that it all starts with your suppliers. Can you expand on that?**

Friberg: Failure within the value chain is not limited to the factory. The supplier is an extension of the process. If a supplier has a great price, but unreliable delivery performance, it is very difficult to correctly schedule the manufacturing site simply because operations are not sure/confident of when the parts will arrive. Unfortunately, too many companies spend a lot of money deploying expediting teams to continually run down where late parts are in the pipeline.

> "If a supplier has a great price, but unreliable delivery performance, it is very difficult to correctly schedule the manufacturing site simply because operations are not sure/confident of when the parts will arrive."

If the supplier is not part of the organization's dock-to-stock program, not only is there waste (muda) from the redundant inspection at the receiving dock, but also costs multiply when a defect is found. Is the failure only on this lot of parts or have there been other escapes into the manufacturing facility that could show up later— or even worse at the end-user—as a latent defect?

It is important to research and evaluate suppliers based on price, quality, selection, service, support, availability, reliability, production and distribution capabilities, transportation cost, and supplier's reputation and performance history. Then, enhance supplier development by communicating performance standards and developing joint improvement initiatives with quantifiable measures of success.

***Williams:* Selecting suppliers by evaluating their performance and capabilities seems like simply good business practices. Why do you think so many organizations just don't do their homework when it comes to their supply base?**

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Friberg: Buyer-supplier relationships in the supply chain are one of the most important elements of supply chain integration. Establishing and managing effective relationships at every value-link in the supply chain is a critical prerequisite of business success.

However, at times that relationship becomes one where a company says, "Well…we have a history with this supplier and they know our business model; if we start to measure everything they do, we will lose them as a key vendor." With this approach many companies simply don't feel the need to develop the toolsets/skills to reset the playing field. Complacency sets in.

Williams: I had to think about this for a minute, Fane, because like most of us, I normally think of quality problems when discussing the war on failure. But what your example really drives home is that delivery has just as great an impact on failure as quality. Should delivery and quality be weighted evenly when developing a supplier scorecard?

Friberg: In my mind, any time the full terms of the purchase order are not fulfilled, it's a failure. In a high-tech business, we naturally progress to the technical aspects, because by nature we want to solve. Supply relationships are binary; they are either transactional or relational. A key implication for leaders is that they should recognize the goal of buying, the strategic importance of the object of purchasing, and choose accordingly between the different types of supplier structures. The supplier scorecard highlights the purchasing strategies of their supply relationships and the motive for purchasing. Different strategies highlight different aspects and events that ultimately manifest themselves in the firms' business models.

Williams: So that's a yes?

Friberg: In a very long-winded answer, absolutely!

Williams: Over the course of your career you have seen how a lot of different companies manage their supply base, and as we both know, some do it extremely well and others not so much. What are some of the more common mistakes organizations typically make in this area?

Friberg: The most common mistake is having terms and conditions negotiated by the sourcing team that are not consistently measured by the enterprise and communicated formally back to the supplier. Again, basic blocking and tackling:

- Cost: If there is an agreed to PPV (purchase price variance), is that being obtained? Is the consumption rate above, below, or at the negotiated rate?
- Quality: In a Lean value stream, the collaborative goal needs to be, how do we get to 100% dock-to-stock? Checking at the end of the supplier line, or at your receiving dock for defects, is a defect in itself.
- Delivery: Cost is dictated by market, quality is intended to be a given, and the delivery element is the leverage point that can disrupt the overall value proposition—both for the supplier and the manufacturer.

So, from my perspective, the most common mistake is not having a robust, clear supplier scorecard with performance criteria that both the supplier and the manufacturing facility align with. From company to company, the weighting of the supplier scorecard elements should vary between industries and where in the product life cycle that

product is (i.e., if a product is going end-of-life, instead of negotiating PPV, the discussions could be about last-time buys [LTB]).

To successfully manage the supply base, there has to be a regular cadence with the stakeholders from both companies driving continual improvement. Based upon the maturity of the relationship, interjecting a paired comparison process (PCP) into the business reviews is a very powerful tool, but we can save that for another article.

***Williams:** Fane, from an operations perspective, you are only as good as your suppliers, so let's talk quality for a minute. As you know, I preach Lean Best Practices, and whether it's raw material or component level products, I feel improvement can always be made through this path. Would you agree?*

Friberg: I absolutely agree. We talked earlier about PPV. If in an effort to meet the PPV objectives, the supplier begins to choose lower qualities of raw materials and tries to modify their manufacturing process to make the part faster, quality will inevitably be impacted. The reason successful companies are adopting the Lean Six-Sigma approach is specifically to improve current processes and move towards achieving and sustaining reliability in a high-quality, cost-effective manufacturing process.

***Williams:** We have talked about supplier performance metrics, but what about supplier development? Since the customer is paying (one way or another) for a supplier's inefficient processes, wouldn't it be in everyone's best interest for customers to take an active role in helping their suppliers get better?*

Friberg: That's a great point, Steve. As manufacturing firms outsource more parts and services to focus on their own core competencies, they increase the expectation of their suppliers to deliver innovative and quality products on time and at a competitive cost. So my recommendation is to have the supplier scorecard as part of the normal quarterly business review with the customer. Since the customer most likely owns the drawing and specifications, their understanding of the potential drawing changes via a three-way collaboration between the customer-provider-supplier, which yields easy-to-fix supplier problems that helps build momentum. In the healthcare industry, many times the supplier is specifically called out in the drawing, thus hindering proactive supplier development.

“As manufacturing firms outsource more parts and services to focus on their own core competencies, they increase the expectation of their suppliers to deliver innovative and quality products on time and at a competitive cost.”

When working on supplier development, the scorecard is a powerful proactive tool in clearly establishing the performance expectations that are going to be required (and measured) by the organization. In my own experience, when you approach the customer with a situation and indicate that you have some options, but really want to partner with them during the evaluation, they willingly and actively participate, thus further entrenching your organization as a business partner with that customer vs. a vendor.

You've heard my take on vendors vs. suppliers: Suppliers are partners in the value chain; vendors sell hot dogs at Miller Park during the Brewers games.

***Williams:** One of your guiding principles to operational excellence is the formula:*

*Cost * Quality * Delivery = Customer Experience*

Can you walk me through what this means and how companies can leverage this model in their organizations?

Friberg: The measure of an organization's reputation in the market is the customer experience (some companies utilize a net-promoter-index to try to gage this). In the aforementioned formula, it's critical to understand that these elements are not additive but rather multiplicative.

At times it is said by a customer that a supplier is "world class." In that context, world class is an adjective.

To truly leverage the C*Q*E=CE, world class needs to become considered a noun (a person, place or thing) and clearly qualified and quantified. When the supplier (and subsequently the manufacturing group) delivers great service the customer or shareholders don't usually see down at the personal level. Supply chain provides the sort of experience that the public doesn't usually see at the personal level, but which can result in outcomes that are commented on (sometimes with wonder) at the enterprise level without reflecting on how they came about. We within the supply chain world acknowledge and appreciate projects that have demonstrated a truly excellent customer experience.

Williams:* *Fane, you talk a lot about big data; what exactly does that mean?

Friberg: Years ago I coined a phrase "buy-by-wire," much like the B2 Bomber was the first "fly-by-wire" advanced aircraft for the Air Force. The concept of big data is to fully leverage and maximize the information flow between the customer, the manufacturing facility and the supply base. Eliminate redundant rekeying of information that in most cases is outdated before an individual has a chance to update the system of record.

Rather, leverage big-data and EDI (electronic data interchange) to perpetually share information in the value stream. If the customer changes the demand profile, update your ERP system real-time. Depending on the change, the resulting analytics maybe require a change to the demand profile with your supplier (cancel, defer, expedite, etc.). Take note that not every action/change will drive an equal or opposite reaction (sorry, Mr. Einstein). If the change is for two pieces of a C-level part by a day, the resulting bullwhip effect to the supply chain would not be passed with a revised purchase order to the supplier. But if there is an impact to an A-level part over an extended series of fiscal periods that needs to be acted upon, in this case the system would prompt the change, but a supply chain analyst would do additional discovery.

"Depending on the change, the resulting analytics maybe require a change to the demand profile with your supplier (cancel, defer, expedite, etc.). Take note that not every action/change will drive an equal or opposite reaction (sorry, Mr. Einstein)."

The sooner a company can implement the short list of EDI transactions, the more time the supply chain can manage exceptions vs. every transactions. My view of the short list is:

- EDI 850—Purchase order
- EDI 855—Purchase order acknowledgment
- EDI 856—Ship notice/manifest
- EDI 860—Purchase order change request, buyer initiated
- EDI 861—Receiving advice/acceptance certificate
- EDI 865—Purchase order change acknowledgment/request, seller initiated
- EDI 870—Order status report

Product availability via the 855 and 865 can be utilized in the manufacturing ERP system to help identify manufacturing sequence and priorities based on current and accurate dates, equipment availability, constraints, etc. The revised information can then be flowed to the customer establishing the current plan of attack.

Williams:* *Once again this prompts us to look at failure differently; if we define failure as anything that compromises meeting a customer requirement, delivery and transactional inaccuracies certainly meet that definition!

I can personally attest that your first question on most issues is usually "What does the data show?" Let's talk first from a high level about developing an appropriate strategy for initial supplier identification and qualification. What type of predictive metrics can be put in place to make sure a company engages with the right suppliers up front?

Friberg: Although various supply chain structures are successful, my personal preference is to align the supply chain managers by commodity. If one does not exist, then a high-level supplier scorecard will need to be developed that each commodity manager reviews the objective outputs (Cost*Quality*Delivery) vs. the subjective performance execution. In parallel, determine how many suppliers the organization will need within that commodity family to be successful. More times than not, this yields a few of the predictive metrics and "a-ha" moments you mention in your question:

- The suppliers that are sometimes thought to be the best from a customer experience perspective may not be the best performers.
- Conversely, suppliers that are perceived as poor performers may not be poor. Somebody is relying on something from 10 years ago that has followed this supplier through the years.
- As it relates to how many suppliers are needed, most times this process shows, "Wow we have way too many suppliers in that commodity, not enough in that one, and some of our suppliers are not in the best geography to support our execution dividend."

Start with very simple predictive analytics, but get a common baseline to drive improvements. As the organization gets deeper into supplier scorecards and paired comparisons, the model can be enhanced to obtain more finite analytics.

Williams: OK, so now we have developed a supplier onboarding process to make sure that we are engaging with suppliers that have a high probability to become long-term partners. Let's talk about what kind of analytics can be put in place to not only monitor ongoing supplier performance, but also drive supplier improvement.

Friberg: The most critical step here is that the supply chain organization agrees on what are the expectations of supplier analytics. The entire process will lose market credibility if the data shows one thing, but the commodity leadership conveys a message to the supply base that is subjective in nature and not fact-based.

I mentioned paired comparisons a couple of times during this discussion. Let me channel my GE days here a little. If there is not a quantifiable analytic for improvement, go get 10% Year/Year. If you are able to use the paired comparison model, you can show each supplier how they are performing against the other suppliers in their commodity (excluding information like cost, pieces, PO count, SKUs, etc., which would derail the conversation to suppliers spending time trying to figure out who the other suppliers are vs. driving improvement on the specific metrics). Even if the supplier you are working with is #1 in the commodity C*Q*D, there is always an element that they can improve upon. Establish that improvement objective to be reviewed at the new business appraisal.

To quote Herm Edwards, "Hello—you play to win the game."

Williams: As always, Fane, this has been a very interesting and enlightening discussion and I appreciate your willingness to share your expertise on this topic. Any final words of wisdom?

Friberg: How to win the war on failure: Continue to break any and all constraints that keep the supplier from having any negative impact on your competitive advantage. Align strategy with people and culture to optimize the supply chain: passionate pursuits, measurable success, and sustainable results. **PCB**

Steve Williams is the president of The Right Approach Consulting LLC and the former strategic sourcing manager for Plexus Corp. He is the author of four books, including *Quality 101 Handbook* and *Survival Is Not Mandatory: 10 Things Every CEO Should Know about Lean.* To read past columns, or to contact Williams, click here.

Electronics Industry News
Market Highlights

“White Graphene” Structures Can Take the Heat in Electronics
Three-dimensional structures of boron nitride might be the right stuff to keep small electronics cool, according to scientists at Rice University. Rice researchers have completed the first theoretical analysis of how 3-D boron nitride might be used as a tunable material to control heat flow in such devices.

Cloud, Big Data Driving Growth of Data Center Equipment Market
TMR analysts state that the global data center equipment market was worth US$32.15 billion in 2013 and will display a 12.9% CAGR between 2014 and 2020. Digitalization of data across various industry sectors has created unparalleled demand for data storage and data backup facilities.

IPC Releases PCB Industry Results for May 2015
“North American PCB sales continued below last year’s level, but orders resumed positive growth and the book-to-bill ratio remains positive for the eighth straight month,” said Sharon Starr, IPC’s director of market research. “This indicates the likelihood of strengthening sales growth in the second half of this year,” she added.

Global Graphene Market Growth to 2025 Led by Asia
RnRMarketResearch.com offers new graphene market research reports titled Global Graphene Industry Report 2015, The Global Market for Graphene to 2025: Market size, production volumes, applications, products, prospects, research and companies as well as Research on Global & China Graphene Industry, 2015 in the materials and chemicals collection of its library.

IPC Lauds U.S. House of Rep on Passage of TSCA Modernization Act of 2015
IPC supports bipartisan efforts to reform the Toxic Substances Control Act (TSCA) of 1976, which needs to be modernized to reflect 21st century realities. A strong, cost-effective, science-based federal chemical regulatory program is important to our members, who use chemicals to manufacture electronics for the nation’s defense, transportation, consumer and other industries. H.R. 2576 includes sensible, balanced provisions for modernizing U.S. chemical safety laws.

Graphene Development Breakthrough Gives Light to Flexible Electronic Skin
A pioneering new technique to produce high-quality, low-cost graphene could pave the way for the development of the first truly flexible ‘electronic skin’, which could be used in robots. Researchers from the University of Exeter have discovered an innovative new method to produce the wonder material Graphene significantly cheaper, and easier, than previously possible.

