I-Connect007 Presents

March 2016

the pcb magazine

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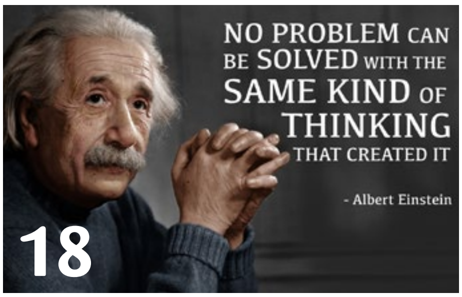

Strategies for Increasing Profits

In this highly competitive industry of ours, where material costs squeeze from one side, and customers squeeze from the other, what is the answer to increasing profits? This month, our contributors offer strategies that we think will both surprise and enlighten!

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Profiting from Advice

by Patty Goldman
I-CONNECT007

We all want to increase profits—even in our everyday private lives, right? Who wouldn't you like to increase his personal profit? But does it always happen? Unfortunately, no, but don't we wish!

Often, especially in today's world, profit is considered a dirty word. How dare a company make a profit while paying me beans, or while charging me an outrageous sum? Or so the thinking goes. Of course, profitability is crucial to just about any business; without it, a private company wouldn't be in business very long. But in this tough, highly competitive industry of ours, how do you make that happen? Material costs squeeze from one side and your customers squeeze from the other. Are there strategies you haven't tried or don't know about? Yes, I believe there are.

Naturally, we first wanted to hear your thoughts, so we conducted a survey. One of the first questions was, "What is your target percentage of profit?" I must say, I was a bit surprised to see that some people were expecting a profit of more than 30% (well, maybe not in manufacturing). But most were targeting 11–15%, which seems a bit more realistic.

Then we asked another question: "What part of your process and business has the greatest impact on your profit?" We offered a few choices and left room for comments. The results were not surprising—raw materials and labor were the biggest costs of doing business. However, we had some interesting responses in the "Other" column. Several respondents mentioned software, and some mentioned taxes and fees. And a few brave ones brought up that dirty word—scrap.

Clearly, our task was to get down to business and provide you with some good advice from this month's contributors (Figure 1).

Steve Williams of The Right Approach Inc. leads us off with a case for reducing inspection as a means to profitability. His argument is that inspecting for quality does not work, and he has provided a little test for you to take to prove it. It may change your mind about inspection.

Next, systems expert Dave Dibble furthers the cause for systems-based thinking and acting by recounting the true story of a company he worked with, and its remarkable double turnaround, from loss to profit, back to loss and then back again to profit. He shares his three

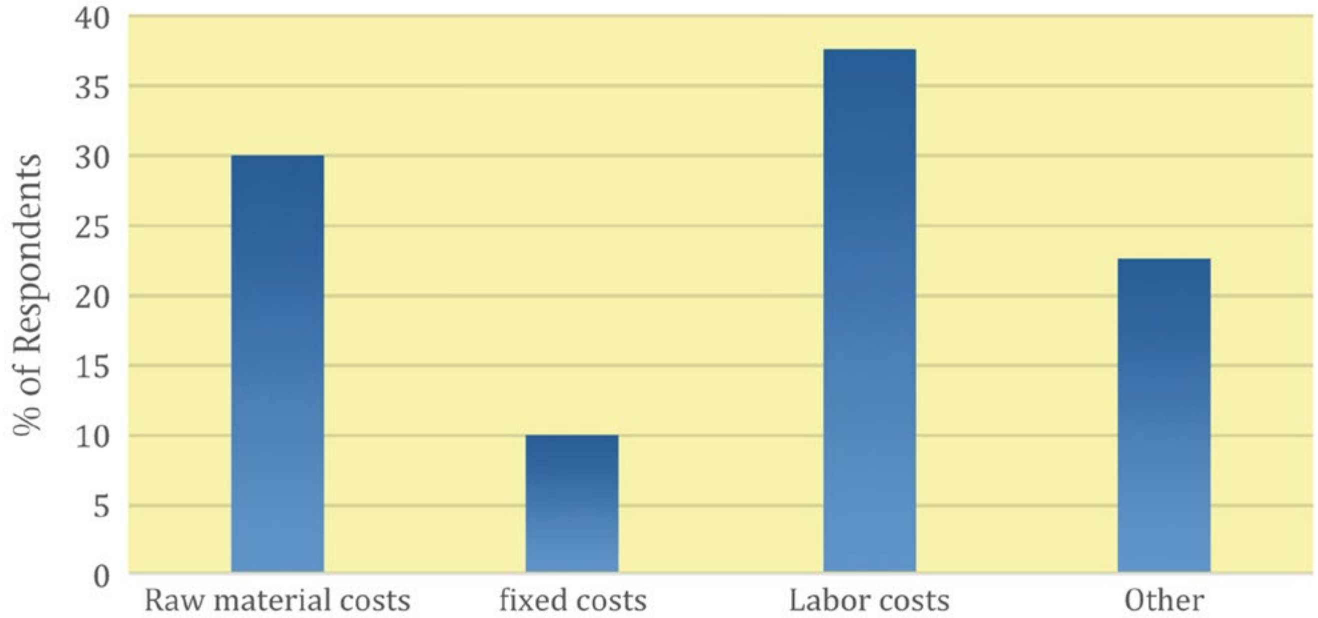


Figure 1: Reader survey results to the question, "What part of your process and business has the greatest impact on your profit?"

keys to profitability as well as valuable information on systems thinking.

Several columnists offered their thoughts on profitability for this issue. Omni PCB's Tara Dunn discusses how your sourcing strategy can affect yields and hence, profitability. Dave Becker of All Flex Flexible Circuits chimes in with the case for Lean manufacturing and NPIP to reduce waste, thereby enhancing profitability. And guest columnist Akber Roy of RUSH PCB shares his favorite cost-saving tips for PCB fabrication.

A slightly different approach put forth by Mike Jennings and Patrick Riechel of ESI has to do with optimizing laser processing for greatest efficiency to minimize cost of ownership. They touch on a number of issues including automation, utilization and extending system longevity.

To satisfy the hardcore techies out there, we have a great article by Dr. Rita Mohanty, et al., of MacDermid Enthone Electronics Solutions. It covers a new direct metallization process specifically designed for flex and rigid-flex circuits.

Karl Dietz gives us a very thorough overview of the green legislation around the world that affects our industry, explaining each in clear language. He then details the impact these have had on the electronic materials and equipment used in the manufacture and assembly of PCBs.

And as a finale, we're introducing a new columnist this month—from Brazil! Renato Peres, with Circuibras, gives us a quick overview of the electronics industry in Brazil, and promises a column on process engineering for April's issue. We'll bring you Renato's Brazilian perspective every month. Time to see what the rest of the world is up to.

Enjoy our March issue, and be sure to tune in next month when we will discuss process engineering, trouble shooting and testing new processes and equipment. **PCB**

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

Increase Profits by Minimizing Inspection

by Steve Williams
THE RIGHT APPROACH CONSULTING LLC

"We strive to decide our own fate. We act with self-reliance, trusting in our own abilities. We accept responsibility for our conduct and for maintaining and improving the skills that enable us to produce added value."

–Excerpt from Toyota Motor Corporation's internal document, "The Toyota Way"

Wrong-Headed Thinking

The opening quote captures the values and ideals of Taiichi Ohno, one of the inventors of the Toyota Way tasked with transforming Toyota into the world-class manufacturing enterprise that it is today. Some of my columns may sound like a broken record to my readers regarding best practices/Lean as a "be-all, end-all" to every problem a company can have. It may surprise you that I strongly disagree with that; Lean certainly has limitations and does not play particularly well in high-mix, low-volume (HMLV) operations like PCB manufacturing. That being said, what I do believe is that there are very few problems that cannot be helped with a thoughtful, selective application of best practice tools appropriate to the situation.

Unfortunately, one of the first reactions to a process problem with many companies, especially in a very complicated operation like PCB manufacturing, is to throw more inspectors at it. This knee-jerk reaction has a triple impact on profits:

1. Inspection by definition is a non-value-add reactive process.
2. Inspection doesn't address the root cause of the issue and assures it will resurface at some point.
3. Inspection is not effective.

Inspection Is Evil

A wise man once said, "Inspection is evil." Actually it was me, and I didn't say it just once, I say it every chance I get. Inspection is a non value-add activity and companies tend to use it to hide many sins. Traditionally, leaders of American industry have had a one-size-fits-all solution to just about any manufacturing problem they encounter: they throw more inspectors at it. Customer returns increase and/or internal yields decrease: "Let's hire more inspectors to make sure our customers do not receive the results of our inefficient process." Whether you find bad parts internally or ship them, the customer is paying for your process inefficiencies either by defects, or the cost of your inspection, rework and repair. I am here to tell you that this approach simply does not work, and I will prove it to you shortly.

From a functional standpoint, there are three types of inspection:

1. Judgment/standard inspection
2. Informative inspection
3. Point of origin inspection

The first two are widely used and considered traditional methods of quality control. Point-of-origin inspection is the only method that actually eliminates defects by putting the responsibility for quality back at the manufacturing source, which is quality assurance.

Not only is inspection non value-add, it is ineffective as well! How effective would you think visual inspection is? Would you be surprised if I said that *100% visual inspection is only 80–85% effective!* Don't believe me? Then I would challenge you to gather up at least 30 people from your organization and perform what I like to call "Steve's F Test." Your 30 people are your "F" Inspectors, inspecting the product for the presence of the letter "F." Put the following paragraph up on a screen and administer the test with the following instructions:

"Read through the text in Figure 1 below ONCE in the time allowed and count the number of times the letter "f" appears. Do not read through the paragraph twice, as this would be 200% inspection. You have 60 seconds!"

The necessity of training farm hands for the first class farms in the fatherly handling of farm livestock is foremost in the minds of farm owners. Since the forefathers of the farm owners trained the farm hands for the first-class farms in the fatherly handling of farm livestock in the first place, the farm owners feel they should carry on with the family tradition of training farm hands of first-class farms in the fatherly handling of farm live stock because they believe it is the firm basis of first class fundamental farm management.

Figure 1: Steve's F Test.

Once the time is up, go around the room and write down each person's count, construct a quick histogram and show the results. Reveal the correct answer (39) to the group. I can guarantee that in almost every single case, you will end up with a normal bell-shaped distribution, proving that your "F" inspectors may be hard pressed to even hit the 80% accuracy level. I have administered this test literally hundreds of times and not once has this not been the case. And remember, this was only a 60-second test; think about the drop of efficiency due to fatigue, distractions and boredom of inspectors over an eight-hour shift!

Believe me now? So is inspection a good way of ensuring quality and profit? I think not. Considering the multiple negative impact of excessive inspection, I would argue that inspection is one of the more hidden destroyers of profits in any organization. Inspection is evil.

What is the Solution?

That is simple: applying the appropriate best practice tools discussed in detail in my past columns to drive to true root cause to permanently eliminate profit-sucking process problems from your operation.

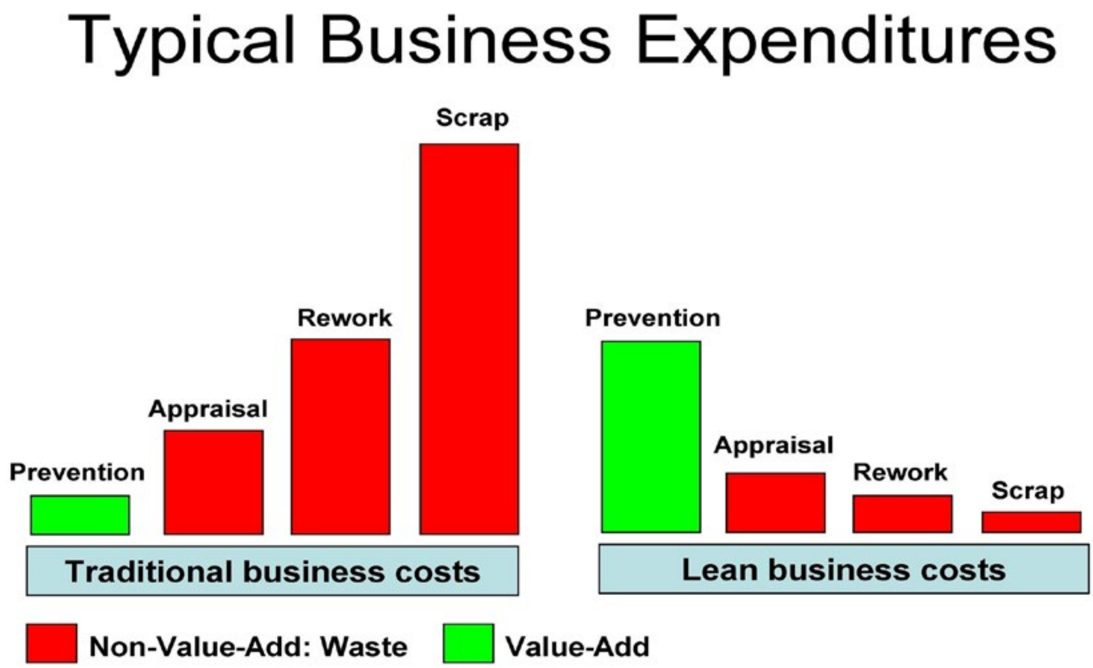


Figure 2: Typical business expenditures.

Let's take a macro look at where companies spend their money in terms of the cost of quality. The cost of quality refers to costs related to prevention, appraisal (inspection), rework, and scrap (customer returns are factored into either rework or scrap). Figure 2 shows the relative distribution of expenditures in a typical company, with largest portion of expense resulting from bad quality (scrap). The traditional business will spend about *three times the amount of money on appraisal (inspection) than they do on prevention*. When you combine appraisal costs with the exponential amount of dollars that are being wasted on rework and scrap, it is clear that this is not an effective model.

Now, contrast that with the Lean business model. By spending a majority of their expenditures on prevention, appraisal costs can be greatly reduced and rework and scrap are maintained at minimal levels. Not only are the dollars being spent in the right places, consider the order of magnitude of total cost. ALL the costs in the lean business model, combined, *amount to less than the money a traditional company is wasting in scrap alone*. Talk about financial metrics; these savings transfer directly to bottom line profit!