Aerostat Systems Market to Reach $10 Billion by 2022
According to a new market report published by Transparency Market Research “Aerostat Systems Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2014–2022,” the global aerostat systems market was worth US$3.60 billion in 2014 and is expected to reach $10.11 billion by 2022, growing at a CAGR of 13.8% from 2015–2022.

US Medical Imaging Industry Faces Transition
Medical imaging is a notoriously data intensive field with its volume, variety and speed of data generation multiplying every day. Conventional tools are incapable of efficiently managing such large and complex datasets; posing limits on scalability, sustainability and usability.

IPC Releases Report on Lead-free Electronics in Mil/Aero Applications
IPC’s new market research study examines the current and future state of lead-free usage in high-reliability applications, as well as the impact usage will have on the industry.

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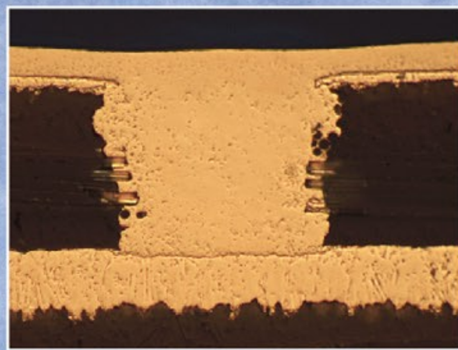

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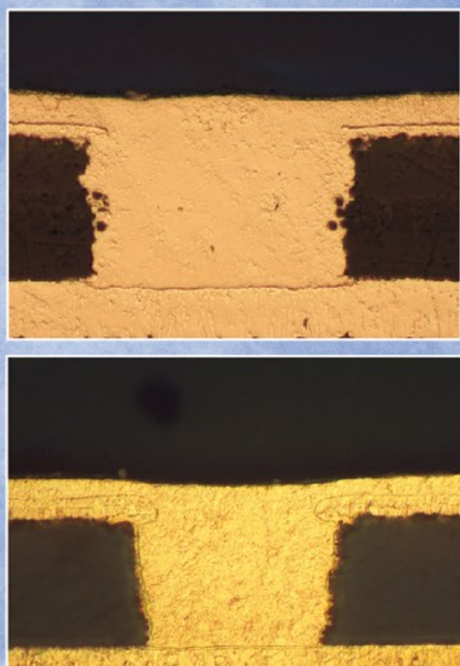

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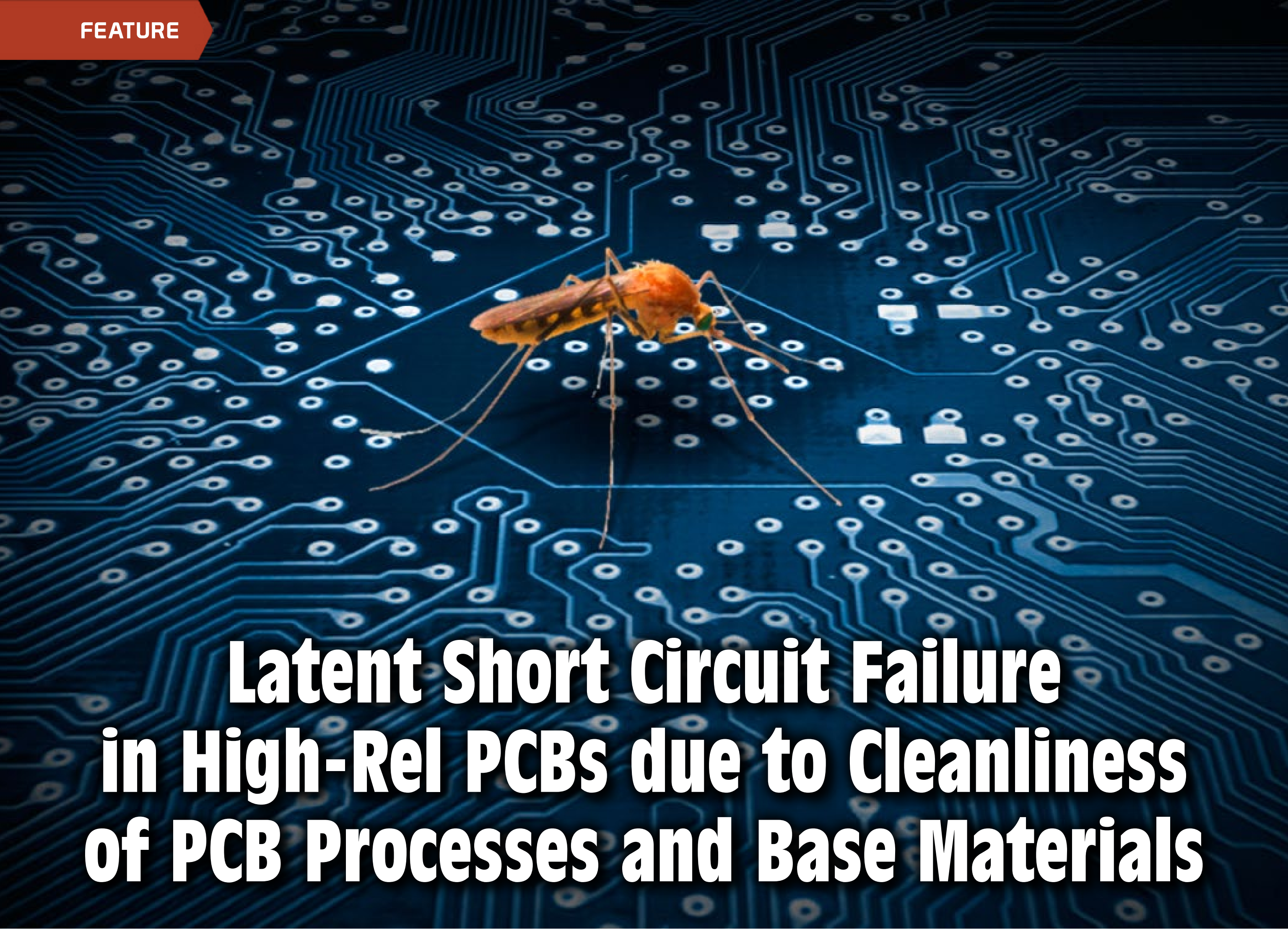


Latent Short Circuit Failure in High-Rel PCBs due to Cleanliness of PCB Processes and Base Materials

by Stan Heltzel
EUROPEAN SPACE AGENCY

Abstract

Latent short circuit failures have been observed during testing of PCBs for power distribution of spacecraft of the European Space Agency. Root cause analysis indicates that foreign fibers may have contaminated the PCB laminate. These fibers can provide a pathway for electromigration if they bridge the clearance between nets of different potential in the presence of humidity attracted by the hygroscopic laminate resin. PCB manufacturers report poor yield caused by contamination embedded in laminate. Inspections show that fiber contamination is present on prepreg and etched innerlayers. Further fiber contamination may be attracted in the manufacturing environment due to static charging. The requirements for cleanliness that are specified for final PCBs are orders of magnitude more stringent than those specified for base materials. This paper describes inspections performed on base materials, manufacturing processes and final PCBs. It describes test methods that detect reduced insulation caused by contamination and electromigration. Moreover, a proposal is presented specifying tightened requirements for a new class of base materials for the manufacture of high-reliability PCBs.

I. Introduction

Latent short circuit failures have been observed in PCBs during testing of power distribution units of spacecraft for the European Space Agency (ESA). Root cause analysis has been conducted under review of non-conformance review boards (NRB). Printed circuit board assemblies failed after prolonged functional testing in ambient laboratory environment or after thermal vacuum cycles. Due to the large amount of damage caused by the electrical overstress, it was not possible to obtain direct evidence of the

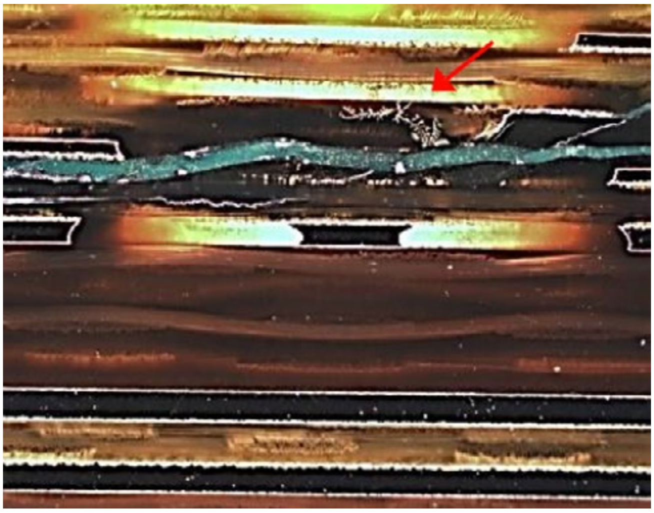


Figure 1: Cross-section of a failed PCB showing extensive damage due to electrical overstress and a dendritic structure.

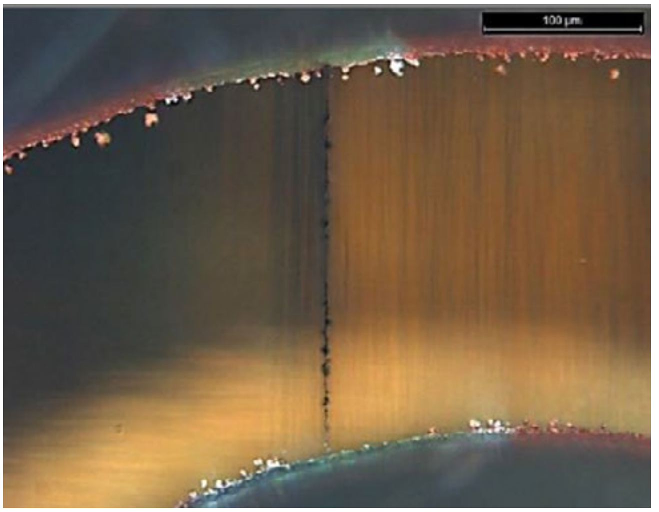


Figure 2: In-plane section of a failed PCB showing a trace of electrical discharge along glass fibers in the clearance of a via through a plane.

failure. However, a working hypothesis has been developed indicating that fiber contamination may have caused a latent short circuit. This hypothesis was further substantiated by reports on contamination issues in base materials and by a test method that demonstrated the breach of insulation due to fiber contamination.

At the time of the observed failures at equipment level, PCB manufacturers reported poor cleanliness levels of base laminate materials, causing poor yield. It is not possible to screen in an efficient manner for contamination in copper-clad laminate, since visual inspection requires stripping of the copper. Several inspection methods show the lack of cleanliness of base materials, which is specified in IPC-4101[8]. This paper identifies a major gap between the requirements specified on base materials and the requirements on manufactured PCBs and presents a proposal for a new class of cleaner base materials for the manufacture of high-rel PCBs.

The processes of PCB manufacturing are an additional contributing factor to possible contamination in the dielectric insulation. PCB manufacturers are audited for their cleaning methods on etched innerlayers and on prepreg prior to stack-up for lamination. Recommendations have been issued[1] for a cleanliness control plan, for in-process inspections and for electrical testing on final PCBs[5].

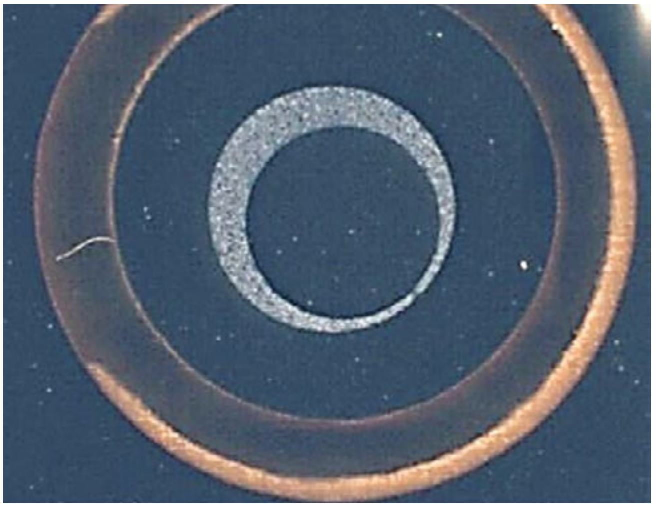
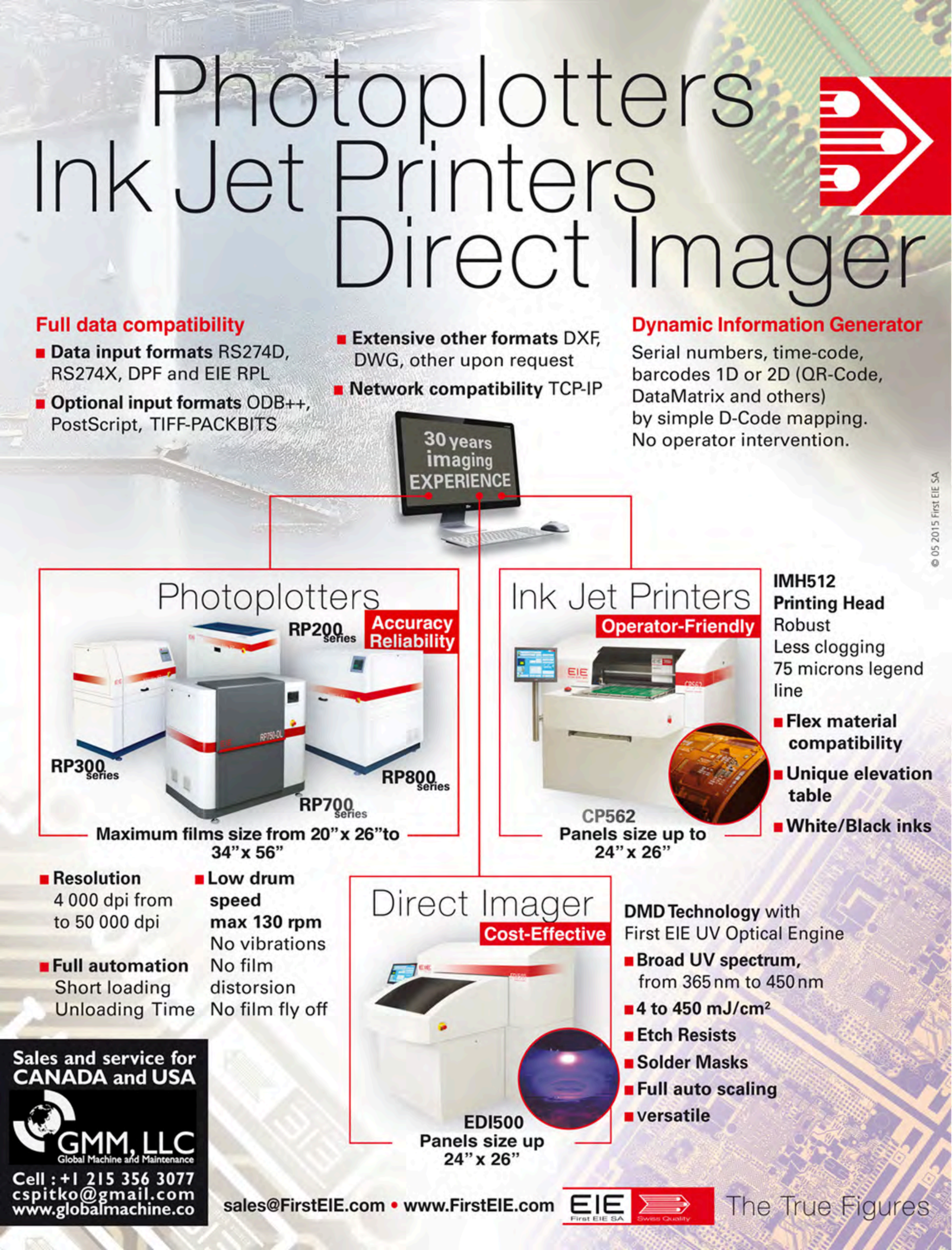


Figure 3: In-plane section of a failed PCB showing fiber contamination in a clearance of a plated through-hole.

Concerns with cleanliness of PCBs initiated the formation of a dedicated working group comprising of space agencies, original equipment manufacturers, satellite integrators and PCB manufacturers. The objectives of the working group are to inventorise the sources of contamination and to define risk mitigations, as described in the present paper.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II. Failure Mechanism

A. Electrochemistry

For electrochemistry to occur, the following factors need to be present: a pathway, an electrolyte (i.e., ions in a mobile substance) and a bias voltage[2].

Dendritic growth is a type of electromigration causing metallic deposition from the cathode. It is typically associated with surface migration. Use of flux in assembly can contaminate the surface and increase the probability of dendritic growth. Surface properties have been the main focus of specifications for PCB cleanliness and for surface insulation resistance (SIR) tests.

Conductive anodic filament (CAF) growth is a specific type of electrochemistry causing copper salts to deposit from the anode along the glass-resin interface. CAF is typically associated with subsurface electrochemistry. Thermal stress deteriorates the glass-resin interface which increases the susceptibility to CAF. Hollow glass fibers provide another pathway for CAF.

B. Discontinuities in Laminate

Any kind of inhomogeneity within the dielectric material can provide a pathway for electromigration. Bromine flame retardants have a limited solubility in polyimide resin and may separate during high-pressure lamination. Conglomerations can be formed by the flame retardant or, likewise, by ceramic fillers, as typically used in epoxy materials with high glass transition temperature. Manufacturing problems causing voids or delamination can degrade the insulating properties. A brittle resin system prone to cracking has previously been subject of ESA Alert EA-2010-MAT-12-B after critical short circuit failure in a power application during ground based testing.

In addition to the above, PCB laminate can be contaminated by foreign material, such as chemical residues from the production process, epoxy resin dust in polyimide laminate, metallic debris, dust or fibers. Contamination of PCB laminate by foreign fibers can provide a pathway for electromigration if fibers bridge the clearance between nets of different potential. Mobility within the PCB laminate can be provided by humidity. PCBs for space applications are typically made from polyimide laminates, which are thermally stable materials. However, polyimide resin is hygroscopic. Small amounts of chemicals can provide mobile ions creating a conductive electrolyte, even when cleanliness requirements for PCBs are met.

Another problem associated with contamination is loss of insulation caused by metallic particles or by carbonization of organic contaminants during lamination or during assembly. These failure mechanisms occur earlier and

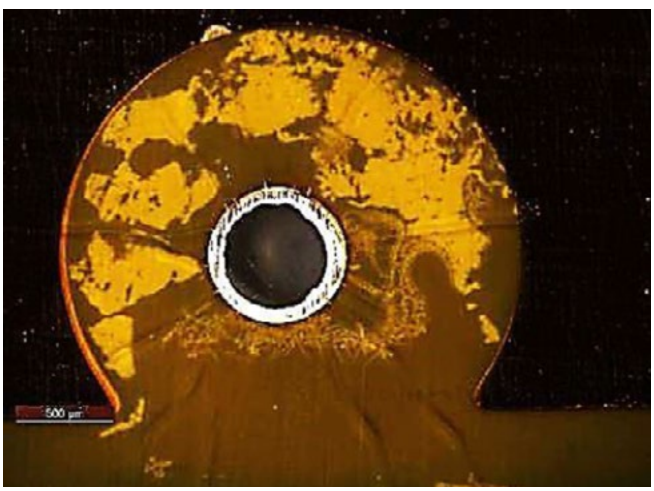

Figure 4: In-plane section of a via showing radial resin cracks and a dendritic structure on a delaminated flex layer.

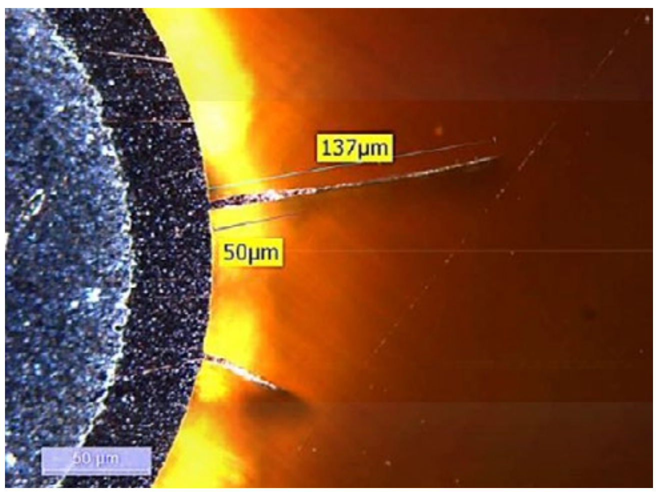

Figure 5: In-plane section of a via without capture pad showing cracks and copper ingress caused by drilling in brittle resin.

are easier to detect compared to the latent short circuit caused by electromigration.

C. Sources of Contamination

Contamination of dielectric materials can occur in the PCB manufacturing process and in base material manufacturing. PCB manufacturers procure copper-clad laminate and prepreg sheets from base material suppliers. The PCB manufacturer is in control of cleanliness in prepreg layers and on the surface of etched innerlayers. The base material supplier is in control of the cleanliness inside copper-clad laminate and also of the cleanliness of prepreg.

PCB manufacturers report poor cleanliness levels in base materials and low yield as a result. In addition, audits of PCB manufacturers show that there is variation in cleanliness of the manufacturing environment and in the cleaning methods used on internal layers.

D. PCB design

IPC-2221 is the standard that is commonly used to specify insulation distance in a PCB as a function of voltage. Manufacturing tolerances are often overlooked when implementing design rules. In one failed PCB assembly, a 4-mil (100 µm) laminate was used to accommodate a voltage of 100 V between copper planes. This was intended to comply with 1 kV/mm as specified in IPC-2221. However, worst-case projected peak-to-peak insulation distance includes tolerances for laminate thickness as well as for copper surface profile. A thickness tolerance of 13 µm is specified in IPC-4101 for class C laminate with nominal thickness of 4 mil. A maximum copper foil profile of 10 µm is specified in IPC-4562 for a nominal foil thickness of 70 µm. Adding these tolerances can give a projected peak-to-peak insulation distance of about 68 µm for a nominal thickness of 4 mil.

Likewise, etching tolerances need to be included when specifying intralayer insulation distances between conductors in-plane of the PCB. Recently, PCB design specified in ECSS-Q-ST-70-12C[3] has been endorsed by the space industry. This standard takes worst-case manufacturing tolerances into account when specifying voltage rating.

Double insulation is a frequent requirement for critical high-voltage signals in space applications. ECSS-Q-ST-70-12 specifies for the first time a set of PCB design rules that combines the use of two individually cured insulators as well as additional margin for voltage rating of critical signals. Furthermore, the ECSS-Q-ST-70-12 specifies the presence of non-functional pads to mitigate the risk of drilling cracks in resin-rich areas and it specifies the use of two sheets of prepreg between copper layers as well as two

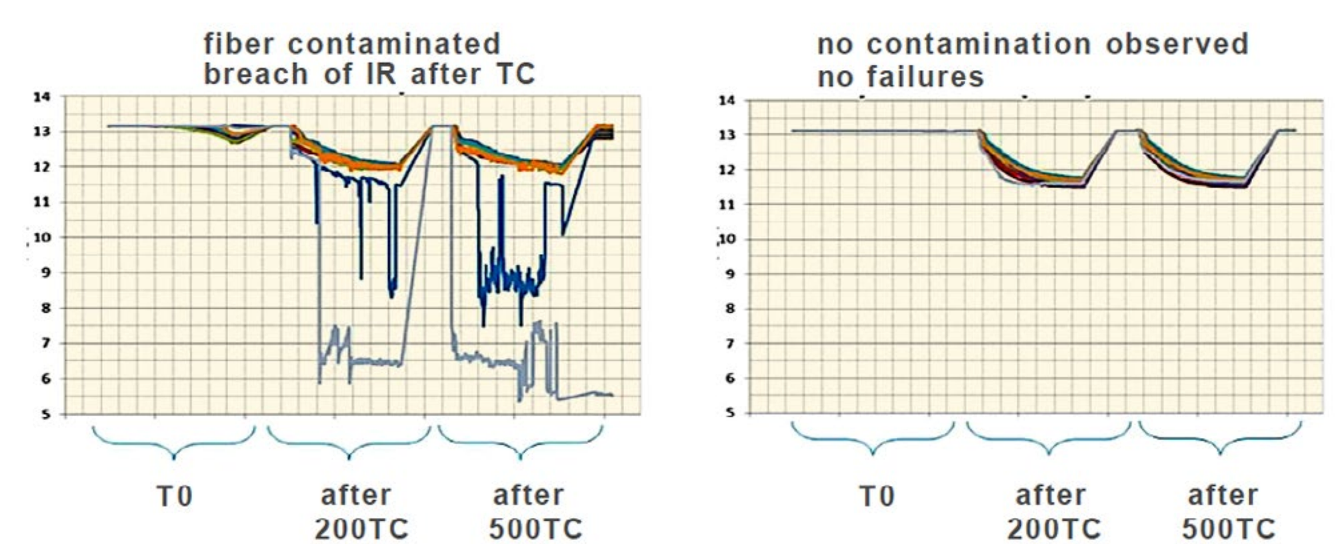

Figure 6: Insulation resistance (log Ω) before and after thermal cycles (TC) from -65°C to +135°C, showing two failed innerlayers of a comb pattern that appeared to be fiber contaminated.

layers of woven glass reinforcement in laminate, to mitigate the risk of contamination.

Evolutions in the capability of the electronics industry have caused denser PCB designs, combining signal and power circuits with large ground planes, thick copper layers, thin dielectric insulation and dense component assembly. While the PCB design may not have taken full account of manufacturing tolerances, this cannot be considered the root cause of failures. The electrical strength of laminates provides an order of magnitude margin compared to the design rule for voltage rating. However, PCB materials are not perfect and requirements are specified for tolerable imperfections. Conservative PCB design is, therefore, an important risk mitigation.

III. Insulation Resistance Test

Conventional SIR test equipment was used in a recent investigation[4] to measure insulation resistance (IR) on internal layers. The test was set-up in support of the working group on the ECSS-Q-ST-70-12 and had the objective to verify the voltage rating of 1 kV/mm for space applications. PCB coupons were manufactured using various base materials by two different PCB manufacturers. Coupons were submitted to thermal cycling representing end-of-life for space applications. Before and after thermal cycling, coupons were characterised by IR testing at 75% relative humidity (RH) and 85°C while a bias voltage of 100 VDC was applied across comb patters with intralayer insulation distances of 100, 150 and 200 µm.

An unexpected result of the test campaign was that one set of coupons appeared to be contaminated with fibers, which caused breach of insulation after thermal cycling. After the campaign, the short circuit was located using infrared thermography while applying a low current. Destructive Physical Analysis (DPA) was performed and progressive polishing finally revealed the fault location. In all cases for which the fault location could be identified in this manner, it was observed that the breach of insulation was associated with fiber contamination. In some cases it was evidenced that copper migrated from the comb pattern and re-deposited along the fiber. The fibers were observed in prepreg layers and therefore associated with the PCB manufacturing processes.

The main conclusion in support of the ECSS-Q-ST-70-12 was that the insulation at end-of-life was adequate for the field strength of 1 kV/mm, provided that no contamination was present. The other main conclusion was that fiber contamination in PCB laminate provides a pathway for electromigration to occur and can lead to latent short circuits in PCBs.

A similar test campaign has recently been performed on coupons that were manufactured by using different cleaning methods on inner-layers and prepreg sheets, prior to lay-up for lamination. It showed that the risk of breach of insulation could be significantly reduced by cleaning internal layers.