Permanent Problem Elimination is Key to Profit

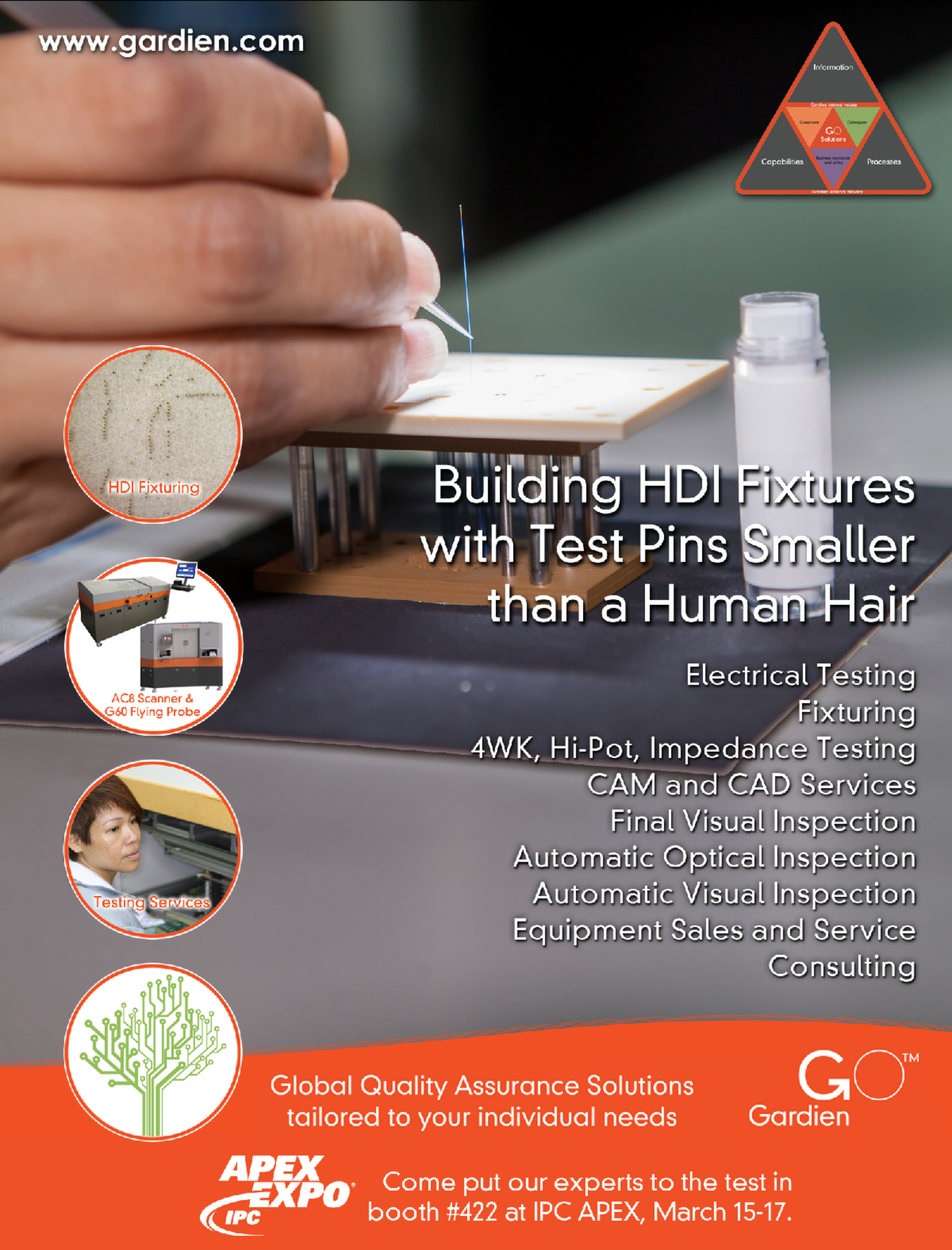
Identifying and fixing problems instead of foolishly trying to "inspect in quality" by sorting will have a greater impact on profit than raising prices your product, hammering your suppliers for lower costs or most any other traditional profit enhancement initiatives an organization can implement.

I will close, as I began, with a quote that sums up this worthwhile discussion in one sentence, by one of the true greats:

"The most dangerous kind of waste is the waste we do not recognize."

–Dr. Shigeo Shingo, consultant to Toyota Motor Corporation **PCB**

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



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The Four New Agreements to EXPLODE PROFITABILITY

by Dave Dibble

In the area of increasing profitability, what I am sharing with you here is a true account of what I believe is an unprecedented event in the history of modern business. Within this story you will be introduced to a new theory and practice that will allow you to optimize results and increase profitability in your business as never before. Although the following story is not set in the high-technology or interconnect industries, I assure you, and experience proves, that the principles outlined in this story and article will work in a similar fashion in your business, assuming leadership is willing to grow and change.

The Gila Regional Story, Part I

In 2006, as a consultant and trainer, I had been doing systems optimization and conscious leadership growth work in various industries for 16 years. We had had a lot of success, as had our clients. Out of the blue, I got a call from Brian Cunningham, the director of a rehabilitation and wellness center in Silver City, New Mexico. The center was part of Gila Regional Medical Center (GMRC), a 50-bed regional hospital, also in Silver City.

Brian said he had read an article I had written about the power of systems and conscious leadership, and wondered if I might be able to assist the hospital with some thorny issues that

Figure 1: Brian demonstrating his systems optimization tools at the conference.

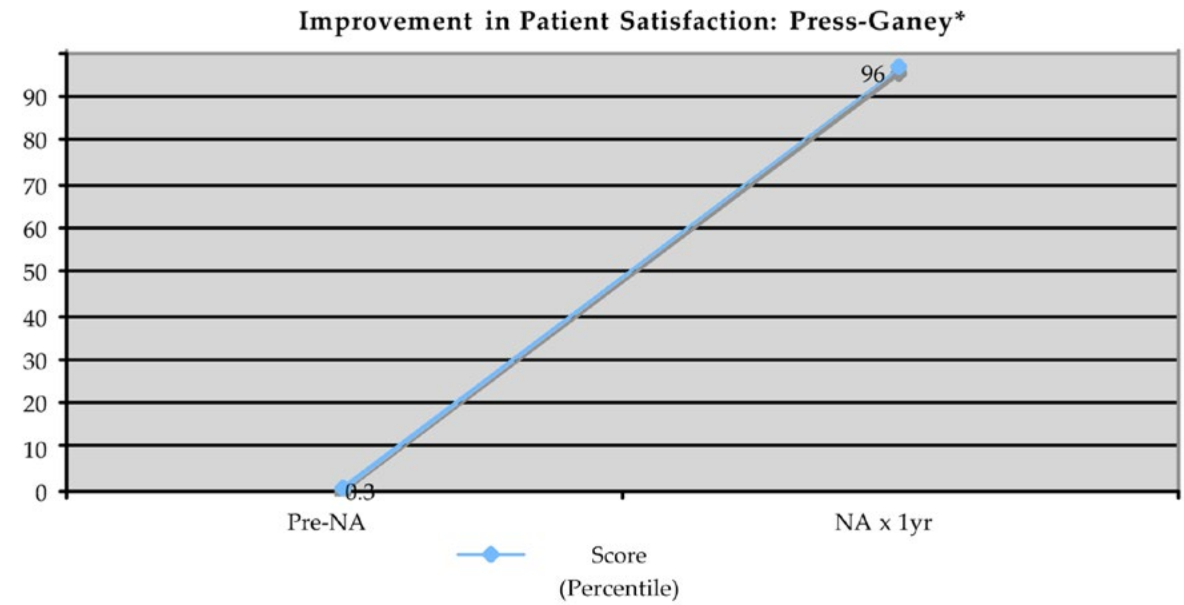

Figure 2: Patient (customer) satisfaction moved from last to the 96th percentile in 12 months.

had for years adversely affected profitability and patient satisfaction. I responded that, if leadership was willing to grow and change, I could be of assistance.

A conference call was set up with CEO John Rossfeld and members of his executive team and board. John asked me if I had ever worked in a hospital. I said no. He asked me if I knew anything about healthcare. Except that the entire system appeared to be a basket case, I said no. His next query was why a hospital would want to hire a consultant/trainer who knew virtually nothing about their business. I answered that not knowing anything about healthcare was a plus. I had no preconceived ideas. I used a line I am quite fond of that I stole from Mark Twain: "John, it's not what you don't know that is hurting your business; it's what you know for sure that isn't so." I added, "Besides, your problems are mostly systems based, and systems theory and practice are universal."

After a month of vetting, I was hired and one of the first places management wanted me to work was the Rehabilitation and Wellness Center (Rehab), which was Brian's responsibility. To say Rehab was a mess was being kind; it had been losing money for years. Morale of employees was at rock bottom while turnover was sky-high. Worse, patient satisfaction levels had sunk to the lowest levels possible; Rehab was dead last out of 272 similar facilities nationwide in patient satisfaction. Stating the obvious, Brian appeared on the hot seat to lose his job.

When I met with Brian to begin the process of fixing Rehab, he was demoralized and anxious. I think he feared for his job and thought I might be the bearer of bad news. I assured him we would get the place running right, but he had to be willing to grow and change. I also asked him where he saw himself in the future if everything worked out perfectly. He said he'd like to one day be the chief operating officer of a hospital. I said that sounded good but he was shooting too low; he should aspire to be a CEO. I told him that, if he was willing to learn and practice what I would teach him over the year or so we would be together, he would be a great CEO. He enthusiastically agreed to learn and apply as much as possible in our time together.

At Rehab, we did all the things required to turn around the center: We implemented new systems that produced the desired results. For the first time in many years, the center became profitable. Within one year, patient satisfaction scores moved into the 96th percentile, a move we believe to be unprecedented in the history of healthcare.

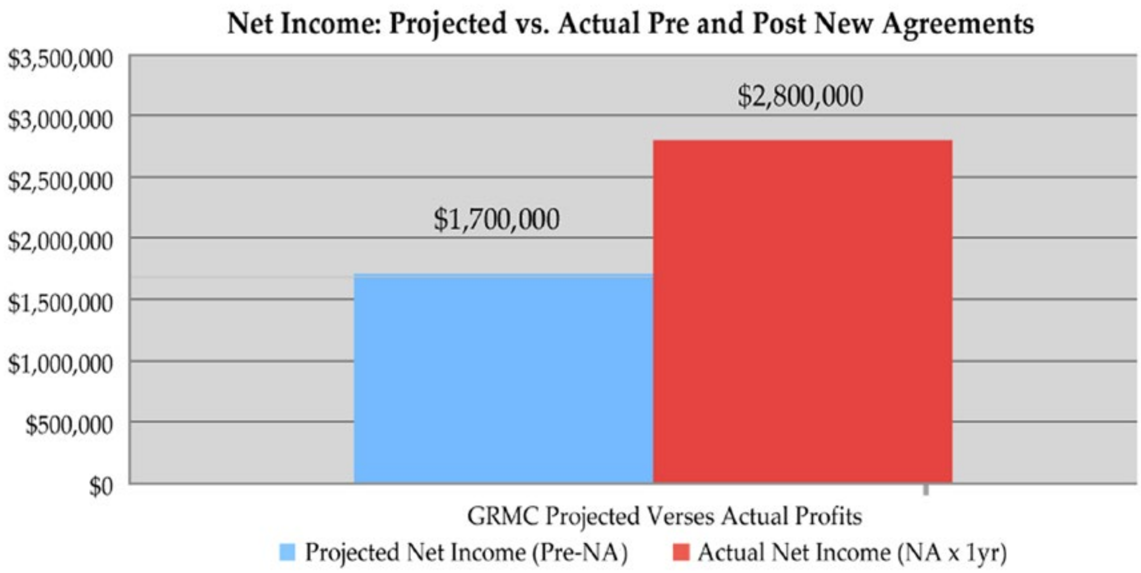

Figure 3: Net income increase of $1.1 million in 14 months (+ 62%).

Brian was not only a great student, but he also became a recognized leader at GRMC. As I was preparing to leave my assignment, Brian asked me what he should do going forward. I replied he should help out his fellow directors with their systems optimization, because we learn the most when we teach others.

Good News for the Hospital: 62% Increase in Profitability

On sales of approximately $30 million, through the systems optimization work we did over 14 months at GRMC, the hospital was able to add in excess of $1.1 million to its bottom line, an increase of over 62%. Mission accomplished.

The Gila Regional Story, Part 2

Brian continued his good work and began moving up in the organization. He became a vice president and was John Rossfeld's right-hand man. However, all the good times were about to change.

John Rossfeld left GRMC and was replaced by a new CEO, who had his own ideas about how to operate a hospital. The new ways did not include a systems-based approach. Instead, the new CEO hired five new vice presidents, who followed him around and began undoing much of the systems work we had put in place. He seemed especially intent on gaining back control of systems optimization from the front-line care providers.

When care providers brought potential solutions to problems to management, they were outright dismissed. Often, although several years after I left, my name would be brought up by care providers as a way to explain what they had been taught about systems optimization and problem solving. The CEO would have none of it. It became such an issue that my name was banned from use at the hospital. It's true. With unconscious leadership, no good deed goes unpunished.

In fiscal 2013, GRMC lost $9 million on sales of approximately $30 million. The GRMC board of directors panicked (as they should) and fired the CEO and the VPs he had hired. The only executive left was Brian and he was made the interim CEO while a search was conducted for a permanent CEO. Brian did the only thing he knew to do: reinstitute all of the systems which had been torn apart by the old regime. Where there were voids in management, Brian simply found people in the departments that had been trained in systems optimization and turned them loose with the new tools we had developed for systems optimization.

The Turnaround of the Century

In 11 months, Brian took GRMC from a $9 million loss to a $1.1 million profit *with no layoffs.* It appears this type of turnaround is unprecedented in the history of modern business and almost certainly in healthcare. Brian jokes that the use of my name has been reinstated at the hospital. Brian was made permanent CEO. He brought back some key people who left the company during the dark days of the previous regime and continues to expand upon the results created during the turnaround. End of story.

Critical Factors: The Profit Possibility for You

Profitability is a function of many factors, but only three key factors make up the foundation of profitability for all types of businesses, including the high-technology and PCB space. These three factors may surprise you. We have been conditioned to believe that factors such as margins, costs, overhead and other financial measures drive profitability. While these measures are key components of the calculation of profitability, they are not the drivers. The drivers of profitability are the *systems in which people work, the tools used for system optimization and the consciousness (thinking) of leadership and management.* I will start with a discussion of the consciousness/thinking of leadership.

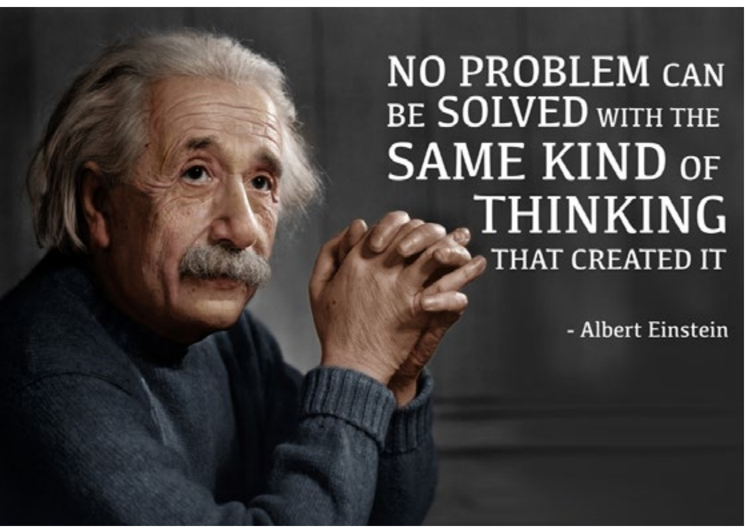

Figure 4: Albert Einstein on the power of the mind (thinking).

The Three Keys to Profitability

1. Leadership Consciousness and Thinking

Albert Einstein reminds us that we can't solve problems with the same level of thinking (consciousness) used to create them. Still, many business leaders seem put off by the discussion of consciousness. This topic is seen by some to be "woo woo" and is not acceptable in many boardrooms or C-suites. Possibly this is because discussions of consciousness elicit images of meditating yogis or chanting gurus. Consciousness is none of these things. These things are simply practices that some use to quiet their minds or expand their consciousness. For business purposes, I will define consciousness as *thinking.*

It is well known that we identify with our thinking. We use phrases like, *I think this or I think that.* We don't say, *my mind thinks this or my mind thinks that.* We know that our thinking and the accompanying emotional energy that is part of every thought is what defines human reality. Life is good or life is bad. Profitability is good or lack of profitability is bad. We become what we think about and anything we put our attention on expands.

We pull realities to ourselves based upon our thinking, including business realities. As a leader of a business, your thinking has pulled to you and your business whatever profitability you are currently experiencing. If you want to increase profitability, you cannot do it with the same thinking used to create the status quo.

Instead of actually expanding consciousness/thinking when profitability problems arise, most leaders fall into the trap of *more-better-different.* Leaders 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—all based upon the old thinking. In a rapidly changing business environment, more-better-different often makes things worse rather than better.

2. Systems and Systems Thinking

Data are clear that in excess of 90% of the results we experience in the workplace is a function of the systems in which people work, not

Figure 5: The power of systems thinking in leadership and management.

the efforts of people. How many leaders and managers know or understand this fact? Not many. Legacy leadership and management training tends to focus on people and behavior and specifically how to get people to behave the way management wants them to. This is like constantly asking your people to bale faster instead of fixing the hole in the boat. Leadership or management unconsciously think, *Oh, the hole in the boat has gotten bigger? I have to get the people to bail more, or bail better, or bail differently.*

Instead of learning to optimize our systems at work to get the results (profitability) we want, most leaders and managers focus on trying to get people to behave differently to get those results. While occasionally our problems are people related, the great majority of the time those problems are systems related. You will only get what the system will deliver within a range.

Look at the huge resources expended to resolve problems by attempting to get workers to behave differently in some way. Team building events, retreats, meetings upon more meetings, cracking the whip, firing bad workers, hiring good workers, training and more training—always to the old systems. The list goes on as we may or may not become better at baling out the boat. Most of this well-intentioned effort is simply a waste of time unless the right systems optimization work is part of the equation.

3. New Tools and Methodology for Doing Systems Optimization Work

Many of you reading this article will be at least somewhat familiar with systems optimization programs in vogue today such as Six Sigma, Lean and Lean Sigma. These types of programs are being implemented in many companies in attempts to create systems-based cultures that significantly increase quality, lower cost and, of course, increase profitability. The methodologies and tools used in these programs are well known and we have an abundance of qualified experts and black belts to help companies through the process. Why then are the vast majority of these programs underperforming or failing in most western companies?

It appears that one major factor for this failure, among others, is that the tools we use to teach frontline workers to optimize their systems are intimidating for many. When I taught the most basic statistical process control (SPC), the foundation of these and other legacy quality programs, people's eyes would glaze over. Fear and trepidation were normal reactions for many workers. People do not learn easily or well when they are afraid. Something had to be done.

I spent a year or two reworking basic SPC tools to make them user-friendly, simple, fast and even more effective for most Western companies and workers. With these new tools, we can have workers, middle managers, and even C-suite personnel doing good systems optimization work in a day or two. Gratefully, we have found that these tools also significantly enhance most standard implementations of Six Sigma, Lean, Lean Sigma or other systems optimization programs.

The real breakthrough in the application of these new tools is that frontline workers embrace them. Use of these tools becomes the way frontline workers do their jobs, problem solve and constantly improve their results. Notice that it is the frontlines, not the quality department, IT or compliance, which is implementing systems-based improvement. Only when the front lines embrace systems optimization as their own will an organization create a quality, systems-based culture. It is through this improvement on the front lines where the work is actually being done that the potential for increased profitability is greatest.

The Four New Agreements for Leaders and Managers

In 2002 I wrote a book called *The New Agreements in the Workplace*[1], and in 2006 I wrote another, *The New Agreements in Healthcare*[2]. These books speak to what I believe is now an evolutionary next step in leadership and manage-

Figure 6: Demonstration of the New Agreements Tools.

Figure 7: A higher purpose for work transforms the workplace.

ment that obsoletes much of the nonsense we have been programmed to believe about leading and managing.

Because profitability, in the final analysis, is more about leadership and management than any other factor, I want to introduce you to *The Four New Agreements for Leaders and Managers*. It is these four new agreements that are the basis of the successes in Brian's story described herein and many other businesses over the 25-year period in which the agreements have been implemented. You will find the agreements, with the support of leadership, as effective in the high-technology, interconnect and PCB space as they are in healthcare.

First New Agreement:
Find Your Purpose (for work)

With 70% of U.S. workers disengaged from their work, the losses in productivity (and profitability) for many companies are huge. Add to this the mostly hidden costs of high levels of absenteeism and employee turnover and we most certainly want to include in our search for profitability the creation of meaning or purpose at work.

Data are clear that people are not motivated long-term by money. Similarly, companies that focus on profitability as the driving metric find that, long-term, they lose both employee engagement and profitability potential associated with engaged, motivated employees. Savvy leadership and management in the high-technology and interconnect spaces will create meaning and purpose for workers, possibly even a higher purpose that extends to community and beyond.

Second New Agreement:
Grow and Serve Others

The most important thing a conscious leader or manager must do to increase profitability potential in the high technology, interconnect or PCB space is set his or her people up to be successful in their jobs. While leaders creating good systems most influence the success of workers, a mindset of service to others is a close second. Servant leadership has been around for a while as a proven effective alternative to fear-based, top-down management. Do you value and genuinely care about your people? If you don't, you miss out on significant profitability potential.

By continuously growing your people through cultivating their talents, increasing their capabilities, and expanding their skill sets, you'll enhance the performance and production of the whole organization, thereby making the business more profitable. Data indicates that returns on continuous, in-depth train-

Figure 8: Servant leadership means growing and serving others.

ing for all employees run from 5:1 to as high as 33:1. Where in your company will you get higher returns on investment than a commitment to this type of training? When you grow your people, you grow the company.

Third New Agreement: *Be a Systems Thinker*

As we discussed earlier, more than 90% of the results we produce in the workplace are a function of the systems in which people work, *not* the efforts of the people. Profitability is a result, not a process. Profitability, as a result, is a function of the systems in which the business is operated, including supply chain management and outreach to customers and potential customers. Everything is connected.

Sadly, most leaders and managers who are responsible for improving profitability are not aware of the powerful role that systems play in determining profit or loss levels. Instead, in efforts to boost profitability, leaders may look at cutting costs by mandating reduction of full-time employees, cutting benefits or services, or hollowing out the organization in some other way. These are short-term solutions at best and hasten the demise of the company at worst. Instead, fix the 20% of the systems that will give you 80% of the returns (profitability).

A Systems-Based Approach to Turnaround

Early in my career, as owner of my own PCB company, I made a very poor hire and turned day-to-day operations of my company over to a new COO who turned out to be incompetent. By the time I realized the mistake, my $10 million per-year business had become a $7 million business with a significant negative net worth. When I took over to try to save the company, we were losing over $300,000 per month. I quickly realized that if we were to any chance of saving the company, we had to take a systems-based approach to the turnaround.

It took only 3–4 months to get the company back to break-even and we remained profitable enough to both begin growing the business again and pay off a huge debt load that adversely affected operations and financial performance for almost three years. There is no doubt in my mind that if we had tried to take the usual (non-systems-based) approach to this turnaround, the company would not have survived. Literally, the rapid move from a loss position to one of profitability was the dynamic that spurred this remarkable turnaround.

Figure 9: Systems thinking means thinking differently—beyond the box that's already there.

I'm going to take liberty here to share my opinion on the critical nature of systems thinking. Of the Four New Agreements, systems thinking is the most important one. If leaders and managers can learn and practice this single agreement, any business can be transformed quickly, easily, and sustainably.

I believe systems thinking should be taught in school every year from grade school through graduate school. If people, both in the workplace and at home, could begin to think in terms of systems, the whole world would change in profound ways—for the better. It appears widespread systems thinking, particularly in the workplace, could be a catalyst for resolving the many seemingly intractable problems facing humanity worldwide.

The rise of terror, climate change and other sticky issues are, for the most part, systems problems. Our current response: *more-better-different*. I normally keep my opinions to myself on these types of issues. However, as I'm becoming older and looking at the world we are leaving for our children and grandchildren, I feel a need to speak out. Thank you for listening.

Fourth New Agreement: *Practice a Little Every Day*

Realizing life purpose and attaining certain levels of mastery in the workplace requires practice. It's the same for organizations. If we desire to learn something new and make this new skill set a part of how we operate in the world, the organization must create and maintain a practice. The most effective practice is done every day. For example, if you want to make the New Agreements real in your organization, you will need to practice using the tools that make these powerful agreements real. Practice doesn't have to be arduous. Actually, we do our best practice when we are inspired or having fun.

We must remember that, good or bad, we become what we practice. If your organization practices suppressing workers in the name of control, you will get good at it. Conversely, if you and your organization practice purpose-driven, systems-based service to your workers, suppliers and customers, you will become a master of the workplace. Profitability will rise dramatically—not because you drive it—but because you are doing the right things that allow profitability to happen.

Conclusion

We have been brainwashed to focus on a relatively small number of metrics such as revenue and profits as the driving force behind critical outputs of our organizations. The actual driver of these critical metrics is the mostly informal systems in which the company operates. Because in excess of 90% of the profitability of a company is systems-based, a sustainable increase in profitability requires changes (optimization or re-creation) in existing systems.

The biggest challenge to increasing profitability or making any significant change in a business is the existing thinking of leadership and top management. The mind (thinking) tends to filter anything unlike itself and send the company into the more-better-different firefighting trap, with no real changes in the systems.

The Four New Agreements for Leaders and Managers offers a comprehensive roadmap for building great companies with high levels of profitability. Of these four new agreements, "Be a Systems Thinker" is the single most powerful one and one upon which anyone can build a transformed business. Adding the other three agreements significantly speeds the process and makes work life for leaders, managers and workers more fulfilling and meaningful. As a now proven roadmap to significantly increased profitability, consider implementing the four new agreements in your company. **PCB**

References

1. The New Agreements in the Workplace
2. The New Agreements in Healthcare

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, *The Four New Agreements for Leaders and Managers.* To reach Dibble, click here.

MilAero007 Highlights

New Made-in-NTU Satellite Technologies Pass Space Tests

Nanyang Technological University, Singapore (NTU Singapore) and BAE Systems have signed a $2.5 million partnership to jointly develop next-generation cybersecurity solutions in an era of rising cyber attacks.

Footsteps Could Power Mobile Devices

When you're on the go and your smartphone battery is low, in the not-so-distant future, you could charge it simply by plugging it into your shoe. An innovative energy harvesting and storage technology developed by University of Wisconsin, Madison mechanical engineers could reduce our reliance on the batteries in our mobile devices, ensuring we have power for our devices no matter where we are.

High-Performance Laminates

High-performance laminates are characterized as base materials that in one or more aspects exceed the performance of FR-4, CEM, or paper/phenolic laminates. In this article, Karl Dietz talks about the different types of laminates, their dielectric requirements, and how they are being manufactured.

Fabrication Drawings and Electrical Test—Reading the Fine Print

When a new PCB design is born, designers envision what the product will provide when completed. Whether the product is for the consumer, aerospace, military, medical or countless other markets, the designers—or more likely, the customers—expect certain deliverables on the commodity they wish to purchase.

FTG Receives New Multi-year Contract Awards for its Circuits Business

Firan Technology Group Corporation (FTG), a leader in aerospace and defense electronics, announced today that it has renewed two long-Term Agreements with a prominent US based Aerospace, Space and Defense Contractor for its Circuits Toronto and Chatsworth facilities.

New Galaxy-hunting Sky Camera Sees Redder Better

A newly upgraded camera that incorporates light sensors developed at the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) is now one of the best cameras on the planet for studying outer space at red wavelengths that are too red for the human eye to see.

New Tool Provides Successful Visual Inspection of Space Station Robot Arm

As NASA takes a break in RRM operations, it's looking back on past achievements and celebrating one of its latest accomplishments: the successful inspection of Canadarm2, the International Space Station's (ISS) robotic arm. In time, this visual inspection capability may help future servicing ventures at other orbits inspect for damage and failures on their spacecraft.

Mission Teams Prepare for Critical Days

Moments after Sentinel-3A separates from its rocket, a team of European mission control specialists will assume control, shepherding new spacecraft through its critical first days in space.

Global Defense Industry Business Confidence Report H1 2016

This defense Industry Business Confidence Report H1 2016 presents executives' opinion on the business environment over January 2016–June 2016. Organizations can understand the market by analyzing existing economic conditions, supplier price variations, sales performance, industry and company growth outlook, spending patterns, and key priorities.

Robotic Drones to Print Emergency Shelters for Those in Need

A new research project aims to develop the world's first flying robots capable of autonomously assessing and manufacturing building structures to help areas suffering from natural disasters.

PCB Sourcing? One Size Does Not Fit All

by Tara Dunn
OMNI PCB

When I am asked how to improve yields or reduce cost with a printed circuit board design, my mind immediately races ahead to the most common cost drivers. Has the part been designed with manufacturability in mind? Does the material selection make sense when balancing cost and performance? How many layers and lamination cycles are needed and could that number be reduced in any way? Has part size and panelization been considered? Are there any specific design features that push traditional design rules? All of these things have a direct impact on the manufacturer's yield and the subsequent cost of the PCB.

One question that is rarely asked however is this: How does a PCB sourcing strategy impact yields? I know yields are typically associated with the manufacturer's process capabilities and process controls as related to the printed circuit board design, but let me pose a few questions to help shed light on the impact that PCB sourcing can have on manufacturing yields and subsequent profitability.

Have you ever wondered why it is so difficult to find a fabricator that can meet ALL of your needs? Wouldn't it be great to find the perfect manufacturer, the one that has amazing service, does exactly what they say they are going to do AND has competitive pricing (total value, not just board price) across all the various technology levels?

The fact is, it is extremely rare for an OEM to have a homogeneous technology level across their entire PCB demand. On any given project, there may be a few 2–4 layer designs, a few 12-layer designs, a difficult motherboard design and maybe even a flex or rigid-flex design.