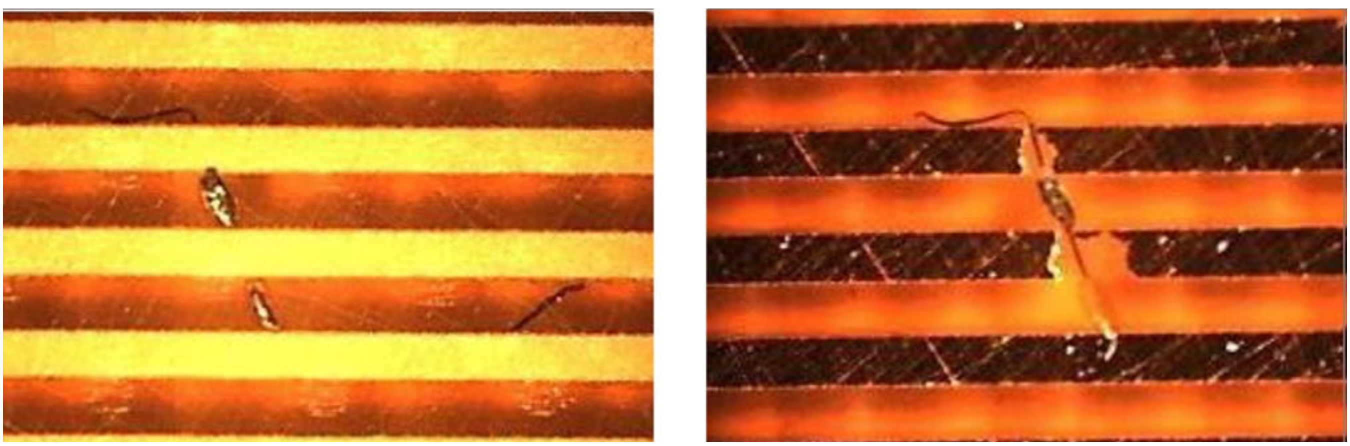

Figure 7: In-plane sections of comb pattern after progressive polishing showing copper migration from the conductor along the fiber contamination.

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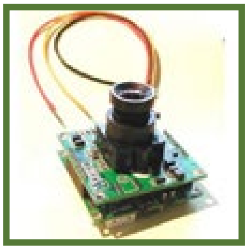

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Figure 8: Top view of a laminate after etching of copper cladding, showing a plant seed embedded in the dielectric material, probably carried into the clean room on clothes of personnel. The scale is in mm.

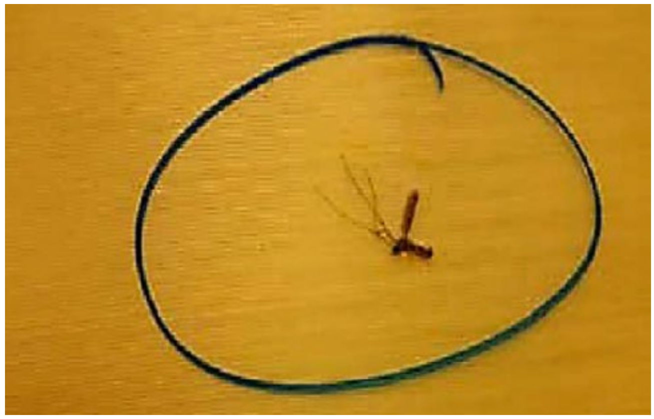

Figure 9: Top view of a prepreg showing an embedded insect.

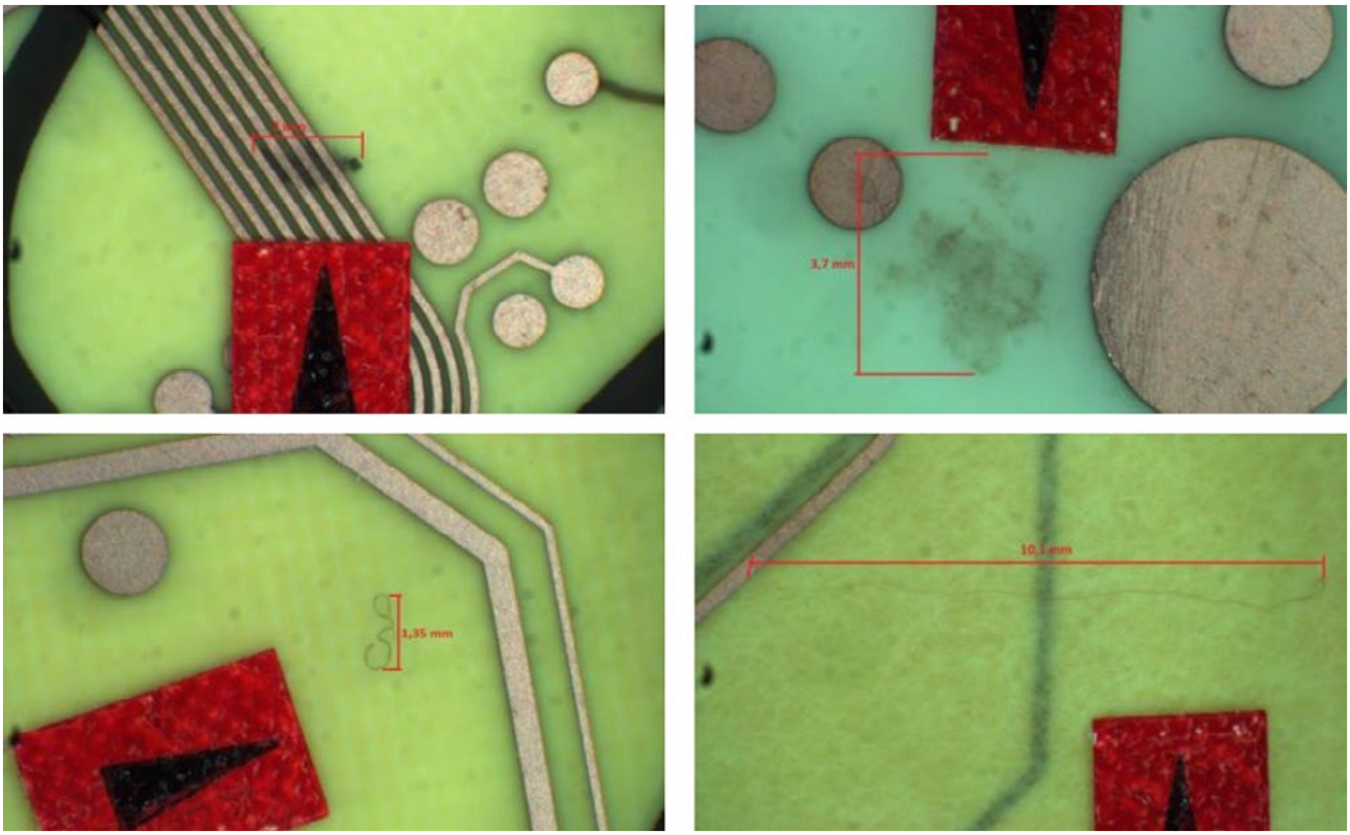

Figure 10: Examples of etched innerlayers scrapped due to the presence of contamination.

IV. Risk Mitigations at PCB Manufacturer

A. Sample Inspection on Base Laminate

IPC-4101[8] specifies sample frequency and criteria for acceptability of sub-surface imperfections. Some PCB manufacturers use this as a test method for incoming inspection of batches of base laminates. The method may be inefficient, since copper cladding needs to be etched from the laminate before inspection is possible, after which the laminate cannot be used any more for PCB manufacture. Furthermore, the sample

size needs to be significant to provide reliable statistics due to the probabilistic nature of contamination. Nevertheless, this method is a useful addition to the total package of risk mitigations, as it provides the PCB manufacturer with a simple quantification of cleanliness. In case of non-compliance to IPC-4101, the results can be used to return the batch and to file a claim with the base material supplier.

One PCB manufacturer gathered reliable statistics over a period from Jan 2012 until Feb 2014 and reported that about one-third of incoming batches did not comply with requirements from IPC-4101 and another 8% did comply with IPC-4101, but did not comply with internal requirements. The base material supplier accepted all claims, also those that were strictly in compliance with requirements of IPC-4101.

B. Inspection on Etched Innerlayers

To overcome the lack of statistical significance of sample inspections on base laminates, one PCB manufacturer implemented a 100% visual inspection of clearances on etched innerlayers using a light table. During manufacture of a critical batch of PCBs for a power unit, it was reported that 130 innerlayers were scrapped out of a total of about 10,000, due to the presence of embedded contamination as shown in Figure 10. This is not only a laborious inspection method; in addition, low yield has a high cost impact that late in the manufacturing process flow.

The visual inspection step is complementary to automated optical inspection (AOI). This latter test equipment verifies the conductive circuit and discriminates the circuit from the dielectric by the specular or diffuse reflection. It is typically not considered to be an efficient method for determining discontinuities within clearances when these have similar optical properties. However, recently one PCB manufacturer provided contaminated etched inner layers to an AOI supplier for their assessment by new software using grey scales to successfully detect contamination.

Both visual inspection and AOI can only be performed in clearances and do not provide information on the quality of dielectrics below surface copper. This is a problem on plane layers when only a small amount of copper is etched away. A breach of insulation between layers is possible in case of particulate contamination when it penetrates the layers of woven glass reinforcement. This has been seen for chlorine-bearing particles and metallic debris. This failure mechanism has been the reason to require a minimum of two layers of glass reinforcement between copper layers. Contamination caused by fibers or chemical residue is considered to be more of a risk for in-plane insulation and this can be mitigated by the visual inspection and an efficient AOI method.

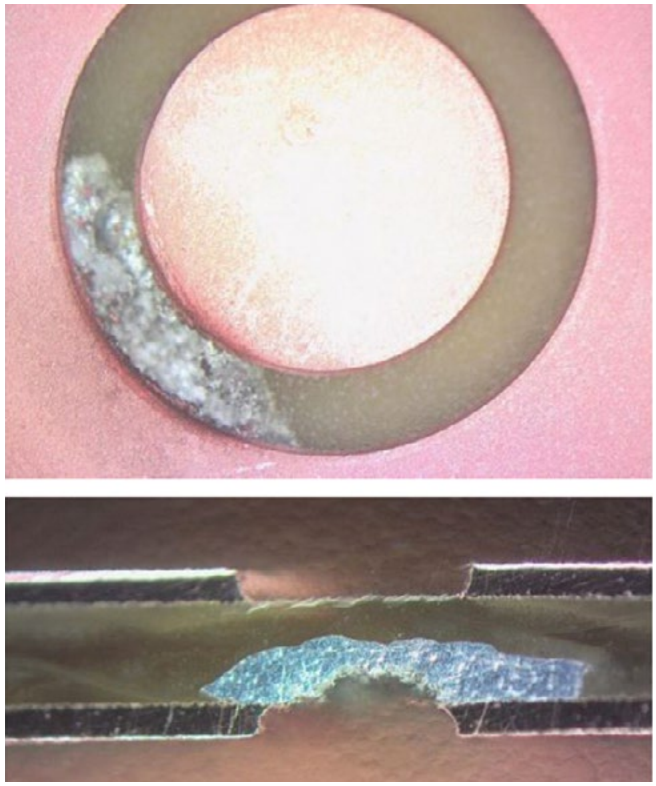

Figure 11: In-plane view (top) of contamination embedded in clearance of etched innerlayer and cross section (bottom).

C. Cleanliness in the PCB Production Area

The PCB manufacturing processes take place in an industrial environment, which add to the risk of contaminating innerlayers with dust particles or fibers, for instance. Copper surface treatment of innerlayers includes a drying process as a last step. Air filtration needs to be verified for this process. Furthermore, this process is prone to static charging of innerlayers. This is also the

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case for polymeric interleavers that are used to separate and protect innerlayers. Prepreg sheets also show a large amount of static charging.

Interleavers, transport trolleys, trays and work benches that are in contact with innerlayers and prepreg should be inspected and cleaned regularly. The lay-up area in which etched innerlayers and prepreg are stacked up prior to lamination, should be under control by clean room practices such as air filtration, humidity control, overpressure, regular cleaning, protective clothing, restricted access, smooth unpainted surfaces, etc. Furthermore it is recommended to implement laminar flow benches for lay-up and the use of de-ionisation equipment. These recommendations are specified in[1] and have become subject to audit of PCB manufacturers.

D. Cleaning and Inspection of Innerlayers and Prepreg at Lay-up

Due to the fact that the environment of PCB manufacturing is relatively uncontrolled with respect to cleanliness and PCB materials, and consumables are prone to static charging, it is essential that a cleaning step be implemented prior to lamination. The best process for last-minute cleaning is the lay-up. The use of so-called tacky rollers, based on Van der Waals attraction of particles without risking contamination of the rolled surface with an adhesive residue, is widely endorsed. Cleaning of prepreg sheets, however, is not so widely performed.

Verification of the efficiency of the cleaning can be done by visual inspection under bright light and ultraviolet (UV) light. UV flashlights as well as bright lights are readily available in various wavelength ranges. Using UV light inspection, it was shown that sealed bags of polyimide prepreg are occasionally contaminated as delivered from the base material supplier. Polyimide resin dust was shown to not be fluorescent, whereas epoxy resin as well as dust fibers do show UV fluorescence. Either source of contamination is unacceptable in polyimide production processes at high temperature.

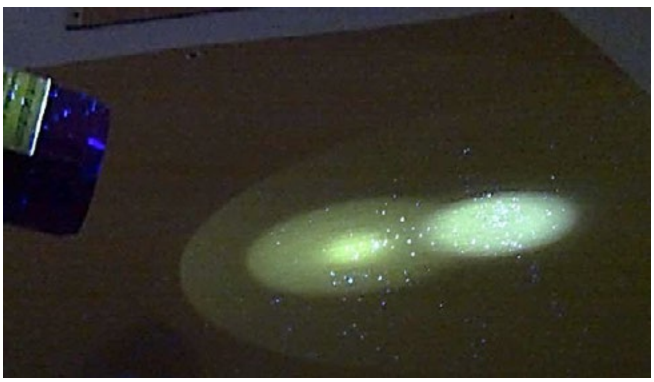

Figure 12: Inspection of a sealed bag of polyimide prepreg showing UV fluorescence of particulate contamination.