It is also a fact that PCB fabricators have a sweet spot that best fits their equipment set, engineering expertise, facility size and company

culture. Very often, browsing through a website or brochure will leave the impression that a manufacturer provides a "full range of technology"? Two-layer to 30-layer, .010" drill to microvias, standard materials to specialty materials, quick-turn prototype through volume production. At the end of the day, no fabricator wants to turn away business and they try to do their best to supply what their customers need.

However, there will always be a technology level, material set, or delivery window that each shop excels at. Their yields are maximized, the corporate culture embraces the technology and lead-time, and ultimately prices are the most competitive. As an example, a supplier that excels at building 4–8 layer standard technology likely runs with yields in the 97%+ range. But, if they were asked to build an 18-layer with blind and buried vias and via fill, the yields would drop dramatically. If the supplier that excels at building 18-layer blind and buried vias and via fill with yields in the high 90% range was asked to build a rigid-flex, yields would drop dramatically.

When sourcing PCBs and creating a robust sourcing strategy, the challenge is identifying that sweet spot that maximizes a manufacturer's yields and selecting the best group of suppliers to meet YOUR unique needs. Logically, if a circuit board is being sourced with the supplier that is the best fit for that specific technology level, their yields are going to be maximized, pricing will be its most competitive and ultimately profits will be increased for the OEM and the fabricator. While this sounds like a simple concept, the implementation of this strategy takes time and resources that are not always available.

Printed circuit board sourcing strategy: Are you guilty?

Printed circuit boards are often one of the most expensive components of an assembly and arguably the most important due to their functionality and criticality. All too often, when time and resources are stretched too thin, these custom electronic components are purchased using the same strategy and structure as commodity items.

A PCB sourcing strategy might look like this:

- Treated as a commodity versus a custom component
- Procurement strategy is often made at a tactical, not strategic, level
- Many are doing business with suppliers without a full understanding of the technical capabilities, capacity or financial situations of their suppliers
- Static strategies in a dynamic market—this market is changing rapidly
- The same strategy is used for domestic and off shore sourcing. One size fits all.

This strategy can result in increased risk in terms of price stability and performance, increased risk of supply chain disruption and increased overall cost.

Revamping your PCB strategy: Where do you start?

You start with the basics. First review your PCB technology and volume requirements. Your requirements can then be segmented by attributes such as standard technology, HDI, heavy copper, flexible circuits, etc. Then search to match suppliers to these requirements. Audit the facilities. Don't hesitate to ask the tough questions to REALLY understand the type of work each supplier excels at.

Next make sure that you have fully developed your procurement spec. Does it clearly spell out your requirements? Are any of your requirements adding unnecessary expense? It is not unusual to find that a corrective action implemented for an issue that happened 10 years ago is driving a requirement that increases cost and just isn't necessary in today's manufacturing environment.

Case Study: Using a Strategic Sourcing Strategy

Once a strong, diversified supplier matrix is put in place, analysis on large programs is simplified. To give an example, we were asked to assist with a pricing review and analysis of how to reduce cost on a specific project. This project included a set of PCBs with a wide spread of technology. One design was a simple two-layer design, another included microvias with cop-

Case Study: Using the Best Fit Supplier for your technology				
	Low Tech Mfg	Med Tech Mfg	High Tech Mfg	
2 Layer Design	$ 10.00	$ 16.00	$ 22.00	
8 Layer Design	$ 50.00	$ 60.00	$ 70.00	
12 Layer Design	$ 100.00	$ 70.00	$ 90.00	
22 Layer Design	No Bid	$ 180.00	$ 160.00	
Micro Via Design	No Bid	$ 300.00	$ 200.00	
Single Source	Can't Build Package	$ 626.00	$ 542.00	
Dual Source Low/High				$ 510.00
Dual Source Low/ Med				$ 610.00
Dual Source Med/High				$ 506.00
Source Best Fit				$ 490.00

Figure 1: Case study: Strategic Sourcing Review, project volume 1,000–5,000, annually.

per via fill, and there were three with technology between those two extremes. The volume required was expected to be between 1,000 and 5,000 pieces annually. We started first with the design for manufacturability questions and recommended adjustments where possible to increase yields at the manufacturer and ultimately reduce the total cost of the package.

After this, we looked at the current supply base and sourcing strategy. The decided-upon approach was to select three suppliers, each with different technology specialties, gather pricing for the package and review the total package to determine the best path forward. The results of that exercise are included below.

As you can see, the lowest price option for each part number is highlighted in yellow. From there, we reviewed the package from a single-source, dual-source or three-source perspective. The single-source option was ultimately the more expensive approach, with a three-source strategy providing the lowest cost option when looking at the PCBs only.

With a savings of $16 per set over the two-source approach, the company can be expected to save between $16,000 and $80,000 per year on this project. From here, they can determine if the additional costs associated with managing three suppliers on this project is justified by the savings.

Conclusion

When analyzing a set of PCBs to improve yields and maximize profits, the first place to start is with a critical review of each PCB design. Are there any attributes that are pushing your manufacturer's standard design rules? If so, is this necessary to the design or is there another approach that could improve the manufacturer's yields, reduce cost, and ultimately increase profit? Once the design is finalized, a critical review of the PCB sourcing strategy should be completed. Does the technology of each design fit the sweet spot of the selected fabricator? Would a multi-source strategy result in cost savings that justify the expense of managing more than one supplier on the project? Just as time and effort are spent reviewing and analyzing the design, time and effort should be spent reviewing and analyzing the subsequent sourcing strategy. Matching the technology to the best fit supplier will optimize manufacturing yields and reduce overall cost. **PCB**

Tara Dunn is the president of Omni PCB. To contact Dunn, or read past columns, click here.

Lean Manufacturing and NPIP for Flexible Circuits

by Dave Becker
ALL FLEX FLEXIBLE CIRCUITS LLC

Many companies are familiar with lean manufacturing concepts and have successfully used these techniques to improve manufacturing processes. Lean techniques, while most often used in printed circuit fabrication and assembly operations, can also be applied to non-manufacturing processes. One such process is new part number introduction (NPIP).

The main thrust of lean manufacturing is to eliminate or reduce waste. There are typically seven wastes (mudas), as defined by Toyota executive Taiicho Ohno, when he developed Toyota's Production System (TPS)[1]. ("Muda" is a Japanese word meaning uselessness, idleness or other synonyms of waste.) The seven mudas are:

- Transport
- Inventory
- Motion
- Waiting
- Over-processing
- Over-production
- Defects

The typical part number startup for flexible circuits often can suffer from a number of those wastes. Certain waste items are specific to a part number (customer out of office, conflicts in documentation, iterative design conversations, etc.) or be ingrained as accepted gaps in a supplier's product launch system. As part of a continuous improvement mentality, wastes should be identified for reduction through a documented and monitored part number introduction process.

Some of the more common waste elements are:

Transport: In a new part number introduction process (NPIP), transport is the movement of documentation (electronic or paper) from one department to another requiring successive reviews and sign-offs. Excess transport is a symptom of a departmentalized approach to part number start-up rather than a process flow approach. A cross-functional design review team with one leader can remove departmental barriers and help assure that reviews and

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inputs are done in parallel rather than serially. Transport can also include sending information requests and approvals to customers and suppliers. These requests need to be challenged regarding their usefulness and necessity.

Waiting: New part number start-up requires information flow. Oftentimes the process becomes stalled at various steps when someone is waiting for information. This can happen from within the company, the customer, or the supplier. A good NPIP system includes checklists so the needed documentation is quickly identified and missing components can be requested immediately. Team members are focused on rapid communication so that there is as little waiting time as possible. Customers, internal team members, and suppliers all need to be intimately involved to foster good communication. Again, parallel processing is an important message. Sometimes a decision followed by a course correction, is a faster journey to the destination than waiting for all the information to become available.

Over-processing: In the design and launch startup system, the equivalent of over-processing is over-specification. It is tempting to specify a tighter tolerance than required because designers believe it gives them a larger safety margin. While this is sometimes the case, other times a tighter tolerance will push a manufacturer to make tradeoffs that reduce manufacturing yields, require additional tooling, and add time to the processing sequence. Additional delays occur when acceptance standards are defined in absolute terms. Criteria specifying "no stains" or "no foreign material" can create an inspection struggle until a meeting of the minds occurs between the customer and supplier. Having a well-documented design and layout guide, as well as having knowledgeable manufacturing engineers on the startup team, will help assure that a new part number launches with acceptable manufacturing yields and meets the customer's requirements.

Over-production: The equivalent of over-production in a part number startup system is over-design. As in the case described in over-processing, designing in "safety margins" might be desirable, but it can also backfire. An example in the world of flexible circuitry might be specifying thicker copper to allow higher amperage capability, but thicker copper can also degrade flexibility. Over-design might also add cost, so one needs to understand if the added cost truly yields a more reliable product.

Defects: The result of a poorly executed part number introduction may result in low manufacturing yields causing high scrap rates, late deliveries and potentially defective product delivered to the customer. A startup process should be rigorous enough to avoid pitfalls seen on previous part numbers. It's not possible to have everyone review every part number prior to product launch, but using multiple subject matter experts to preview design layouts is a good first step. Capturing the collective wisdom of the organization is the goal as this can help identify "gotchas" that can be avoided. This review should be considered a proactive step but in the world of custom flexible circuits and heaters even the best plans may result in surprises. When this happens, a team focused on quick reaction is critical. The best NPIP system is a combination of pre-launch proactive review and a reactive team ready to respond quickly when the gremlins inevitably are revealed.

All Flex has developed an NPIP system called Jump Start™. It is a continuous improvement effort program to supply intensified customer support during initial part number design and delivery. It is a methodology tailored to a company that provides custom engineered products. Similar methods and disciplines can help reduce the mudas encountered during part number startup. **PCB**

References

1. Leanmanufacturingtools.org

Dave Becker is vice president of sales and marketing at All Flex Flexible Circuits LLC. To contact Becker or read past columns, click here.

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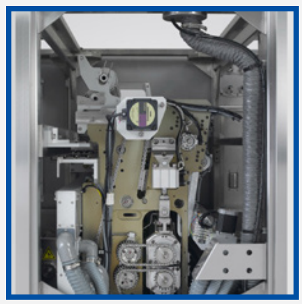

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Cost Saving Tips for PCB Fabrication

by Akber Roy
RUSH PCB INC.

Money is the most common problem in any type of business, and many American companies are looking for ways to cut costs, but still make sure they turn a profit. They also want to ensure the quality of what they produce remains the same, or exceeds present quality, and in the electronics sector this is essential for staying in business. Therefore, cutting costs while ensuring quality can be especially concerning.

One of the biggest issues many electronic companies face is that technological advances are occurring on a regular basis, with nothing ever staying the same for any length of time. To satisfy consumer demands, electronics are becoming increasingly more complex, forcing companies to seek newer processes to meet that demand. The following tips can help you save money and still keep the quality of your merchandise high.

Better Designs

You can scale back your spending by engineering boards more strategically, and using fewer parts and other components. This will enable your company to reduce the cost of each PCB, thus increasing the savings realized. This can be achieved by involving your manufacturing vendor right from the design stage for raw material availability, providing ease of manufacturing with expected or better yields.

Supplier Relationships

Find one or two parts suppliers that you can rely on, and develop a good working relation-

ship with them. This often leads to discounted prices because they appreciate the business you bring them, and they may even offer lower prices if you buy in bulk, or pay in cash each time.

Keep your Business Stateside

If you are thinking about going offshore in hopes of saving money, don't. You are running the risk of ending up with poor quality workmanship that can affect your reputation considerably. You can also end up paying hefty fines if the parts used are not genuine or fail to comply with U.S. standards.

Hire a Contract Manufacturer

While this may seem like an additional expense, partnering with a team of experts may be saving you a lot of money over time. These professionals have access to equipment and resources that you may not have, and they can now work for you without you having to pay them a salary for their expertise! Otherwise, you may accrue unnecessary costs for added manpower.

There are many ways for you to save money on the PCB fabrication process without compromising the integrity of your product. Learn how to cut your own costs without sacrificing quality.

The tips listed here are only a few ways for you to cut your costs without losing your profit margin. Work with members of your company to come up with other strategies to effectively reduce expenses, while at the same time developing and manufacturing a PCB that meets public expectations and demand. **PCB**

Guest columnist **Akber Roy** is the CEO of RUSH PCB Inc. and has 20 years of experience in electronic contract manufacturing.

An Onboarding Process Can Build a Strong Organizational Culture

by Tony Bellitto, *FIRSTRONIC*

One of the biggest challenges faced by U.S. manufacturing companies is finding ways to attract, engage and retain workers. Today's generation of 20-something workers are unfamiliar with manufacturing as a career option. Factory work is something their grandparents did. At the same time, some companies, such as Firstronic, are proving that U.S. factories can be cost competitive and the jobs they create are transformative, in that production operators have a career path beyond entry-level work if they choose to pursue additional company-sponsored training.

In 2014, needing to double its workforce, Firstronic began a hiring and training program to add new workers. However, by early 2015, the turnover rate was deemed excessive, especially on the late and weekend shifts. Analyzing the program, determined that some new employees were not well-suited for the jobs, the intensive training was overwhelming and in classroom theory not as effective as on-the-job (OJT) based training.

Working with a third party employment screening firm, a new program was developed that not only pre-screened employees for suitable positions but also involved focused OJT training, mentoring, and a comprehensive process to engage the employee's interest from day one. Turnover dropped by more than two-thirds and teams became more focused on the responsiveness and quality their customers expected. "Design the onboarding process with the goal of making employees feel valued by the company." Read the entire article in this month's *SMT Magazine*.

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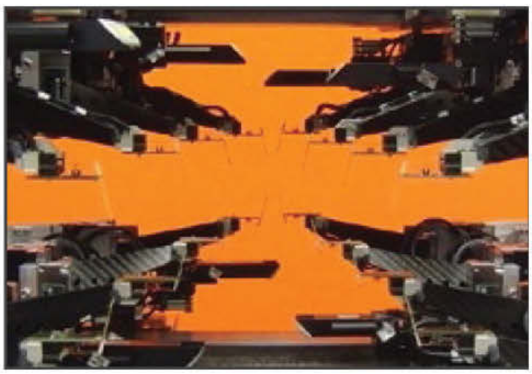

Test area:	610 mm x 620 mm (24.0" x 24.4")
Number of test heads:	16 (8 top + 8 bottom side)
Smallest pad / pitch :	35 μm (1.4 mil) / 80 μm (3.2mil)
Test voltage:	Up to 1000V
Max. measurements / minute:	Up to 15000 measurements /min. *
Loading capacity:	390 mm , max. 80 kg weight
Max board weight:	20 lbs
Marking option:	Barcode label

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Supply Lines
Highlights

New CEO Jeff Waters Outlines his Roadmap for Isola

Jeff Waters, Isola's newly appointed CEO and president, comes to the laminate supplier after more than 25 years in the semiconductor industry, working for companies like Texas Instruments and National Semiconductor. Only a few days into his new job, I met with Jeff to discuss the transition and what we can expect from Isola under his leadership.