One PCB manufacturer performs vacuum cleaning on etched innerlayers as well as on sheets of prepreg. Special non-contaminating brushes are used and the motor and air exhaust of the vacuum system is placed outside the clean room. Another PCB manufacturer recently demonstrated the efficiency of different cleaning methods using rollers and vacuuming. Sample coupons were manufactured using different cleaning methods and were submitted to IR testing, as previously described.

E. Inspection on External Layers of Final PCB

As part of the release procedure for the final PCB, a visual inspection is performed on external layers to detect defects in the surface finish, circuit or clearances. It is common for PCBs for space applications to be designed with laminate on outer layers, rather than copper foil and prepreg. Contamination embedded in laminate remains covered by copper cladding throughout the production process, until the final tin-lead pattern plating and etching process on the outer layer. Rejecting a final PCB often affects on-time delivery.

In some recent cases, small but critical fiber contamination remained undetected at outgoing inspection as well as incoming inspection at the customer, which is described as NC#1 as part of ESA Alert EA-2014-EEE-3-A. Only after assembly and conformal coating, it was discovered that fiber contamination was embedded within the outer layer laminate and bridging the gap between pads. Waiving such non-conformance by repair and testing under careful assessment by NRB was performed but requires high effort and cost, in particular when the delivery of the

Figure 13: Contamination embedded in base laminate on external layers bridging the insulation between pads, at outgoing inspection and after assembly.

PCB assembly is on the critical path of satellite integration.

F. Electrical Testing

Typical electrical testing applied on PCBs by flying probe equipment is specified in IPC-9252 and is based on an insulation threshold of 10 MΩ, corresponding to level C for IPC class 3. The objective of this test method is to verify electrical design, i.e. the absence of unintended connections in the circuit. For IPC class 3/A this test method is amended in IPC-6012 to 100 MΩ under 250 V bias.

The working group specified a new high resistance electrical test method[5] with a 1 GΩ threshold and monitoring of voltage during ramp-up, to determine the quality of the insulation and to detect possible imperfections in the dielectric material. The rationale is that contamination between nets can provide a high-Ohmic path that can be detected under high voltage bias and therefore fails this test. The requirement for GΩ insulation resistance is specified in ECSS-Q-ST-70-10C[6] and is substantiated by the typical volume resistivity of 10^8 MΩ-cm, determined on dielectric materials at humid conditions of 90% RH in accordance with IPC-TM-650 2.5.17.1.

During recent use of this test method, one PCB manufacturer reported failure of a PCB at 160 MΩ insulation. When the PCB was submitted to 250 V sustained for a longer period of 1 minute, the net eventually failed in short circuit. Subsequent analysis and DPA showed particulate contamination in a 4-mil base laminate. Scanning electron microscopy (SEM/EDX) identified the presence of titanium and iron, among others. The high-Ohmic path would have remained undetected with other test methods.

V. Risk Mitigations at Base Material Suppliers

A. Observations on Base Materials

It has been identified that various production processes may contribute to the cleanliness level of dielectric insulation of a PCB. PCB manufacturers that are qualified in accordance with ECSS-Q-ST-70-10C[6] are subject to an audit process that assesses the implemented risk mitigations. This is however not the case for base material suppliers.

PCB manufacturers perform sample screening on laminates, they perform in-process screening on etched innerlayers and on prepreg sheets during lay-up, and they perform root

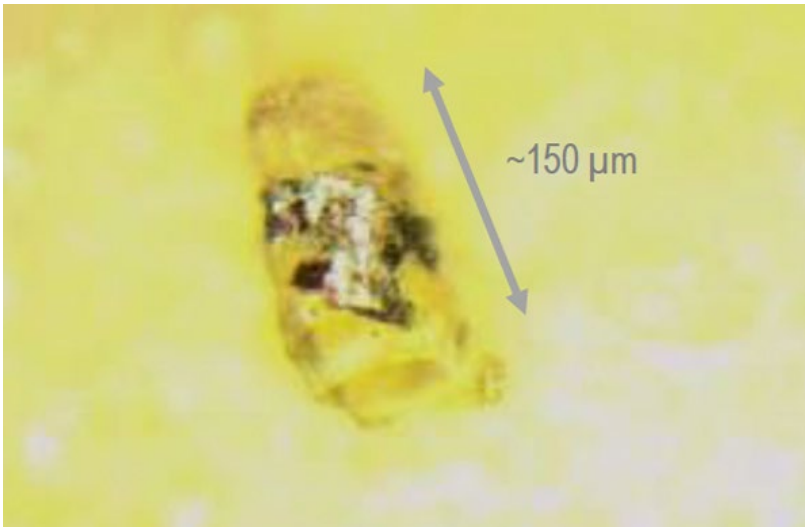

Figure 14: In-plane section of particulate contamination with metallic constituents embedded in base laminate causing high-Ohmic short.

cause investigation when a final PCB fails electrical testing. The results obtained from these inspections are presented in the previous chapter and show varying level of quality of base materials. In some cases, contamination is identified that exceeds the requirements of IPC-4101[8]. In other cases, contamination is identified that is within the requirements of IPC-4101 but is still proven to be unsuitable for PCB manufacture in high-reliability applications.

B. IPC-4101 Specification for base materials

The concerns regarding lack of cleanliness on base materials have been addressed to the IPC subcommittee 3-11, which is responsible of updating the IPC-4101 to revision D. This standard currently has non-stringent requirements for the sample size of screening and for acceptance criteria of subsurface imperfections. Although the sample screening on a batch of laminate may be statistically inefficient, it does provide a simple method to quantify cleanliness level, against which base material suppliers can be held accountable. One remarkably weak requirement of IPC-4101 is to permit fiber contamination up to 13 mm length. This is in contrast with IPC-6012 that does not allow foreign inclusions that reduce dielectric spacing to below the minimum requirement for class 3/A PCBs for space application. As a comparison, common PCB design for space may use in-plane insulation in the order of 0.5 mm, with a minimum as-manufactured of 0.15 mm for 100 V, as specified in ECSS-Q-ST-70-12.

A proposal with tightened requirements for a new class of cleaner base materials has been drafted[7] and presented to the IPC subcommittee. This proposal requires 100% visual inspection on prepreg prior to copper cladding for the manufacture of laminate, as well as on prepreg to be provided as B-stage cured sheets to PCB manufacturers. Furthermore, the proposal requires fibers to be evaluated as opaque foreign matter limiting its size to 0.5 mm. A sample inspection of 2% is required for batch acceptance of laminates. Some base material suppliers report good experience with high-pot testing on thin laminates. This is specified as an optional test method to be agreed between supplier and customer.

C. Procurement Specification to Base Material Suppliers

The proposal described above cannot be seen as separate from the other risk mitigations. The proposed requirements can still cause latent short circuits when contaminants are situated in a critical area with minimum spacing. It has been seen, however, that base material suppliers on occasion struggle to achieve the current requirements on IPC-4101. Implementing a more stringent specification is, therefore, expected to necessitate better cleanliness control. Moreover, the required inspections for batch release provide accountability.

The proposed specification does not describe an ideal material. It is rather deemed to be a compromise that is realistically achievable in an attempt to define a new class of cleaner base materials. It is not the intention to specify requirements on a unilateral basis that cannot be achieved by base material suppliers. This is for instance the case for the copper foil class D

surface roughness specified in IPC-4101, which appears to be unavailable from most suppliers.

Therefore, the proposed specification has recently been provided to key suppliers of base materials for review and for their Statements of Compliance. The cost of investments may be difficult to carry by the base material suppliers since the European space industry is a niche market. This may have a commercial impact that remains to be assessed by the entire supply chain. However, the recent feedback from key suppliers has been positive.

VI. Conclusions

Latent short circuit failure of power PCBs has been associated with fiber contamination of the dielectric material. Tests and inspections have shown various sources of contamination in laminate, prepreg and on etched innerlayers. It has been demonstrated by IR tests that contamination can cause breach of insulation due to electromigration.

Risk mitigations have been specified in PCB design, PCB manufacture and base material supply. These include conservative design of insulation, inspection on base laminates and prepreg, in-process inspections on etched innerlayers, clean room practices in manufacture, cleaning of innerlayers and electrical testing on final PCBs.

IPC-4101 specifies a cleanliness level for base materials that is in conflict with high-rel PCB manufacture and requirements for insulation specified for IPC class 3/A. A specification for a new class of cleaner base materials is being issued to key base material suppliers and is proposed to be included in a revision of IPC-4101.

Acknowledgement

This paper summarises collected results obtained within the PCB-SMT working group of the Component Technology Board, a supporting unit of the European Space Component Coordination. This working group includes representatives of the space agencies CNES and ESA, satellite integrators Airbus, Thales Alenia Space and RUAG and qualified PCB manufacturers TESAT Spacecom, PrinctaGRAPHIC, Systronic, and Invotec. Moreover, improvements in PCB design have been the subject of the working group on the ECSS-Q-ST-70-12. Working group members contributed extensively to the common know-how presented in this paper. Moreover, key base material suppliers have supported the working group in the understanding of cleanliness issues in critical processes and in defining risk mitigations. Without their commitment to the high-reliability space market it would not be possible to improve on quality.

Meanwhile, the proposal (available on www.escies.org/pcb/ as memo QT/2013/378/SH) for an Appendix to IPC-4101 with tighter cleanliness requirements has been presented to the 3-11 subcommittee at IPC APEX/Expo 2015. The subcommittee has accepted to draft the Appendix as an amendment 2 of revision D of IPC-4101 and circulate for review and approval. **PCB**

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Originally presented at 2015 IPC APEX EXPO and published in the proceedings.

Stan Heltzel is a materials engineer at ESA, in the Components Technology and Space Materials Division, Noordwijk, Netherlands. To contact the author, click here.

Declaring War on Failure in Electronics

by Stephen Las Marias
I-CONNECT007

"Failure, in electronics, while not necessarily desired by either manufacturer or consumer, is expected. We are, in a sense, inured to failure. We expect problems."

And so goes Joe Fjelstad's article on the topic, 'War on Process Failure,' which is the feature topic for all of our magazines here at I-Connect007—*The PCB Magazine, The PCB Design Magazine* and *SMT Magazine*—this month.

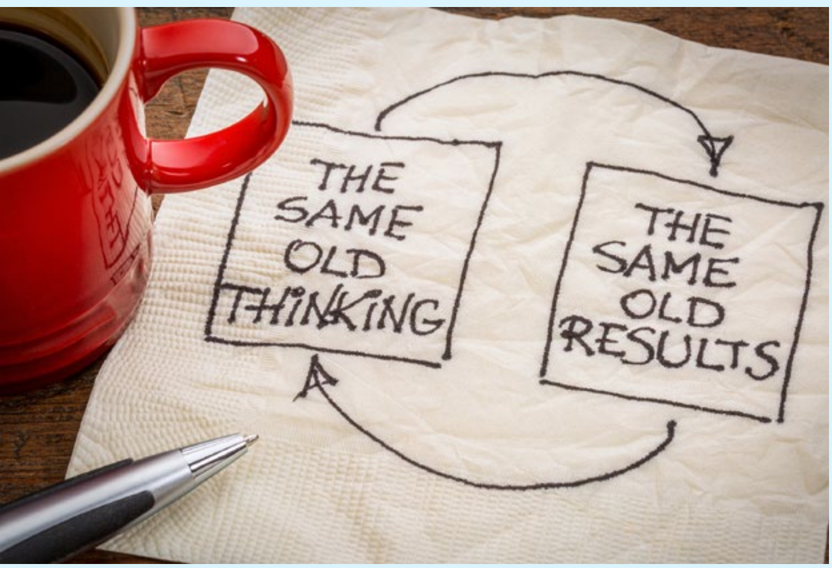
Fjelstad is the owner and president of Verdant Electronics. His company has been promoting the Occam Process, an approach to electronics manufacture and assembly which circumvents the solder process and harbors the conceptual promise and potential for the manufacture of high-density, high-performance, high-reliability, lower cost and environmentally compliant next-generation solutions for products ranging from consumer to milaero applications. We invited him to write something on the above topic, as it is something that is close to his heart.

In his article, Fjelstad notes that much is being done in an effort to improve reliability with new solder alloys, new fluxes, new materials, new equipment and process parameters. But, as he says in the piece, the problem with focusing attention on improving reliability, exclusively within the existing manufacturing paradigm, is that it too often seeks ways to identify and treat symptoms while ignoring the disease.

In electronics, the most prominent causes of defects and failure are found in the soldering process and the trillions of solder joints that are created annually. Soldering, Fjelstad concedes, is a useful technology—and will likely be used in much product in the future as it has in the past—but it comes with many challenges, which have been exacerbated by the forced conversion to lead-free solder to meet needless EU mandates. For evidence, look at any electronics industry journal or conference proceedings and one will find countless articles on solder-related challenges and defects and how to remedy them.

The complexity of the soldering process and all of the expensive test and inspection equipment add cost, but no true value, he writes. He said that they are much like medical tests used to detect disease in humans; they may alert one to the problem but they do nothing to treat it.

Detection should not be confused with treatment, but too often it is. We applaud ourselves more for finding defects than for eliminating them. Clearly, soldering is an imperfect process and one that is unlikely to ever achieve perfection, states Fjelstad. Moreover, it is cause for collateral damage to both components and PCB substrates because of the high temperatures required and the deleterious effects associated with those high temperatures. Even after the product is built, solder remains the weak link. Failed solder joints are a leading cause product failure in use.



Given the situation, how might one defeat such a formidable foe?

Find out more by reading the complete version of Fjelstad's article in the August 2015 issue of *SMT Magazine*. **PCB**

Stephen Las Marias is managing editor of *SMT Magazine.*

MilAero007 Highlights

Avoid Overbuilding your RF Printed Circuit Board

Today, many companies are overbuilding and "overmaterializing" their RF printed circuit boards. In this interview, James Hofer of Accurate Circuit Engineering (ACE) shares some strategies to avoid doing both, which will help lower the total cost of your PCB and improve the overall product quality. Hofer also discusses some of the challenges in the laminate supply chain.

A Look at the High-Reliability Interconnect Market

I-Connect007 Publisher Barry Matties recently met with Mark Cormier of Miraco Inc. to discuss the latest trends and drivers in the high-reliability segment, and their customers' increasing demand for quality.

Changing the Face of Displays... One Button at a Time

Incom produces fused fiber optics with a new polymer process that replaces traditional glass fiber optics. This allows the creation of new applications, and for OEMs it changes the way they can build human control interfaces. Emilijo explains how Fairlight is incorporating this technology into their famous products for the recording and broadcast industries, along with other applications such as elevator control panels.

Exception PCB Solutions Design Service Boosts CID+ Qualifications

Exception PCB Solutions growth and development in 2015 continues with a focus on service including additional investment in Exception's Integrated PCB Design Service which is proving to be highly popular. This has resulted in increased growth not only from existing customers, but also from many new customers across a range of sectors.

NASA, DRS Technologies Collaborate to Create Mid-Infrared Detector

NASA scientist Xiaoli Sun and his industry partner have created the world's first photon-counting detector sensitive to the mid-infrared wavelength bands—a spectral sweet spot for a number of remote-sensing applications, including the detection of greenhouse gases on Earth, Mars and other planetary bodies, as well as ice and frost on comets, asteroids and the moon.

FTG Circuits' Sales Up $1.8M or 15% in Q2

"The second quarter of 2015 saw record sales for FTG with all sites participating in the growth," stated Brad Bourne, president and CEO. He added, "These record sales are enabling us to report strong earnings while still investing in our future."

Multilayer Technology Passes AS9100 Surveillance Audit

Multilayer Technology (MLT), located in Irving, Texas has passed its AS9100C surveillance audits. The audit consisted of 2.5 days (20 hours) of intense auditing by our registrar. All departments were completely audited to ensure compliance to the AS9100C Certification.

All Flex Flexible Circuits & Heaters Achieves AS/ISO Re-certification

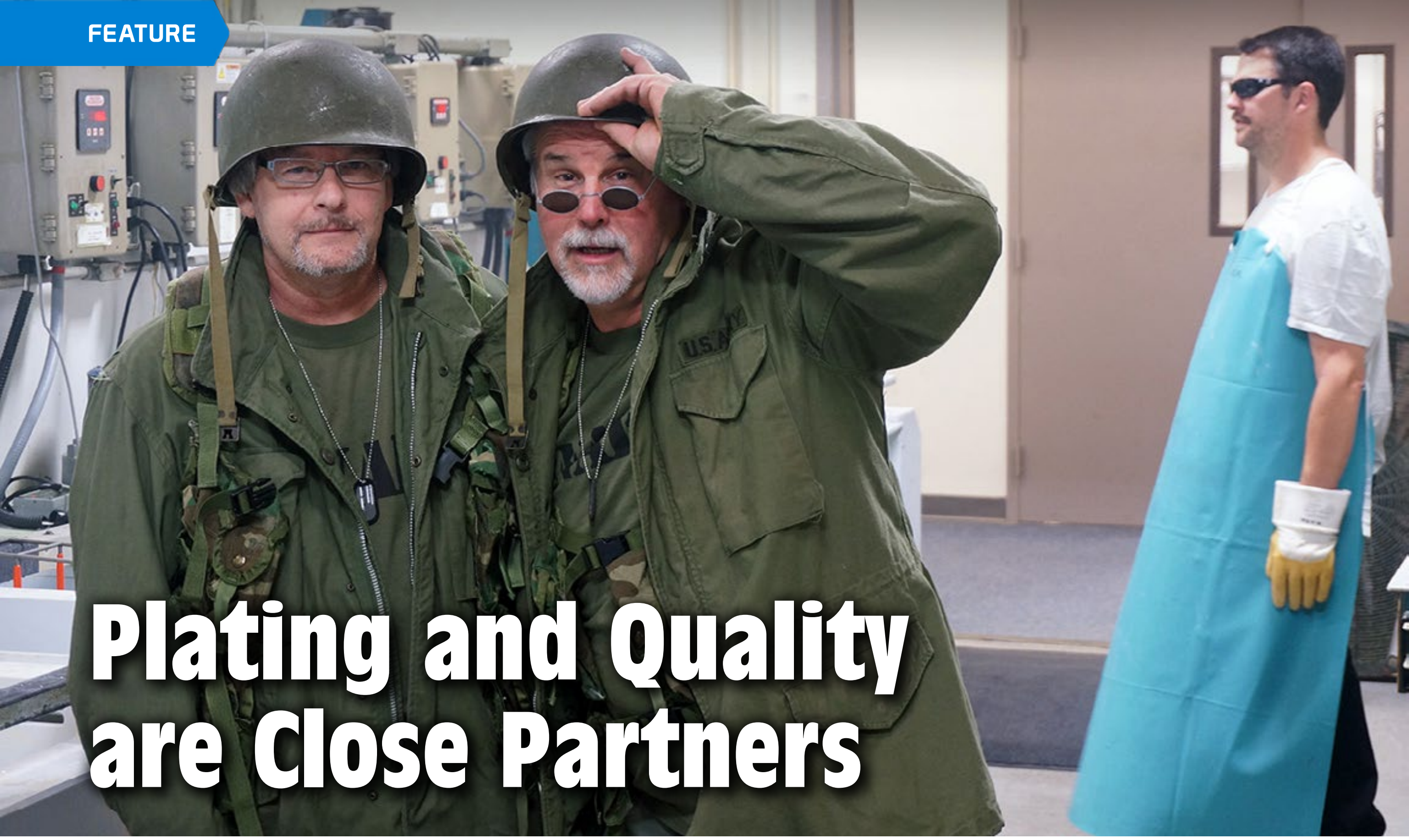
All Flex, manufacturer of flexible printed circuits and heaters announces re-certification to AS9100C and ISO 9001:2008. AS9100 is an international aerospace standard for quality assurance requirements of aerospace companies.

Satellite Project to Clean Up Space Debris Orbiting Earth

The Clean Space One Project has passed a milestone. The space cleanup satellite will deploy a conical net to capture the small SwissCube satellite before destroying it in the atmosphere. It's one of the solutions being tested for eliminating dangerous debris orbiting the Earth.

Alone in the Darkness: Mariner 4 to Mars, 50 Years Later

July 14 marks 50 years of visual reconnaissance of the solar system by NASA's Jet Propulsion Laboratory (JPL), beginning with Mariner 4's flyby of Mars in 1965. Among JPL's first planetary efforts, Mariners 3 and 4 (known collectively as "Mariner Mars") were planned and executed by a group of pioneering scientists at Caltech in partnership with JPL.



Plating and Quality are Close Partners

by Bob Tarzwell

Something that I frequently hear these days is that we are losing the older, seasoned, well-trained people in the PCB business—people who really know how to manage and keep a plating area producing high-quality product. The entire process of plating from end to end, with all its subtle nuances and time-learned tricks, is not something you can just pick up in a few years.

A good plating manager is a seasoned veteran with many years of hands-on experience and probably an engineering degree. I also see first-hand how PCB manufacturers, without the proper plating shop set-up operations, knowledge and experience, adapt and accept poor practices as normal while they continue with poor quality processes—even after attempted corrective input from vendors and consultants. These same companies accept their yields at 70%, while unnecessarily losing millions each year, and just accept it as part of doing business. Yet when told of other manufacturers who are routinely above 98% first-pass yield, they argue with you, find 100 reasons why you're wrong, and do nothing about their own situation.

So I've documented a few of the bigger mistakes I see PCB shops making in the hope of educating readers and changing the way they look at the plating process as a built-in quality requirement, rather than just a dirty, stinky old line that plates copper.

First, if you need rubber boots to walk in your plating area, then it's time to clean it up; good plating areas are clean, well-lit, low-dust areas that have well thought out ventilation. A dirty plating area is hard on quality, because you are fighting contamination and dirt; both have potentially big effects on plating. If your copper tanks sit uncovered and there is dust in the air from either a routing operation that's too close or open doors to the great outdoors, the dust will settle into the tank and give you plating bumps. I have seen plating areas where all boards had to be sanded flat because the copper bumps were so frequent and large. Typically we sort out the problem by finding the dust source, correcting it, super-cleaning the tanks, and adding new solution.

I always seem to be at odds with the plating tank maintenance team regarding carbon treating and proper maintenance of the solution, but then I am, as one person said, "old-school." Yes, I am old-school; we learned how to properly carbon treat a copper plating tank. Today, unknowing people just put a few small 10-inch carbon

filters on the copper tank, run it for a few hours and say, "Voila, it's treated." Sorry, but not even close. Look at your copper tank. If it's not a clear, very light blue, then it's not treated properly; if it's greenish and cloudy, then you have a lot of dry film and other contaminants in the solution that will hurt your plating quality.

The proper way to treat a copper tank is first by heating it and/or adding hydrogen peroxide, which removes the brighteners and levelers. Then run the solution through large bags of activated carbon until the solution is clear and blue, typically overnight. Add a full load of brighteners and levelers and then use a Hull cell. The magic Hull cell is an old-time way of knowing what your plating tank is doing. It tells you if the throwing power is good, if your levelers are proper, and if the brighteners are correct. But not many plating areas use them anymore, let alone even know how to do a Hull cell and what to look for. I have used the automatic titration machines the vendors have sold for many years and they work as they should, telling you the brighter and leveler percentages, but they can never tell you how the tank is plating. Only a Hull cell can do that.

The percentages of sulfuric acid and hydrochloric acid affect the plating speed and quality, as does the copper content of the bath. One of the worst ways to run a copper tank is to put 10-inch carbon-polishing filters on the tank pump and run 24/7. This creates a few problems; most significantly it reduces the levelers and brighteners, which you do not want to do unless you like paying your chemical supplier more money. Meanwhile, the little activated carbon in the filters really does not remove much of the dry film contaminants.

Along with proper carbon treating, another important maintenance item is the proper removal of metals other than copper. The copper tank will have a small percentage of lead, tin and other metals present in the shop, mostly from rack carry-over and accidental cleaning of a tin-lead board in a rinse right before the copper tank. To remove these metals is an easy job, yet lately I have seen few plating staff performing this task or having the special plates to remove these various metals. This is something that we regularly did to keep copper ductility at the proper specification.

A special stainless steel plate is made with sharp, 2-inch zig-zag bends, so as to look like an accordion; the various angles and distances from the anodes facilitate removal of the different metals because they plate out at different current densities. Metal contamination of the copper tank can result in a grainy and bumpy copper surface. It is important to work at fixing the problem by controlling the process/dripping time of the rinse tanks and performing a metal plating clean cycle every few months.

> "The magic Hull cell is an old-time way of knowing what your plating tank is doing. It tells you if the throwing power is good, if your levelers are proper, and if the brighteners are correct. But not many plating areas use them anymore, let alone even know how to do a Hull cell and what to look for."

The type and number of anodes can have a significant effect on the quality of the copper. With too large an anode area and a higher sulfuric percentage, you can easily build up too much copper in the bath from the etching effect of the sulfuric acid. I have used both straight copper/phosphor anodes and titanium baskets with copper/phosphor nuggets or balls. Both work well, with the edge going to 1-inch copper balls and rectangular titanium baskets, as you can keep the copper surface area in control and add new copper balls as needed to maintain area. Both require constant maintenance with scheduled anode removal, cleaning, re-bagging, and smut removal with a proper reactivation plating cycle.

During the '90s, my PCB shop made special heavy copper circuits; we had to learn how to plate up to 40 ounces of copper in three-dimensional layers. Believe me, when a single panel is in the copper plating tank for 40 hours, if you have even the smallest chemical unbalance or the tank design is wrong, you will know quickly.

Along with chemical balance, an equally important area is correct tank design. A tank with limited panel motion, not enough airflow or wrong impingement design will never give you top-notch plating quality. The design of the copper tank should have the correct distance between the anodes and the panel; the panels should have at least 2.5" of travel on the cross slides. I prefer moving the panel along the same plane as the anodes which controls plating evenness as you move the panel across the different plating speed of the anode surface area, but movement towards the anodes works almost as good. I have used vibrators and they do work well in very small-hole situations, but they can also create problems of micro-bubbles on the surface created by the vibration.

I don't use vibrator units all the time, only when I need to. I find a kicker works better than vibration (i.e., a solenoid that kicks the rack every minute or so to remove any hydrogen bubbles lodged in the holes, as opposed to a full on ultrasonic type vibrator). One note of caution: Do not use vibrators with carbon electroless solutions, such as Blackhole or Shadow; the shaking of the vibrator will loosen and remove carbon particles from the holes. This will then pollute your copper tank, producing an outcrop of copper bumps on the surface so bad your boards can be sold as sandpaper.