What a Difference a Year Makes: Voxel8 and the 3D Printing Pioneering Spirit

At CES in Las Vegas in January, Dan Feinberg and I met with Michael Bell, co-founder of 3D printing company Voxel8, to get an update on their developments of the past year, where he sees the company going in the future and whether rapid prototyping might be a valid application for their machines.

LPKF Launches Entirely New Flex Drilling & Cutting Laser

Electronics manufacturing equipment manufacturer and laser specialist LPKF Laser & Electronics is launching an entirely new laser drilling and cutting system specifically tailored to the needs of the flexible circuit industry.

Insulectro Taps Industry Veteran Norm Berry as Director of Laminates and OEM Marketing

Insulectro, a leading distributor of materials for use in the printed circuit board and printed electronics industries, has announced the promotion of industry veteran Norm Berry to director of laminates and OEM marketing in the sales and marketing group. Berry has been a long-time product manager at Insulectro.

American Standard Improves Process; Integrates Orbotech Systems into West Chicago Facility

Anaya Vardya, CEO of American Standard Circuits, has integrated a complete set of Orbotech systems into his high-tech PCB production facility.

ESI Announces New Material Handling Solution for Flex PCB Processing

ESI today announced immediate availability of the RollMaster roll-to-roll material handling system for automating flex printed circuit manufacturing.

Nippon Mektron, Orbotech Collaborate to Optimize Digital Flexible PCB Manufacturing

ORBOTECH LTD. today announced that Nippon Mektron Mektec, the world's most dominant maker of flexible printed circuit boards (FPCBs), is deploying Orbotech direct imaging (DI) and automated optical inspection (AOI) systems in multiple factories.

Nano System Installs Advanced UV/CO2 Laser Drill at Nova Drilling

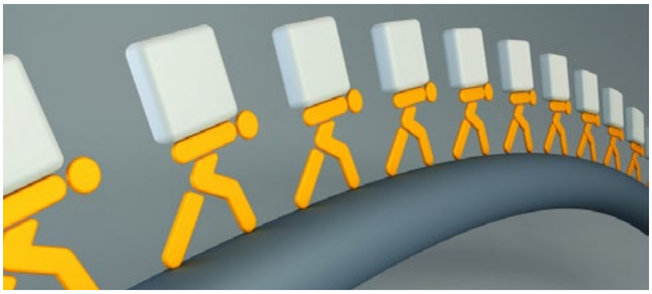
Nano System Incorporated has announced the installation of an advanced UV/CO2 dual beam laser drill at Nova Drilling in Santa Clara, CA. The Model NS1-3228-UC2 machine is equipped with a CO2 laser of the latest technology with over 3kW peak power and a 20 watt UV laser.

Nano System installs Tongtai 2-station drill machine at Colonial Circuits

Nano System Incorporated has announced the installation of a Tongtai Model SD-216B CNC drilling machine at Colonial Circuits in Fredericksburg, Virginia.

Hitachi Chemical Company Announces Changes in Leadership

Hitachi Chemical Co., Ltd. has passed a resolution at the Board of Directors' meeting held on January 27, 2016, to change its chairman of the board, representative executive officer, and president and chief executive officer.



Stepping Up to Laser Processing for Flex, Part 2: Calculating and Optimizing Production

by Mike Jennings and Patrick Riechel
ESI

A Process of Continual Improvement

In Part 1 of this series, we discussed the advantages of adding flex laser processing to gain a competitive advantage. In Part 2 we will build on that discussion, looking at the ways you can optimize your flexible circuit laser processing to get the efficiencies that drive lower cost of ownership. When considering the cost associated with adding FPC processing, where do you look, what should you expect, and how can you control or minimize those costs?

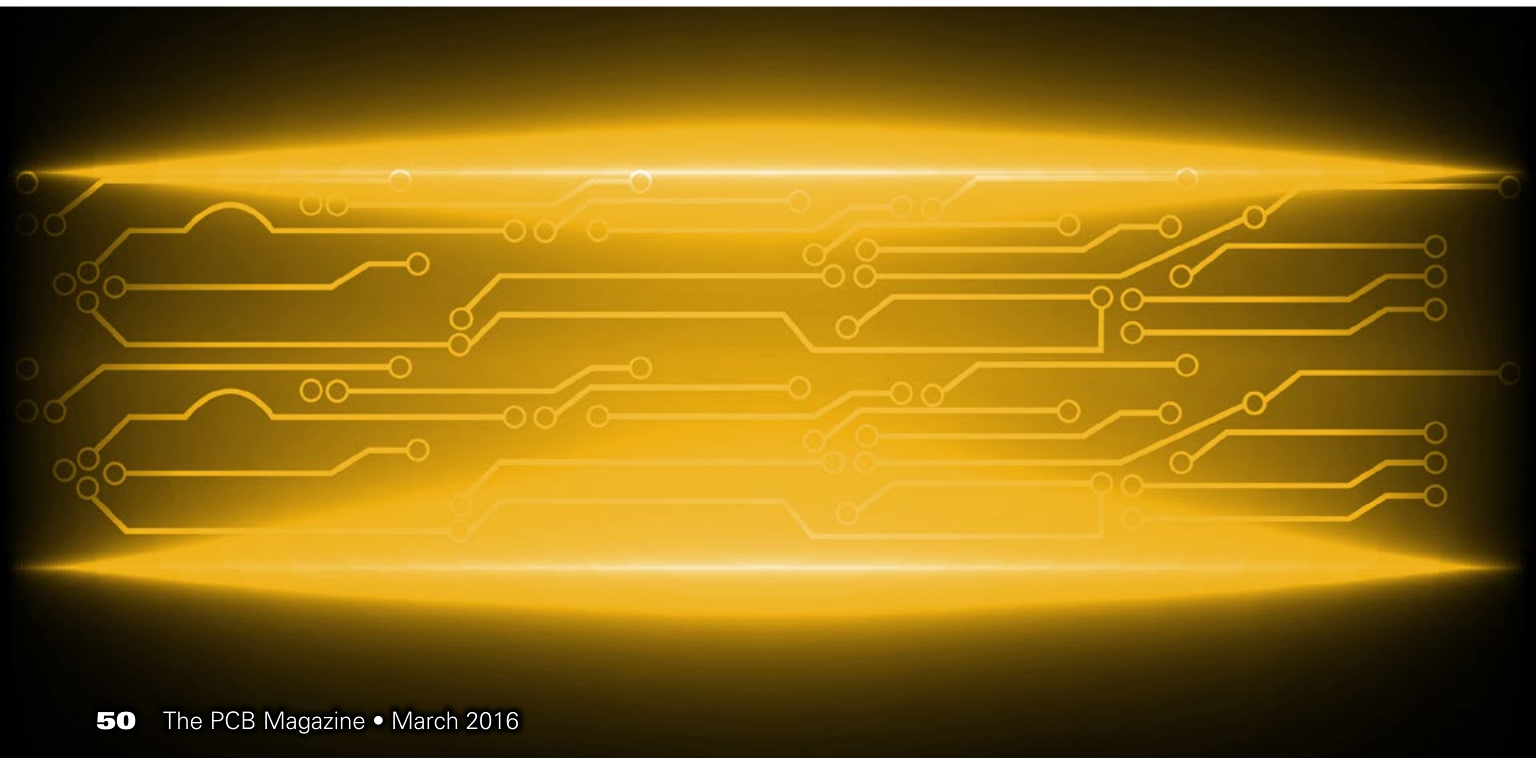
Controlling Fixed costs

Aside from the obvious system purchase price and its associated depreciation expense, there are a variety of other—and less significant—fixed costs to consider. These can include system installation and personnel training costs, costs to qualify the system prior to running production, floor space allocation overhead allocation costs, as well as the costs related to upgrading facilities to meet the system's site requirements. We will discuss site preparation in Part 3.

Typical areas to watch for in laser system site requirements include electrical, vacuum, compressed air, environmental air, as well as temperature and humidity. Neglecting any of these can result in poor product yield, scrap, or even damage to and downtime on your valuable UV laser system. Poor electrical power quality and sporadic brownouts and blackouts often can result in unexpected system errors, yield issues, and scrap.

Extending System Longevity

Typical high-power UV lasers used for flex processing have lifespans ranging from 1–2 years, although those lifespans may be drawn out if the laser is not in 24/7 use or the laser powers used for processing are much lower than the system's work surface laser power specifica-



tion. Most optics maintain a similar replacement cadence, but may be longer or shorter depending on the compressed air and environmental air quality, the amount of debris generated by the laser process, and the frequency of preventive maintenance optics cleaning, among other factors. The system supplier's highly-trained field service engineers generally perform system troubleshooting and major maintenance, while the customer's maintenance team will perform more frequent and simpler preventive maintenance tasks.

Managing Operating Costs

Personnel costs are different for laser processing equipment than for other capital equipment. While operators, maintenance engineers, and supervisory staff are standard for all capital equipment, laser processing equipment requires at least one trained laser process engineer and a laser safety officer. Unlike mechanical drilling, where there is a well-defined set of speeds and feeds that are used for a given material and drill bit, laser processing requires active process development to ensure robust, high-yield processes that are tailored not only to the material and via type and size, but also to the upstream and downstream processes. Any company that uses the Class 4 lasers that are typically used for material processing should employ a laser safety officer to ensure processes are put in place and employees are properly trained to avoid serious laser-related accidents[1]. In a previous article, Keeping on Top of Laser Safety[1], we discussed this in more detail.

"While operators, maintenance engineers, and supervisory staff are standard for all capital equipment, laser processing equipment requires at least one trained laser process engineer and a laser safety officer."

Improving Yield

Yield costs—the number of panels lost due to yield/quality issues multiplied by the cost of a given panel—can become significant if you do not take proactive steps to reduce them. Stringent quality requirements are no longer limited to the medical device and defense industries. Even in the consumer electronics industry, some OEMs have begun to introduce financial penalties considerably above the raw board costs for any scrapped boards. These trends, coupled with the ever-more-sensitive materials and smaller features to be processed, require more sophistication from you and your system suppliers.

Adding Automation

Finally, if you are considering complementing your laser system with an automated material handling solution such as a roll-to-roll handler or stack handler, don't forget that it also has a critical role to play in ensuring high process yield. Especially as materials become thinner and more easily damaged, your material handling solution should be chosen not just on lowest cost, but also on its ability to handle material without wrinkling, scuffing, or other damage at the maximum throughput available through the laser system you are considering.

Maximizing System Utilization

System utilization is the percentage of system time spent in production after subtracting system downtime. Scheduled downtime can typically be estimated by reviewing the system's preventive maintenance guide as requested from the supplier prior to purchase.

Unscheduled downtime, on the other hand, is typically more difficult to judge. The supplier's service team should be able to provide reasonable estimates of service event frequency and how long it takes on average to perform major interventions such as replacing a laser. System troubleshooting often has uncertainties associated with it. The biggest factors related to ensuring minimal downtime include the sup-

plier's service team location, training, and experience level as well as the availability of a local spare parts hub that stocks the most critical system components in order to avoid long transit and customs clearance delays.

In addition to system-related issues, facilities can also contribute to unscheduled downtime. Power outages or brownouts, out-of-tolerance temperatures, humidity, vacuum, compressed air, or air quality each can negatively impact the system utilization. Finally, given the fact that it can be difficult to differentiate between a system problem and a process issue when diagnosing yield issues, it is also important that your supplier have an experienced applications engineering team that can help diagnose potential issues with your laser process.

Summary

In this column, we have tried to provide an overview of the factors related to cost-of-ownership and the main components. When reviewing typical UV laser processing systems, upfront costs and maintenance costs make up the largest percentage of cost of ownership, with the majority of maintenance costs related to laser and optics replacement. As such, system and supplier longevity are especially important in order to depreciate these costs over longest possible period.

Once you have purchased your system, your quest for lowest cost of ownership and cost per panel has not ended. Ensure that your facilities meet the system site requirements in order to avoid future yield issues and excessive system maintenance costs and downtime. Also ensure that your process development team is sufficiently trained to best optimize your processes for both throughput and yield as well as to avoid the common mistake of sacrificing process robustness for process throughput.

Whether you are considering a new UV laser processing system or are attempting to improve the COO of an existing system, keep this framework and these factors in mind. A holistic approach that considers system, supplier, personnel, facility costs, capabilities, and limitations will serve you well and will help ensure that you get the most out of your investment. **PCB**

References

1. Keeping on Top of Laser Safety, by Mike Jennings and Patrick Riechel, ESI.

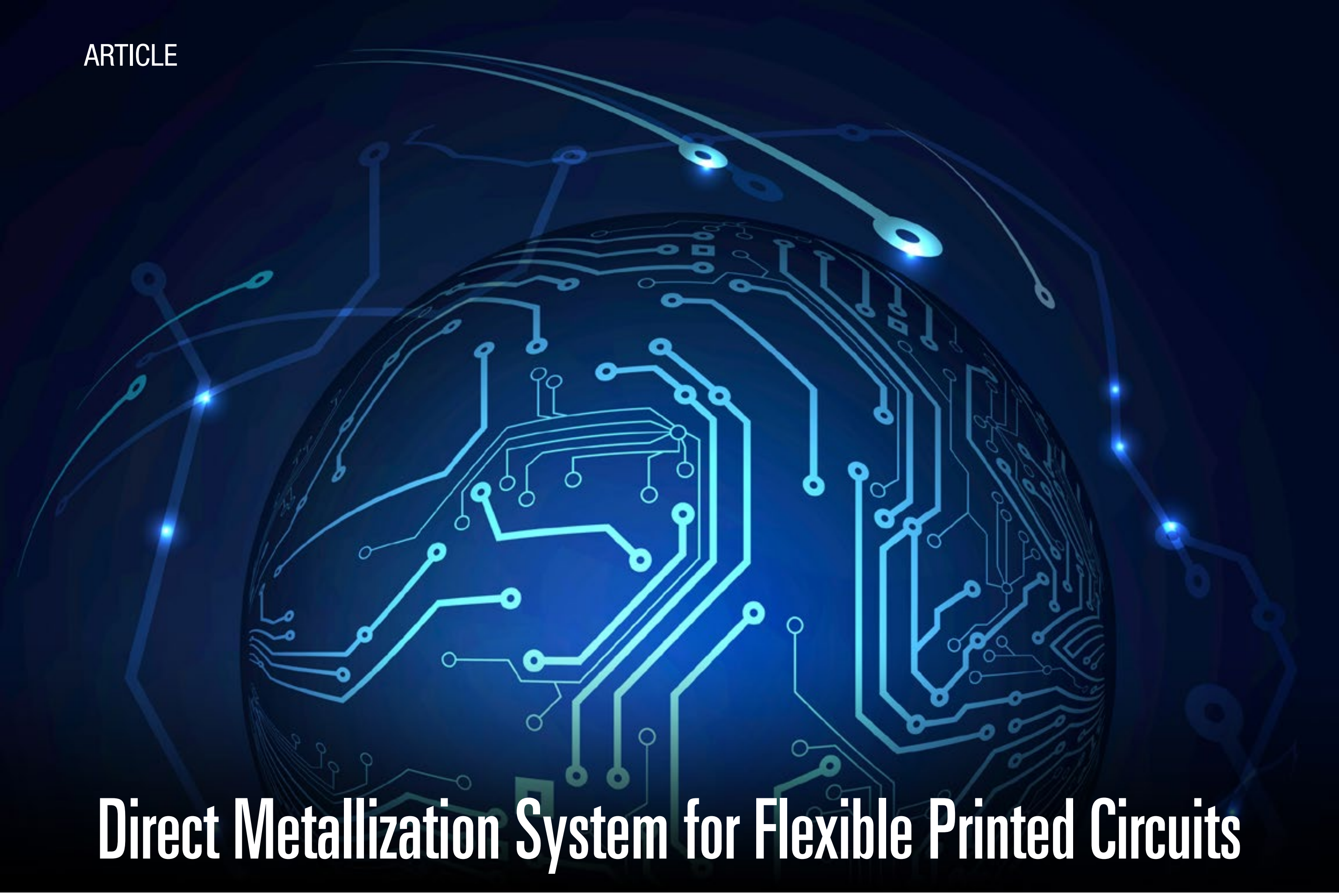
Mike Jennings (left) is director of product marketing with ESI's industrial products division.
Patrick Riechel (right) is product manager for ESI's flexible circuit micromachining tools.