The panel racking should be stout and able to carry your largest currents; I do not like small top racks that only grip in one or two clamps because this produces too high a current area at the singular clamping area. I like racks which have four or five protected clamps down each side to help distribute the high current. Remember to make sure you have a small current available when you place your panels into the copper plating solution, this starts the action of plating

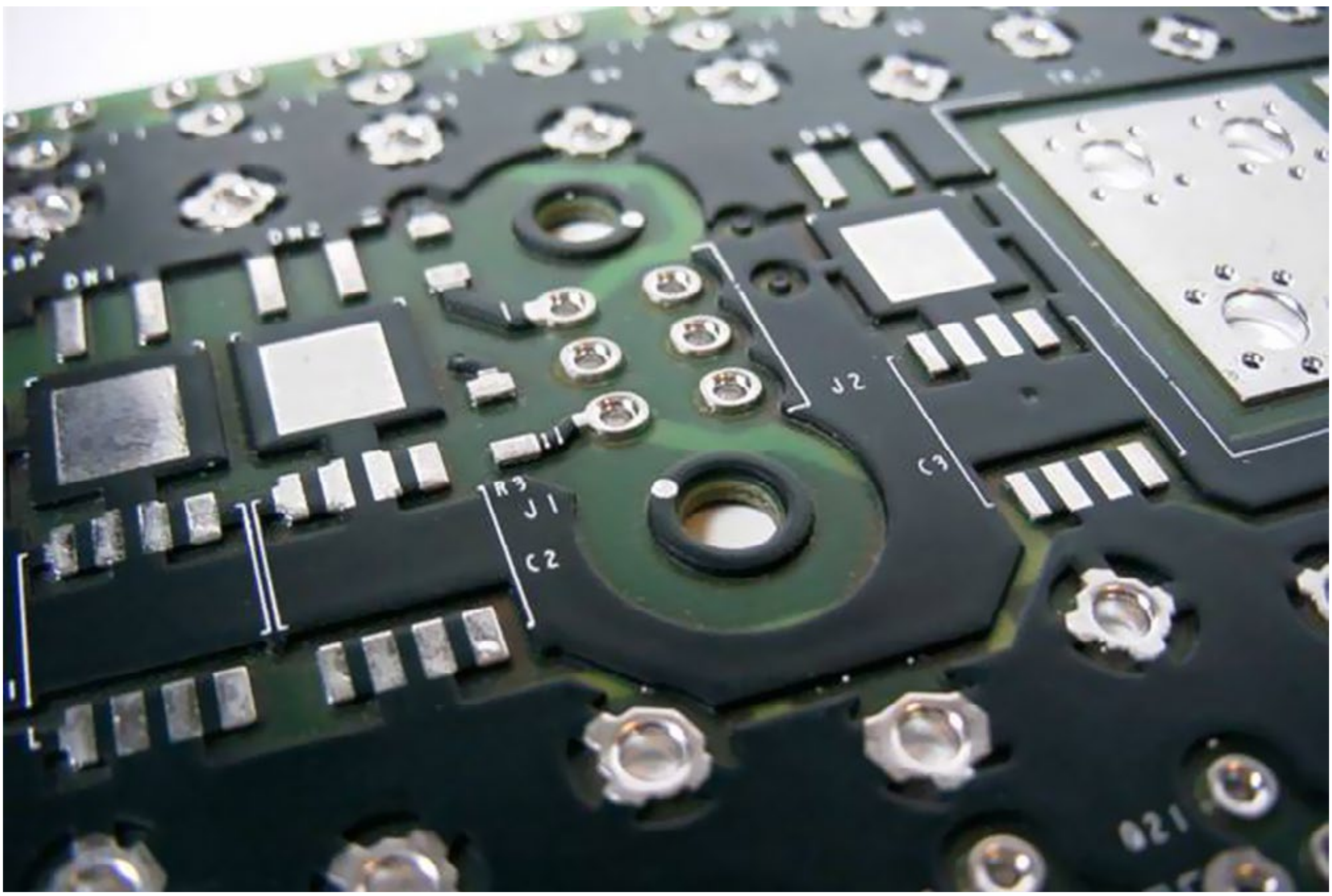


Figure 1: A 15 oz., 6-layer PCB.

immediately and helps avoid etching of the copper. Remember, you have a sulfuric acid solution which will etch copper if no current is flowing. Normally with half-ounce copper this is not a problem, but with today's thinner base copper down to 1-micron more typically being used to produce fine lines, any accidental etching before plating can become a big problem.

The amount of tank air you run is also important in a few ways. I'm not a fan of bottom air-induced tank solution movement. To get the correct replacement copper ion solution flow across the panel from air bubble movement from the bottom to the top of the tank, you need enough air to lift the top of the surface one to two inches with bubbles; any less and you will get panel corner and high current-area burning. The bubbles should not be left on when the tank is not used, as it does speed up consumption of your brighteners and levelers. Also, the bubble action as they burst in the air puts a lot of copper fumes into the air, which we now need to remove via big fans or your employees and equipment suffer. I do try to suggest solution impingement tanks to my clients; the improvement in plating quality and the reduction in fumes alone in the plating area is worth the conversion cost.

Copper ductility is determined by a test done at an outside service, and is affected by extra metals and contaminants in the plating solution, and if the current density is too high it can cause large grain deposits. Ductility testing should be done on a regular basis.

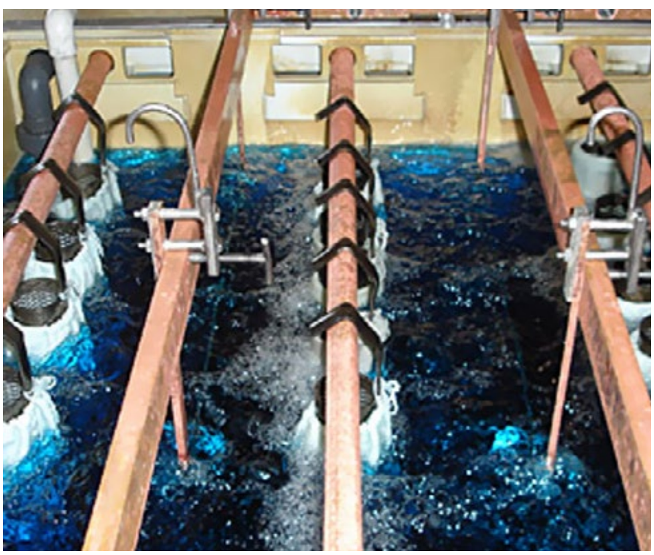


Figure 2: Example of insufficient anode area as well as insufficient air bubbling.

Pre-Clean Line Considerations

First test to see if you are properly removing the last little bit of dry film smut out of the developer—you may be surprised. A potassium sulfide 1:5 concentration can be used to color copper black but will not color any area that still has dry film smut on it. Apply after developing or after your pre-clean line and examine with a microscope for areas that are not fully black; these are caused by dry film residue that did not develop off and will not plate.

Complete developing is important to plating success. The first tank in the pre-clean line is designed to help remove any dry film residues (but it is wise to minimize the work it needs to do by improving the developing process). The next tanks are twin or triple cascading rinses. Using counterflow rinses reduce the volume of water needed as well as reducing the amount of chemical carry-over between active tanks. Many companies have a dead tank at the end of double cascading tanks to further reduce water usage; however, stringent bath change times must be adhered to.

The next tank is the copper micro-etch tank. Quite a few versions are available, including hydrogen peroxide-based or sodium persulfate with sulfuric acid. The tank's function is to slightly etch the surface of the copper and remove a few millionths of the copper surface. Copper is very reactive and oxidizes before you can blink, and this oxide can prevent copper plating from properly sticking to the surface, resulting in peeling copper. It is very important to do micro-etch rate coupons in this tank as it quickly varies in etch rate as it absorbs copper. It is the best way to determine the etch rate and adjust the process time a few times during the day. (We used to have a chalkboard at the micro-etch tank with the present dwell time in the tank, and it was tested every four hours and marked down. Operators were required to follow the time accurately—it's that important.) The best etch rate is around 15–20 millionths; below that etch amount you will get lower copper plating adhesion numbers, and above that is not really better as it consumes

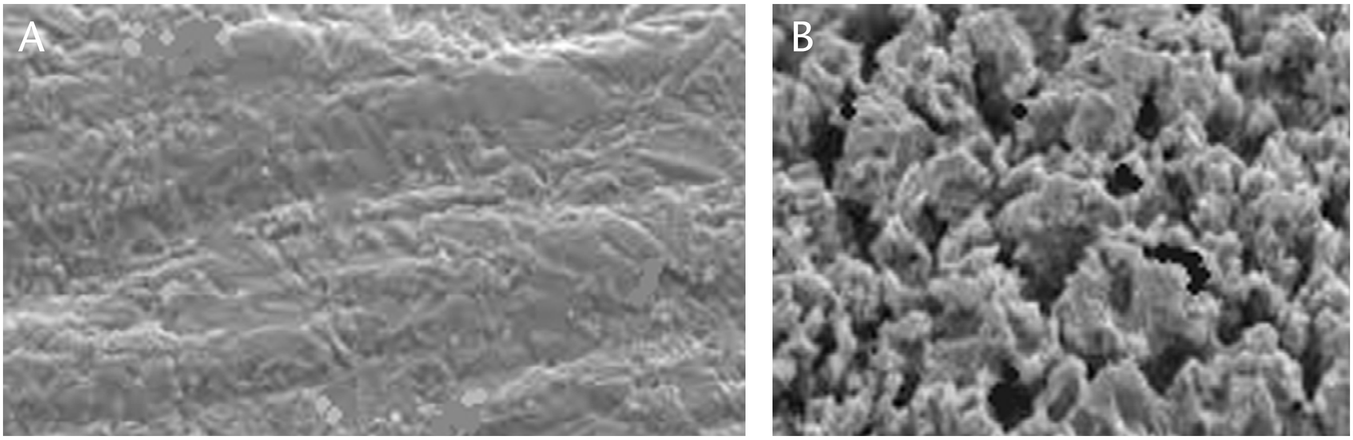


Figure 3: Copper surface before (a) and after (b) micro-etch.

time and can potentially etch some thin copper base laminates.

The micro-etch test coupon is a 3-inch by 3-inch single-sided copper laminate that has been dried and weighed. The test sample is placed in the tank and timed at 30 seconds. After it is washed and re-dried and weighed, the difference in grams multiplied by 365 is the number of millionths removed, or 9.7 times weight loss in microns removed in the 30 seconds. Copper plating adhesion can be tested quickly by heating a sample etched pad with a soldering iron; if the copper peels off leaving the original copper you have a problem. Severe cases of peeling will cause the tracks to fall off before final processing, and it is solely from not monitoring and controlling your micro-etch tank closely enough. The micro-etch is followed by a second set of cascading rinses; these are important because the persulfate or hydrogen peroxide is a poison to the copper tank.

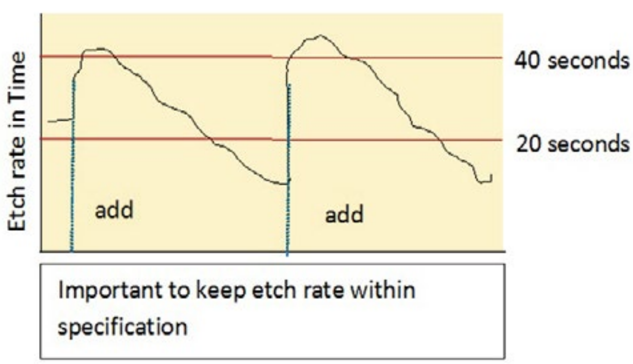


Figure 4: Chart showing etch rate in micro-etch bath.

The last tank is a 10% sulfuric acid tank that helps remove any last oxides and sets the acid pH of the panel going into the acid-based copper tank. After plating, a set of cascading rinse tanks is used prior to going into the tin tank. Many shops have a dead rinse tank after copper plating to further limit the copper drag-over into waste processing. One of the biggest improvements you can make to the copper plating line is to slow down the operation after removal and let the panels drip after each tank, before you move the racks. A “slam dunk” only causes excessive contamination carryover and further pollutes and reduces the life of your copper tank.

Other Points to Consider

Oils in the plating area from a hot-air unit or hot-oil reflow tanks in the plating area will cover any panels waiting for processing with a very thin coating of oil (it’s in the air and is attracted to the panels’ negatively charged surfaces). The oil film is very difficult to remove and causes open spots of non-plating. I have seen this enough times to warrant mentioning it. Run a water break test to see if your plating surface is clean.

The plating current you run is not constant. It should change based on the panels your plating, line widths and copper balance between sides; it will also change during the plating process. In order to have an even amount of plating on each side of the panel, it is important to have a balanced amount of exposed copper on each side. Have your CAD personnel use bleeder strips to even out the sides if necessary. I have used differential plating tanks with two power supplies—one for the back plating and one for the front. This way, you can plate 200 amps on the front and 170 on the back to ensure even plating.

In most shops there is a difference in plating tanks—one may have reverse pulse rectification and another work tank with just straight DC. Reverse pulse plating works better than straight DC in some applications such as copper flatness and high-ratio, deep hole plating. But be warned: There are so many settings on a typical reverse pulse unit that it is easy for a plating engineer who likes to play, to never have it set right.

With the push to HDI and flat via-in-pad, many shops are putting in separate hole-fill copper tanks. These are special tanks with special chemistry that require a significant amount of testing to get the current and chemistry parameters right; it is not just a pour-and-plate situation.

One of the biggest quality improvements in plating is controlling how much copper is in the hole. Below 1 mil the board may not even make it through three assembly heat cycles if the panel thickness is 40–90 mils. At 1.4 mils you have a reasonable chance of a good PCB that will withstand a normal 500 thermal cycles. For higher-reliability PCBs, I use 1.6–2 mils of copper in the hole and compensate by starting with a slightly thinner base copper so the overall trace copper thickness is the same as a normal board; there is just more copper in the hole and this thicker copper can pass 2,000 heat cycles. A good operator can have a rough guess at the copper thickness in the hole using pin gauges, but pin gauges by design are not accurate enough to properly determine if you have 1 mil or 1.4 mils of copper in the hole; the difference is a PCB that fails or one that works. The only way to see plating quality and thickness is constant cross-sections and solder float tests. When you get the tank working correctly and understand plating speed and currents, your operators can be very close to the desired thickness based on time alone. For more accurate measuring, I use a good, deep-throat digital micrometer (in millionths) and measure the panel before, during and after copper plating. I have the CAD department place a special pad on each side of the panel for use in measuring the combined plating thickness of the board.

A water break test, for fingerprints or greases, is used to show why you should work hard to keep fingerprints off the bare copper panels. Try it yourself—take two panels, one with the normal fingerprints all over it (that I hate to see) and one that is new, dip each into a clean water tank and remove and hold vertically. As the water sheen drips away it will hold a thin water film unless grease or fingerprints are present; each fingerprint will leave a break in the surface film, while the clean panel will hold a surface film for a long time. The most impressive test is to now take the panel with all the fingerprints and run it through a scrubber or chemical clean line. It will be clean right? WRONG! Do the water break test after you have cleaned it and you will still see most of the fingerprints. Fingerprints are not easily removed by our cleaning process. They cause poor plating because they add an oily surface that the copper ions will have to break through, slowing down the plating process and resulting in thin or spotty plated areas.

Once exposed and developed, dry film panels should be covered with black plastic until ready to be plated to stop further hardening of the dry film polymers from the UV plating room lights. UV light hardening can increase dry film chipping and reduce adhesion. The copper tank produces hydrogen bubbles as it plates; these bubbles are powerful enough to break off fine tracks if the dry film gets brittle. The black plastic covering also keeps dust, dirt and any airborne oils off the boards.

I hope some of my 52 years of experience in PCB plating will help you, even if it only helps you find and fix one small problem. **PCB**

Bob Tarzwell is a PCB consultant who has spent 50 years in the PCB industry, inventing technology and building almost every type of PCB. He is the co-owner of DB Publishing, publisher of the PCB 101 and Quality 101 handbooks. To contact the author, click here.

PCB007 Supplier/New Product Highlights

Insulectro, Oak-Mitsui, and CAC Create Landmark Partnership

Beginning in July, Insulectro will provide copper foil manufactured by Oak-Mitsui for the PCB outer-layer market requirements. This strategic move will provide long-term sustainable domestic foil to PCB fabrication customers.

Atotech Increases Equipment Manufacturing Capacity with New Facility in China

Atotech, a global leader in specialty plating chemicals, equipment and services, today announced the inauguration of its second equipment manufacturing facility in Guangzhou, China to meet the growing demand for its plating equipment.

Ventec USA Appoints Ken Stem as Technical Account Representative

Ventec USA is proud to announce the appointment of Ken Stem as Technical Account Representative for the states of Washington, Oregon, Colorado, Utah, Arizona and Vancouver/British Columbia, Canada.

Leading PCB Test Service Installed Second atg Flying Probe System

atg Luther & Maelzer GmbH has confirmed the installation of a second atg A7 flying probe test system for high-speed bare board testing at Circuit Technology Services.

Orbotech Divests Thermal Products Business

ORBOTECH LTD. today announced that SPTS Technologies Group Ltd. (SPTS), an Orbotech company and supplier of advanced wafer processing solutions for the global semiconductor and related industries, has sold its Thermal Products business to SPP Technologies Co, Ltd. (SPT), a subsidiary of Sumitomo Precision Products Co., Ltd.

John Perry Explains IPC T-50 Revision M 443

IPC has released IPC-T-50 Revision M, Terms and Definitions for Interconnecting and Packaging Electronic Circuits. This ever-evolving standard provides common language of terms and definitions for the electronics industry.

Maskless Lithography Inc. Appoints Technica USA as Authorized Service Provider

Bill Elder, CEO of Maskless Lithography Inc. (MLI), announced that the company has reached an agreement with Technica USA to become the only authorized service provider for the MLI technology in North America.

MacDermid Electronics Solutions' Julian Bashore Elected to JPCA Board of Trustees

MacDermid Electronics Solutions, a division of MacDermid, Incorporated, a Platform Specialty Products Corporation company, announces the election of Julian Bashore, managing director, Japan, to the Japan Electronics Packaging and Circuits Association (JPCA) Board of Trustees at their annual general meeting held in Tokyo on May 22, 2015.

Registration Opens for Boards, Chips and Packaging Conference from Isola and Semico Research

Isola Group, a market leader in copper-clad laminates and dielectric prepreg materials used to fabricate advanced multilayer Printed Circuit Boards (PCBs) and Semico Research, a semiconductor marketing and consulting research company, announced today that they have teamed up to launch Boards, Chips and Packaging: Designing to Maximize Results.

Bay Area Circuits Selects Seica Flying-Probe PCB Test System

Bay Area Circuits Inc. has purchased a Rapid 270 bare-board tester as announced by Seica Inc.'s sales representative in Northwestern USA, Zero Defects International. This tester will augment a Seica S240 fully automated tester which has been in use at Bay Area Circuits for the past four years.

Designing Flex Circuits for Domestic Prototyping

by Tara Dunn
OMNI PCB

Designing a flex circuit to be prototyped domestically? No problem. Designing a rigid-flex circuit for production offshore? Got it. Designing a part that will be prototyped domestically with a seamless transition to offshore production? That can be a little more challenging.

We have probably all been there. The prototypes are needed on a very tight delivery schedule and are built domestically. The testing is complete and the same files are sent to an offshore manufacturer for the production build. The order is placed and suddenly, the engineering questions start coming in. Can the materials be changed? Can the hole size or pad size be altered to improve manufacturability? These common questions now require time and effort to evaluate and ultimately, time and effort to complete the rev spin before production product can be released. Recently, Omni PWB's Elizabeth Foradori and I sat down with Ashley Luxton of Graphic PLC to learn his recommendations for minimizing these disruptions. Our discussion focused on the importance of supplier selection, universal considerations, and key areas that have more significant variation. To listen to the discussion, click here. Following are some of the highlights from that discussion.

Supplier Selection: Choose your supplier carefully and consider the different options available. There are manufacturers that own both domestic and offshore facilities, domestic manufacturers that partner with offshore facilities, and manufacturers that work only domestically or only offshore.

When working with a manufacturer that has both domestic and offshore capabilities, it is critical to communicate with them early in the design process. The fabricator, understanding both the domestic and offshore preferences and capabilities, will be happy to make recommendations for material selection, panel utilization, and also how to maximize yields for the production volumes.

A domestic supplier who partners with an offshore manufacturer will be able to offer this same type of guidance. Due diligence is recommended. Most domestic manufacturers that partner with offshore suppliers do so to offer their customers a full service option. Significant effort is put into learning their partner's technical capabilities, material preferences and operations. The lines of communication between the facilities are well established.

There are also domestic suppliers that purchase product from offshore suppliers to support a full range of volume requirements for their customers, but have not put the extra effort into learning and understanding the details of their offshore partner's technical capabilities. This model provides the customer with volume production from offshore, but may not be the best solution when looking for design guidance to ensure a smooth domestic to offshore transition.

When working with two independent facilities, take the time to fully understand the offshore supplier's capabilities and material preferences and then apply those criteria to the domestic prototype design.

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Automation in Electronics Manufacturing
BGA/CSP Packaging
Black Pad and Other Board Related Defect Issues
BTC/QFN/LGA Components
Business & Supply Chain Issues
Cleaning
Conformal Coatings
Corrosion
Counterfeit Electronics
Design
Electromigration
Electronics Manufacturing Services
Embedded Passive & Active Devices
Environmental Compliance
Failure Analysis
Flexible Circuitry
HDI Technologies
Head-on-Pillow Board and Component Warpage
High Speed, High Frequency & Signal Integrity
Lead-free Fabrication, Assembly & Reliability
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Nanotechnology
Optoelectronics
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Photovoltaics
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Soldering
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Abstract and Proposal INSTRUCTIONS

Submit Conference Paper Abstracts: www.IPCAPEXEXPO.org/CFPapers
More information: Jasbir Bath, JasbirBath@ipc.org, or Toya Richardson, ToyaRichardson@ipc.org.

Submit Professional Development Proposals: www.IPCAPEXEXPO.org/CFPapers
More information: Anne Marie Mulvihill, AnneMarieMulvihill@ipc.org, or Andrea Pinc, AndreaPinc@ipc.org.

Conference Paper Timeline	Professional Development Timeline
Abstracts due August 14, 2015	Proposals due August 14, 2015
Acceptance by September 4, 2015	Acceptance by September 4, 2015
Papers due November 13, 2015	Final presentation revisions due December 11, 2015
Presentations due December 11, 2015	

Universal Criteria: Whether your PCBs are being manufactured domestically or offshore, certain things are universal. Quality specifications such as IPC class, FAIR requirements, and testing requirements do not change. Some of these specifications may not be as critical at the prototype stage and could be waived, but the interpretation of the specification will be consistent.

Designing to maximize yields may not be as critical with a prototype order, but with the higher volumes typically associated with offshore production, expected yields should be considered. There are universal criteria for maximized yields. Increasing holes sizes, pad sizes, line width and space will all improve yields at the manufacturer and have a direct impact on cost.

Acceptance of X-outs should also be considered, as allowing them in your delivered array will have a direct impact on cost. If X-outs are not allowed, both domestic and offshore manufacturers will factor in the yield loss associated with scrapping any good pieces in an array that has an X-out. If X-outs are not allowed, this should be clearly communicated to avoid any misunderstanding.

Significant Variation: Preferred materials can vary significantly between domestic and offshore manufacturing. This preference is typically a function of material availability and cost. Logically, offshore suppliers will prefer to use materials that are produced locally. These materials are more readily available, with lower transportation costs. Most offshore suppliers will also use the materials that are more common in the U.S., but pricing will be higher and lead time longer.

Be careful not to over specify materials. Referencing the appropriate IPC slash sheet, rather than the specific material, allows more flexibility for the supplier. This flexibility will result in lower cost and shorter lead time. If more control is required for material selection, using an approved list of materials that has been tested and approved is another option that allows the manufacturer flexibility to use their more preferred materials, while giving the designer more control of materials being used.

"Be careful not to over specify materials. Referencing the appropriate IPC slash sheet, rather than the specific material, allows more flexibility for the supplier. This flexibility will result in lower cost and shorter lead time."

Another aspect that varies significantly is panel utilization. Domestically, the most common panel size is 18" x 24" with 16" x 22" of usable space for the manufacturer, and it is most cost-effective to design the part or the array to best fit that space. Offshore manufacturers have much more flexibility with their panel sizes, use many different panel sizes to best utilize material, and generally work with larger panels. Offshore, it is more critical to design the array to best utilize the material within the array so that overall, array size has much less of a cost impact.

Recap

When looking for the smoothest transition from domestic prototype to offshore production manufacturing, research suppliers and select one that can demonstrate knowledge of the offshore facility's technical capabilities, material preferences, and that clearly has a streamlined form of communication. Quality and testing specs are universal and should transfer from one facility to the other with no issue, but special attention should be given to controlled impedance, materials and panel utilization, as these can vary significantly between domestic and offshore manufacturing facilities. A smooth transition from domestic prototypes to offshore production does not need to be difficult, but it does need to be well planned. **PCB**

Tara Dunn is the president of Omni PCB. She works with PCB designers and purchasing organizations to find the best fit solution based on volume, technology and lead-time requirements. [Click here](#) to reach Tara.

Recent Highlights from PCB007

1 Kelly Dack Discusses His Recent Move

It's no secret that Prototron is one of the fabricators to watch in the US. I've known the Prototron staff for years, and worked with them for a number of years as well. So, when I heard they had hired Kelly Dack, a longtime PCB designer and guest editor for PCBDesign007, I wasted no time meeting with Kelly.

2 Catching Up with Vector Fabrication's Quang Luong: Here Comes Vietnam!

I have known Quang Luong, the owner of Vector Fabrication, for many years now, and I have always been interested in his business and how it operates, especially since he is the only PCB shop owner I know of who has a company both in the U.S. and in Vietnam.

3 TTM: Consult Fabricators Early for PCB Designs

Recently, I attended the Designers Council "Lunch and Learn" at Broadcom's office in Orange County, California. One of the speakers at this event was Julie Ellis, a field applications engineer with TTM Technologies. She sat down with me to discuss her presentation and some of the ways fabricators can assist PCB designers.

4 EIPC Summer Conference, Berlin

Berlin, capital of Germany and a world city of culture, politics, media and science, was the venue for the 2015 EIPC Summer Conference, which attracted delegates from sixteen countries, including Russia, Hong Kong, Japan, Israel, USA and Canada, as well as the European Union, to experience a programme of 21 technical presentations over two days. Also included was a visit to the Berlin laboratories of Fraunhofer Institute, Europe's largest application-oriented research organisation.

5 Innovative Technologies Drive PCB Industry Growth

PCB growth has slowed in recent years, though last year the growth rate was slightly higher than the 2% of the last three years. Estimates by IEK of Industrial Technology Research Institute of Taiwan show that the PCB industry will continue to grow in 2015 at a rate of 3-5% with an annual output of RMB 576 billion (USD 93.8 billion).

6 Coated Ultra-Thin Copper on Printed Circuit Laminates

Nanocopper based copper foil has great promise for high-density microcircuits. Utilizing conventional coating capability, volume production is easily scalable and cost-effective.

7 Institute of Circuit Technology 41st Annual Symposium

The Institute of Circuit Technology continues to grow its membership, and the Annual Symposium is a major occasion that attracts most of the leading names and faces of the UK PCB industry. This year's event was not only a platform for exchange of knowledge and ideas, but another great opportunity for building networks and collaborative relationships.

8 IPC Releases PCB Industry Results for May 2015

Total North American PCB shipments decreased 4.2% in May 2015 from May 2014, and year-to-date shipment growth declined to -1.8%. Compared to the previous month, PCB shipments were down 3.5%.

9 IPC Promotes Philip Carmichael to IPC President, Asia

IPC has promoted Philip Carmichael to IPC president of Asia. Carmichael has served as president of IPC Greater China since January 2013 and will now expand his responsibilities to include member acquisition and support in Japan, Korea and ASEAN member states including Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam.

10 iPhone 6S Series Drives Sales of Flex PCBs

The upcoming release of Apple Inc.'s iPhone 6S series, which will feature Force Touch technology, is expected to drive demand for flexible PCBs (FPCBs) as Apple is set to increase its orders from Taiwanese firms Zhen Ding Technology and Flexium Interconnect, according to a Digitimes report. This is expected to boost sales of both Zhen Ding and Flexium for the second half of 2015.

EVENTS

For the 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.

7th Annual SMTA Vendor Show
August 21, 2015
Penang, Malaysia

NEPCON South China 2015
August 25–27, 2015
Shenzhen, China

Capital Expo & Tech Forum
September 1, 2015
Laurel, Maryland, USA

electronica India
September 9–11, 2015
New Delhi, India

productronica India
September 9–11, 2015
New Delhi, India

Medical Electronics Symposium 2015
September 16–17, 2015
Portland, Oregon, USA

SMTA International 2015
September 27–October 1, 2015
Rosemont, Illinois, USA

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: **LISA LUCKE**
(209) 304-4011; lisa@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**

PCB007 Presents
the pcb magazine

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

August 2015, Volume 5, Number 8 • The PCB Magazine© is published monthly, by BR Publishing, Inc.

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Cars: A Driving Force in the Electronics Industry

October:
Cycle Time Reduction