Device 'Fingerprints' Could Help Protect Power Grid, Other Industrial Systems

Human voices are individually recognizable because they're generated by the unique components of each person's voice box, pharynx, esophagus and other physical structures.

Researchers are using the same principle to identify devices on electrical grid control networks, using their unique electronic "voices"—fingerprints produced by the devices' individual physical characteristics—to determine which signals are legitimate and which signals might be from attackers. A similar approach could also be used to protect networked industrial control systems in oil and gas refineries, manufacturing facilities, and more.

The research, reported in February at the Network and Distributed System Security Symposium in San Diego, was supported in part by the National Science Foundation (NSF). While device fingerprinting isn't a complete solution in itself, the technique could help address the unique security challenges of the electrical grid and other cyber-physical systems. The approach has been successfully tested in two electrical substations.



Direct Metallization System for Flexible Printed Circuits

by Rita Mohanty, Albert Angstenberger, Melanie Rischka and Han Verbunt
MACDERMID ENTHONE ELECTRONICS SOLUTIONS

Abstract

Flexible printed circuits (FPCs) are the key enabling technology in the design and fabrication of advanced handheld electronic devices such as smartphones, tablets, and camcorders—not to mention their importance to the automotive, defense and aviation industry throughout the last decades.

The rapid expansion of smartphone and tablet markets coupled with consumer demand for thinner and lighter products is causing the growth of the FPC segment to be the fastest in the PCB market. FPC provides electronic equipment designers greater design freedom when faced with further miniaturized circuitry (thinner lines/pitches and smaller vias) while simultaneously needing to reduce overall cost and increase functionality.

The limitation to further FPC adoption is due to challenges in fabrication, primarily the metallization of the flexible dielectric materials. Metallization challenges are the greatest for adhesiveless polyimide materials due to the higher cross-linked material which is less receptive to standard electroless plating chemistries. Conventional electroless copper processes are also cost prohibitive when it comes to horizontal FPC processing. Other options such as carbon/graphite-based direct metallization processes have had limited success for plating complex multilayer boards with microvia designs. However, new conductive polymer-based direct metallization technologies provide a breakthrough process for FPC fabrication.

This paper will discuss the recent development of a conductive polymer based direct metallization system that enables FPC fabrication of complex designs as a cost-effective alternative to traditional electroless methods. Results from a series of statistically designed experiments to understand the interaction between conductive polymer-based systems and various advanced polyimide materials will be presented here. Guidelines will be provided to FPC fabricators to assist in choosing the most cost effective solution to meet their customers need.

Introduction

Flexible printed circuits are defined by IPC[1] as: "A patterned arrangement of printed circuitry and components that utilizes flexible base material with or without a flexible cover lay." Simply put, a flexible circuit is a conductive pattern laid on a flexible dielectric film. Whilst early 1900s (metal on wax paper) and 1950s (etched metal patterns on insulating polymers or coated paper) inventions strived for replacing complex discrete wiring harnesses, today´s state-of-the-art FPC manufacture utilizes, for example, unreinforced polyesters (low cost), PEEK, polyimides (high reliability) as substrates for any conductive pattern[2].

Figure 1 shows a typical multi-layer FPC stack-up[3]. Within a flexible-circuit construction, the dielectric film forms the base layer, with adhesives used to bond the conductors to the dielectric. In multilayer flexible circuits, adhesives are used to bond the individual layers together. Adhesives can also be used in a protective capacity to cover the final circuit to prevent the ingress of moisture and dirt; hence they are termed cover lays (also cover layers) or cover coats.

Most flexible circuits are passive wiring structures that are used to interconnect electronic components such as integrated circuits, resistors, capacitors and the like; however, some are used only for making interconnections between other electronic assemblies either directly or by means of connectors. In other words, FPC offers the same design options as PCBs, with the added benefit of vibration resistance (e.g., airborne/space applications) and 3D configurations.

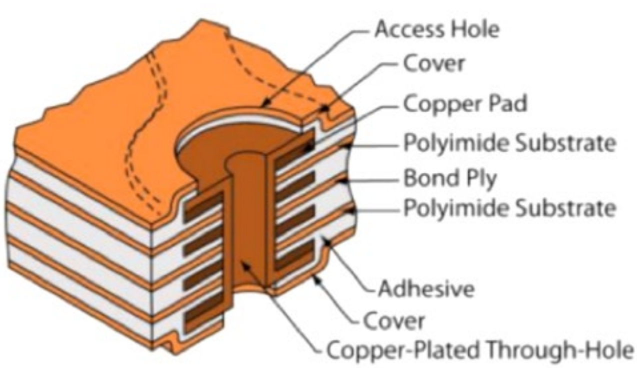


Figure 1: Typical multilayer FPC stack-up.

FPC Technology

A basic flexible circuit has three major components: conductor, adhesive and dielectric/insulator film.

Conductors are usually electrodeposited or rolled-annealed copper foils with various weights/thicknesses. These copper foils are bonded to the dielectric film using an adhesive film or by applying an adhesive-less construction technique. Adhesive-less construction has certain advantages over an adhesive base construction, such as thinner and more flexible circuits with better electrical properties. However, this advantage is reduced when an adhesive base cover coat is used.

When it comes to the choice of adhesive for FPC, acrylic and epoxy based adhesives are the most commonly used systems. Specific application requirements dictate which choice is the best.

All three components, conductor, adhesive and dielectric, have specific roles in making a robust FPC. However, the choice of dielectric film is considered to be the most critical in a flexible circuit. Most commonly used dielectric materials are unreinforced polyester based substrates for low-end applications whereas for complex, high-reliable FPCs, polyimides are the materials of choice. The end application usually dictates the type of dielectric film used to build flexible circuits. Table 1[4] shows key characteristics of the most commonly used dielectric films. Among the dielectric films listed in table 1, Polyimide is the most popular and the focus of this discussion.

Polyimide (PI) Substrate

Polyimides are a class of thermoset polymers with excellent flexing and electrical properties. It has superior resistance to high temperature, hence is an excellent choice for lead-free soldering conditions. The outstanding physical properties (e.g., dielectric strength, stability on thermal impacts, flexural strength) and excellent chemical resistance of polyimides are a consequence of the highly crosslinked nature of the basic polymer (Figure 2) in its simplest form.

CHARACTERISTIC	UNIT OF MEASURE	POLYIMIDE FILM	FEP FILM	POLYESTER FILM
Dielectric Strength	V/Mil-1 Mil	4500	5000	7000
Dielectric Constant	1 kHz	3.4	2.1	3.1
Dissipation Factor	1 kHz	.0016	.0003	.005
Tensile Strength	PSI	20000	4000	25000
Elongation	%	70	300	100
Water Absorption	% By Weight	3	< .01	.8
Operating Temperature	°C	150	204	149
Absolute Max Temperature	°C	300	274	149
Low Temp. Embrittlement	°C	-55	-85	-50
Melt Point	°C	816	280	248
Weather Resistance	MIL-STD-2026	Excellent	Excellent	Fair
Fungus Resistance	MIL-E-5272	Non-Nutrient	Non-Nutrient	Non-Nutrient
Chemical Resistance	N/A	Excellent	Excellent	Excellent

Table 1: Characteristics of thin-film dielectrics[4].

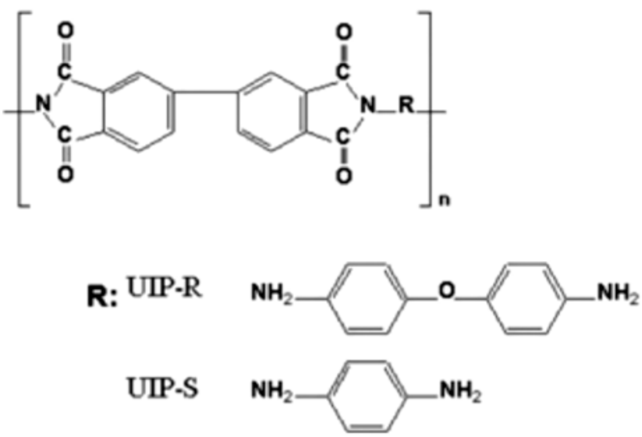


Figure 2: Simplified structure of polyimides.

Flexible PI Brand/Vendor	Glass Transition Temperature T_g (^{0}C, TMA)
DuPont	220
Azotec	300 – 350
Thinflex	320
Panasonic	343
Doosan	245 – 320

Table 2: Glass transition temperature for PI substrate[5].

The degree of crosslinking determines the thermal properties of the polyimide, such as glass transition temperature (Tg). Table 2 shows Tg for commonly used polyimides.

The specific attributes of polyimides, which make it highly desirable for use in flexible circuit applications, also make it highly challenging for the metallization of drilled holes. Especially with resin/woven glass reinforced composite structures of a rigid flexible substrate. Figure 3 shows a typical four-layer rigid-flex circuit with two rigid and two flexible layers[6]. Figure 4 shows an expanded view of the glass reinforced rigid layer. The conditioner needs to prepare the resin surface along with glass fibers to be receptive to deposition of MnO_2, which is the key to the polymerization of the conductive polymer.

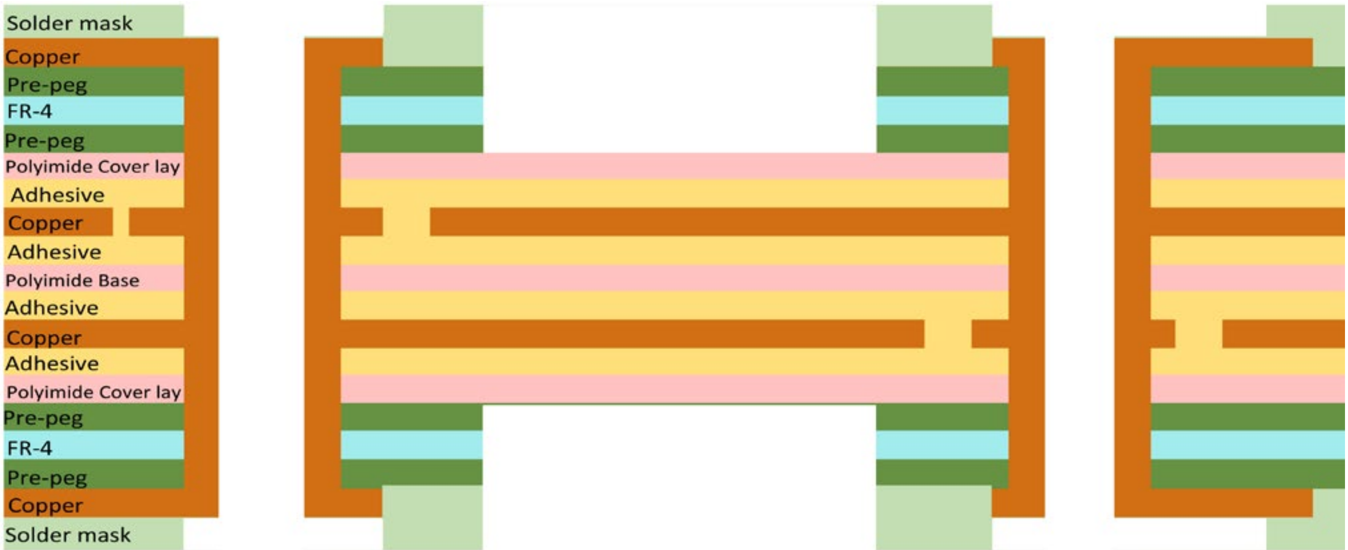


Figure 3: Typical four-layer rigid-flex construction.

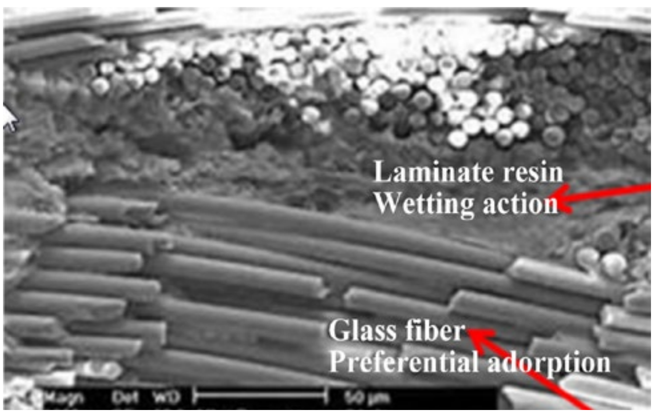


Figure 4: Typical rigid-flex substrate detail.

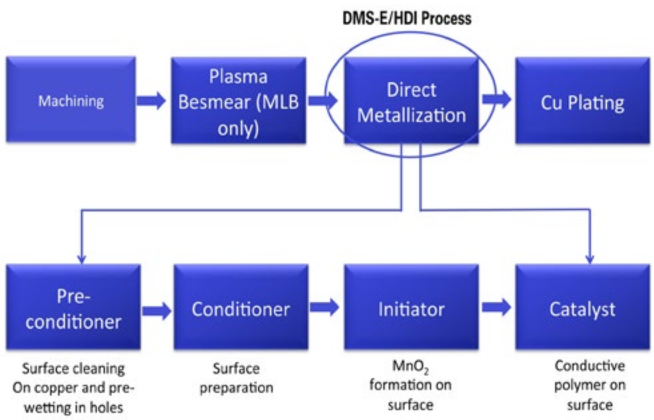


Figure 5: DMS-E process.

Special treatment is necessary to prepare the drilled hole surface, especially with glass reinforced rigid substrates for metallization. There are different approaches to achieve this objective. Of which, direct metallization is one of the most desirable processes due to some of its unique advantages. These are lower energy consumption and greener technology. Figure 5 shows a typical direct metallization process known as DMS-E. Flexible as well as rigid-flexible PCBs do pose substantially enhanced challenges on manufacturing because of cost sensitivity and the need for high reliability, making the use of direct metallization systems and optimized pretreatment procedures essential.

DMS-E Process

DMS-E technology is based on intrinsic conductive polymers that allow metallization of dielectric and electrically non-conductive areas without electroless copper as a seed layer. The conductive polymer film is generated in situ by a three-step process (conditioner, initiator and catalyst) on the non-conductive areas of the PCB (Figure 6).

Conditioner

The primary function of the conditioner is to wet the non-conductive part of the drilled hole to prepare for the initiator step. One possibility for a conditioner is to use a sweller in

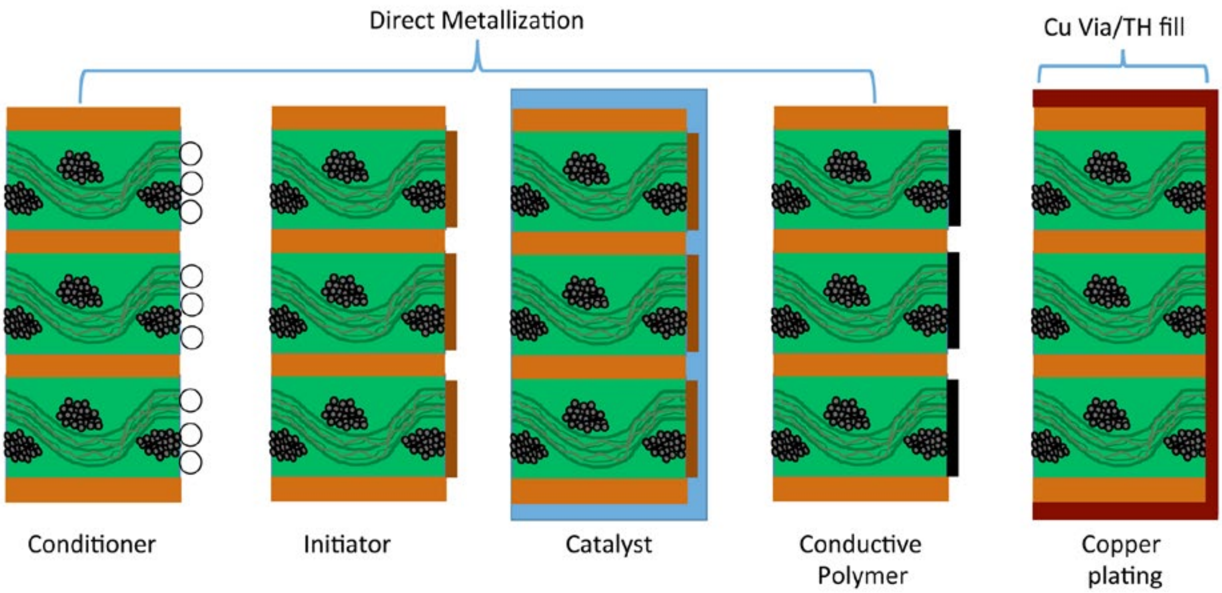


Figure 6: DMS-E process.

combination with reducing agent to modify the PI surface for a better attack of the initiator depositing MnO_2.

Initiator

The initiator is usually an aqueous solution of potassium or sodium permanganate that makes an oxidative reaction to selectively form manganese dioxide (MnO_2) on the conditioned dielectric area of the hole wall. MnO_2 is essential in the polymerization of the conductive polymer on the wall surface. The conductivity of the subsequently deposited polymer layer is highly dependent on the right amount of MnO_2 presence on the surface.

Catalyst

The catalyst in DMS-E process is an aqueous mixture of sulfonic acid and a micro emulsion of EDT that reacts with MnO_2 as oxidizer. EDT radicals, created by the oxidation step, react spontaneously to form the polymer chain (Figure 7).

The high Tg (T_g 220–350°C) polyimide flexible laminates require an extremely effective conditioning (i.e., an hydrophilicity step prior to chemical bonding of the conductive catalyst layer). The task of an effective conditioner system is the wetting of the resin and glass as well

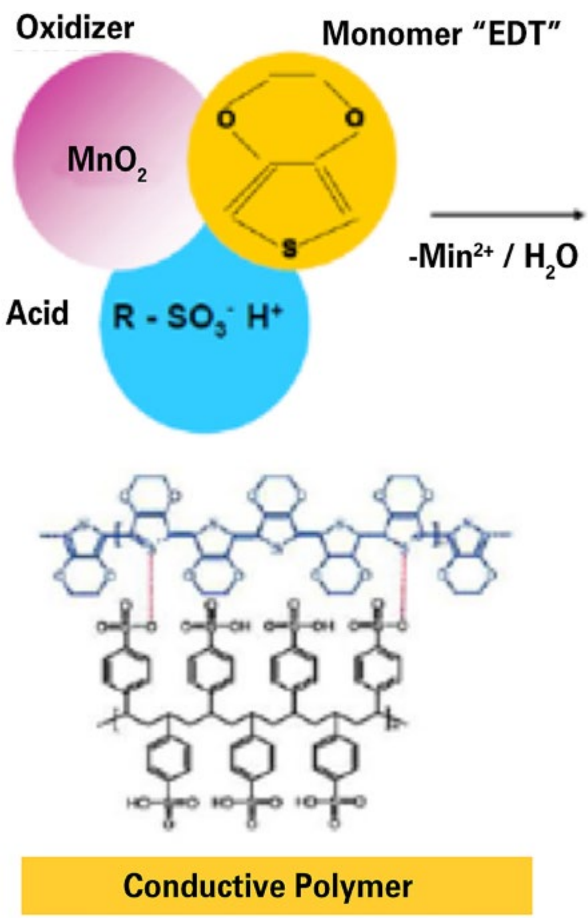


Figure 7: Conductive polymer formation.

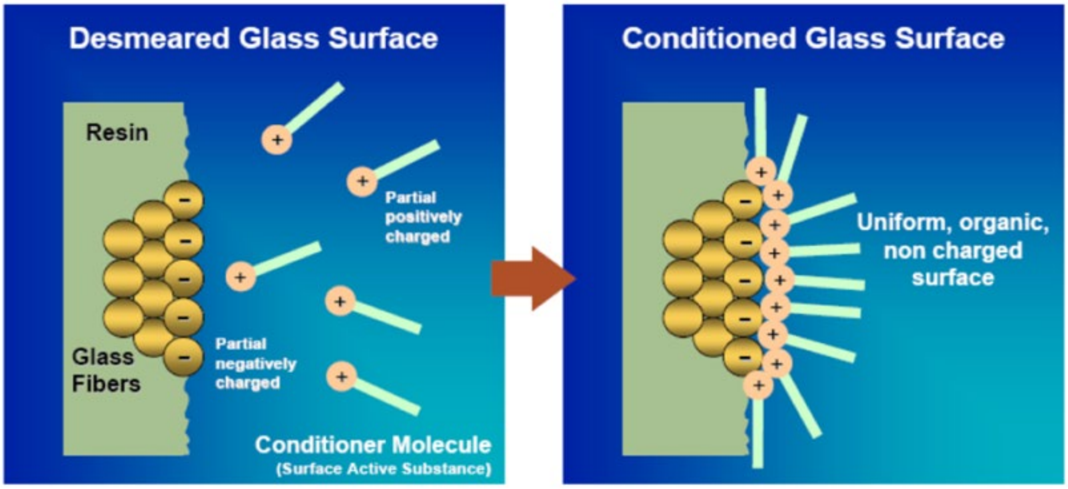


Figure 8: Conditioning of glass surfaces.

as preferential adsorption of the wetting agent to the fibers (Figure 8). The objective of this study has been to develop conditioning systems to provide required wetting and hydrophilicity of PI laminate as well as resin/glass with rigid inner layers of polyimide based laminates. Results from the flexible substrate are discussed here. Rigid-flex, which may need an additional glass conditioning compound, is not discussed here.

Experimental

The experimental strategy was to formulate a low temperature novel conditioning system for polyimide substrate that is compatible with the initiator and long life catalyst for DMS-E process. Three key focus areas of the formulation work were to identify optimum bath pH, sweller, and reducer compounds that perform well at low operating temperature. Each of these components plays a critical role in preparing the PI substrate for the subsequent step, which is to absorb MnO_2, which is a vital part of the DMS-E process.

The sweller compound swells the surface of the PI substrate resulting in a larger surface area and higher surface roughness. This makes the substrate more susceptible to the other additives. An alkaline pH cleaves the polymer end groups and creates functional groups which are more receptive to the reducer compounds. The function groups of the PI substrate are modified by the reducer which allows an optimal reduction and therefore a better formation of MnO_2 by the permanganate in the initiator.

	LEVELS	
Factor	(-)	(+)
Reducer	R1	R2
Sweller	S1	S2
Caustic	C1	C2

Table 3: Screening experimental matrix.

A series of statistically designed experiments were conducted to develop a robust process that included formulation and process parameters optimization. The initial screening experiment focused on the formulation part and included two different types of sweller, two different types of reducer and two different types of caustic for pH adjustment. Table 3 shows the initial screening experimental matrix. Different types of flex substrates were included in the evaluation to gage the effectiveness of the conditioner.

Test Vehicle

The test vehicle used in this experiment was a simple double-sided flex substrate. Depending on supplier, the substrate also had drilled holes. Prior to the DMS-E process, each test coupon

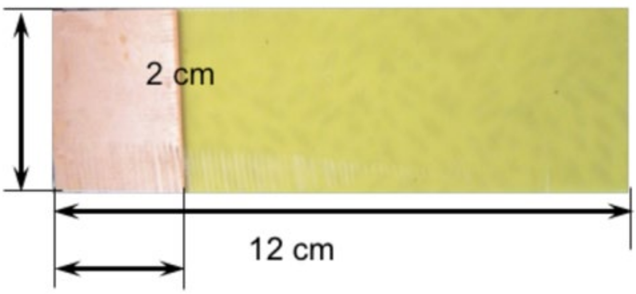


Figure 9: LCG test coupon.

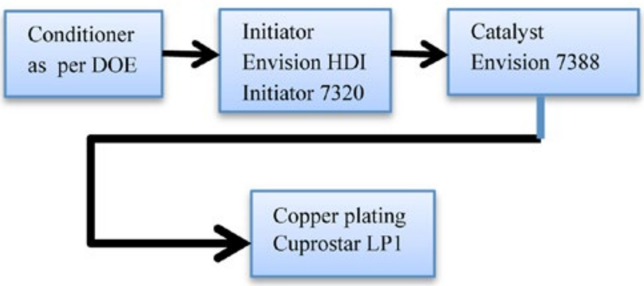


Figure 10: Process flow.

	LEVELS	
Factor	(-)	(+)
Reducer Conc	Low	High
Sweller type	S1	S2
Sweller Conc	Low	High
Caustic Conc	Low	High
Plating time	Low	High
Plating temp	Low	High

Table 4: Example of DOE matrix for process optimization.

was stripped of copper to expose the PI surface. A typical test coupon is shown in Figure 9.

Each test condition was monitored for two primary responses: lateral copper growth (LCG) and plated through-hole (PTH) coverage. LCG was developed as an internal test parameter which can provide an indication of the copper growth properties without needing to evaluate PTH. While the PTH coverage indicates functional attributes. Figure 10 shows the experimental sequence for LCG and PTH coverage determination.

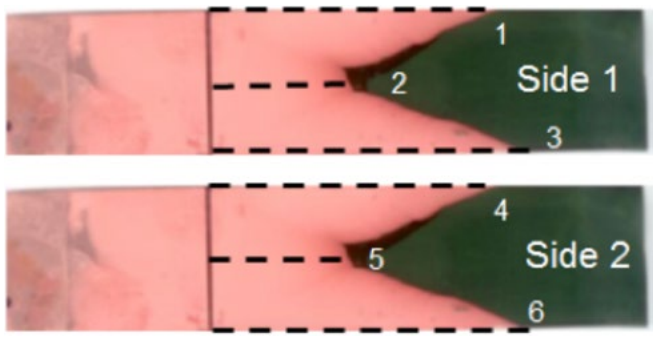


Figure 11: Measurement location for LCG growth.

Results from the screening experiment guided us to a stable formulation where additional DOEs were performed to optimize the formulation, process parameters and establish a robust process window. An example of the optimization DOE matrix is shown in Table 4. Following the optimization DOE, smaller experiments were carried out to refine the operating window of the significant parameters. As before, all DOEs were blocked over different types of PI substrate.

LCG Evaluation

The test coupon as shown in Figure 9 is used to measure lateral copper growth. Following the DMS-E process the coupon was plated in an acid copper bath (Enthone Cuprostar ST2000 or LP1) for five minutes at 2 ASD. The coupon is then rinsed and dried before evaluation. As the edge of the test coupon usually has a higher copper growth than the center, an average value is used for LCG analysis. The difference in copper growth between the edge and center is due to the roughness of the substrate at the edges which allows more MnO_2 to be adsorbed. This results in a higher conductivity and hence higher lateral copper growth. Copper growth takes place not only from the top, but also from the edges to the center of the coupons. The average growth is determined by measuring six points on the surface, as shown in Figure 11 and getting an average of the six points.

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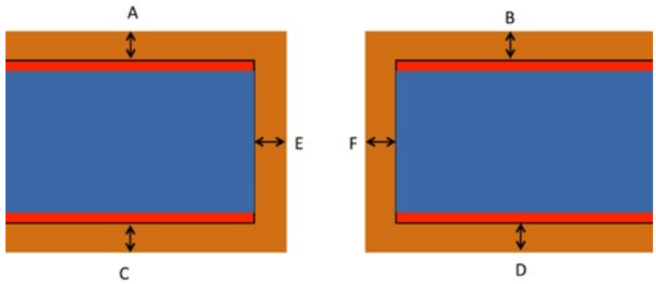

Figure 12: Measurement locations for TH efficiency.

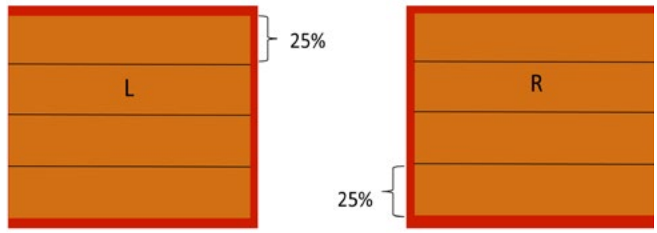

Figure 13: Measurement location for TH Coverage.

PTH Coverage Evaluation

For the though-hole evaluation a test coupon with sufficient holes is required. These coupons are treated in the same way as the LCG test samples except that the plating time in the acid copper bath was increased to 30 minutes. The coverage is evaluated from a cross section as through-hole efficiency (THE). Equation 1, along with Figure 12, describes the through-hole efficiency calculation method.

$$THE\ (\%) = \frac{(E+F)}{(A+B+C+D)/2}\ x\ 100 \qquad (1)$$

For substrates where it was not possible to prepare separate coupons for through-hole evaluation, samples were taken from the LCG test coupon with through hole and a different evaluation method was employed. Due to the shorter plating time for copper, a quantitative evaluation of through-hole efficiency was difficult. For these samples a qualitative method was used to estimate the through-hole coverage (THC). This is shown in equation 2 and Figure 13.

$$THC\ (\%) = \frac{\%Coverage\ L + \%Coverage\ R}{2} \qquad (2)$$

Results and Discussion

Common PI substrates, as provided by different customers have been used to develop an optimized conditioner system for DMS-E process. Presenting results from all substrates used in this experimental work is beyond the scope of this paper. Hence the discussion will be focused on a customer-supplied, hard to plate adhesive base PI substrate labeled as "A." During the experiment, only the conditioner was varied; all subsequent steps of the DMS-E and copper plating processes followed the standard process.

Screening Experiments

Results from the screening experiments are shown below through a series of graphs showing the effect of individual factors on the two key response variables. Figures 14–16 show the effect of pH, reducer and sweller on both LCG and THC/THE for substrate "A". It is evident from these figures that the through-hole performance is not significantly affected by the three chosen factors. However the LCG is affected by all three factors. The graphical analysis shows alkaline (higher) pH, reducer 2 and sweller 1 provided higher LCG. As LCG is a good indicator for plating speed, this finding was considered to be significant. This was also true for most of the substrates tested in this study. Based on this analysis, the follow up DOE was conducted with high pH and reducer 2. Both of the swellers were kept in the optimization DOE to further understand its effect on different standard flexible and rigid substrates.

Optimization Experiments

The LCG result from the optimized DOE (Table 4) was analyzed using MiniTab. The main effect plot and the ANOVA table are shown in

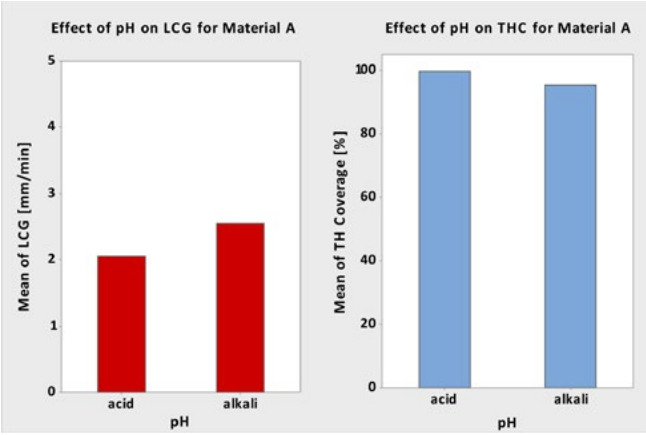

Figure 14: Effect of pH on LCG and THC.

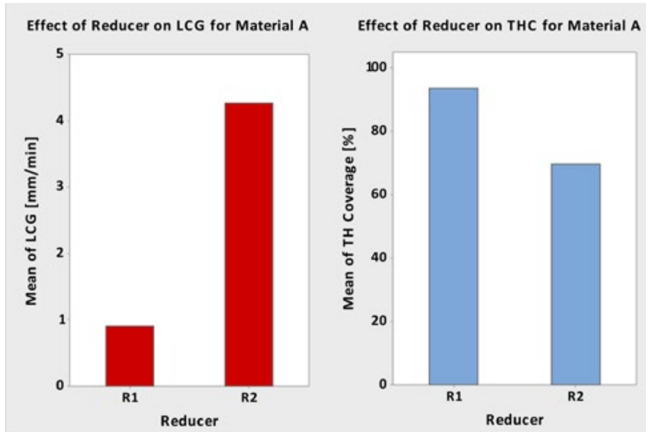

Figure 15: Effect of reducer on LCG and THC.

Figures 17 and 18, respectively. It is clear from the ANOVA analysis that both temperature and caustic (pH) concentration are statistically significant. However, sweller type and concentration proved to be insignificant as was seen before. Furthermore, it shows LCG growth is higher with high temperature and pH.

Following the process optimized DOE, several smaller DOEs were run to optimize the process window. A typical optimization condition is shown in Table 5. Confirmation runs were made to determine the performance of the new conditioner with several different substrates. The LCG results for the PI materials with the

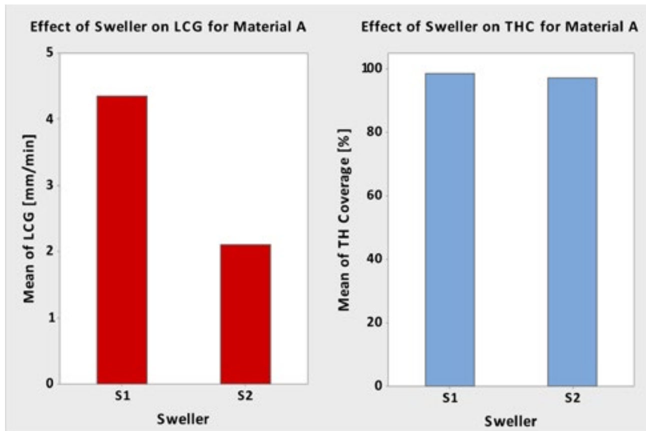

Figure 16: Effect of sweller on LCG and THC.

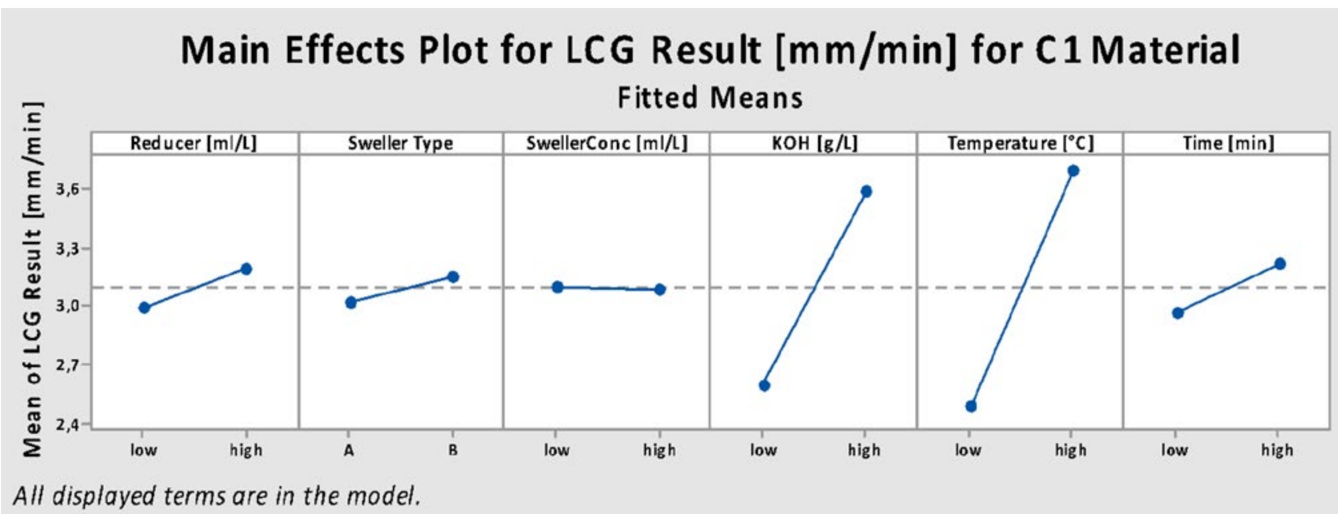

Figure 17: Main effect plots for LCG growth.

Analysis of Variance for C1 Material

Source	DF	Adj SS	Adj MS	F-Value	p-Value
Model	8	43,8181	5,4773	15,39	0,000
Linear	6	41,1833	6,8639	19,28	0,000
Reducer [ml/L]	1	0,7014	0,7014	1,97	0,165
Sweller Type	1	0,3112	0,3112	0.87	0,353
KOH [g/L]	1	15,8338	15,8338	44,48	0,000
Temperature [^{0}C]	1	23,4014	23,4014	65,73	0,000
Time [min]	1	0,9264	0,9264	2,60	0,112
2-Way Interaction	2	2,6348	1,3174	3,70	0,030
Reducer [ml/L]*Sweller Type	1	1,4702	1,4702	4,13	0,046
SwellerType*Time [min] 1	1	0,1646	1,1646	3,27	0,075
Error	63	22,4278	0,3560		
Curvature	1	0,3102	0,3102	0,87	0,355
Lack-of-Fit	8	2,9031	0,3629	1,02	0,433
Pure Error	54	19,2144	0,3558		
Total	71	66,2459			

Figure 18: ANOVA Tables for LCG growth.

optimum running conditions are shown in Figure 19. The substrate list included PI materials from suppliers such as Thinflex, Doosan, DuPont, and Shenyi. Due to confidentiality, exact product name/number has been omitted here. It is clear from Figure 19 that the LCG result varies depending on the PI substrate tested, but the new conditioner has excellent LCG values indicating fast plating times.

Out of the 14 different types of substrate tested, seven were further tested for through-hole coverage (10–16). These seven substrates included materials from ThinFlex, Doosan and Shenyi. The results are shown in Figure 20. As it can be seen from this graph, the new conditioner provided excellent through-hole coverage for all seven substrates.

Reducer	45 ml/L
Sweller Type	A
Sweller Content	250 ml/L
Caustic Content	20 g/L
Plating Time	3 min
Plating Temperature	45 °C

Table 5: Typical set up for the optimized conditioner system.

Conclusion

A novel, one-step conditioning system for the pretreatment of drilled flexible printed circuits has been developed for direct metallization utilizing the DMS-E process. The new conditioning system uses an alkaline solution of wetter, reducing agent and sweller. The system operates effectively at a lower operating temperature for most of the PI substrates tested in this

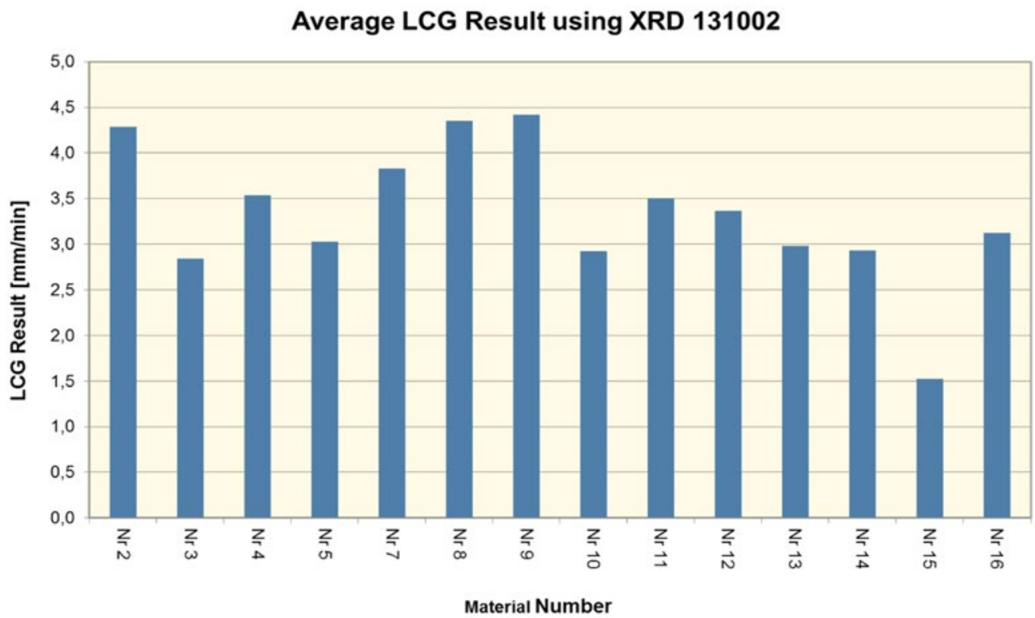

Figure 19: LCG result for various PI substrates with the optimum conditioner set up.

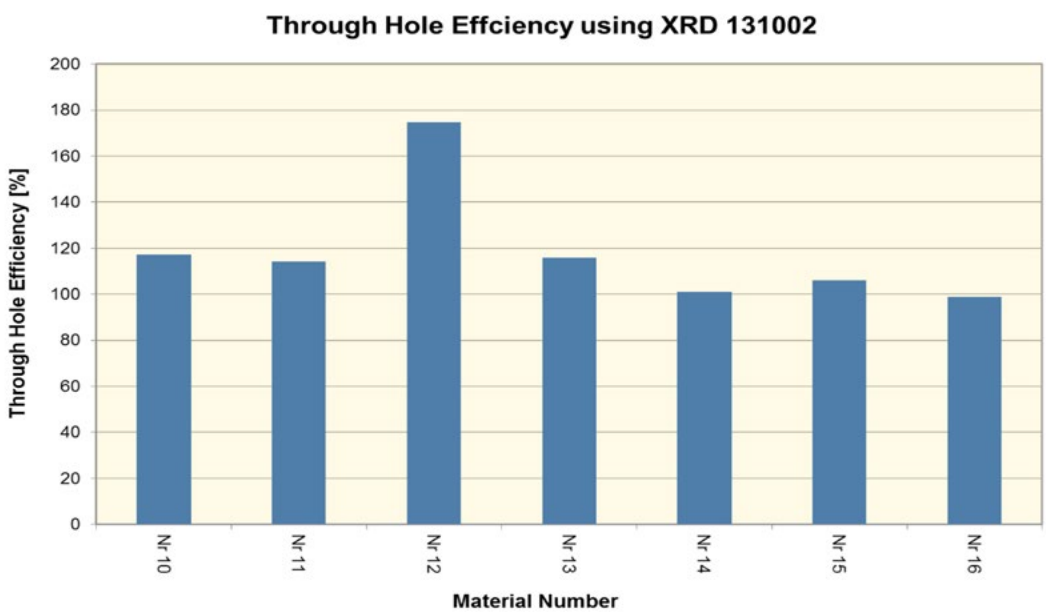

Figure 20: Through-hole efficiency for selected substrates.

study. Based on the experimental results, we can conclude that the new conditioner is highly effective in treating "hard to plate" PI substrates.

Path Forward: Recommendation

The current conditioner system has been tested with several PI substrates under controlled pilot scale environment. All results shows excellent LCG and TH coverage as described in this paper. However, further optimization will be necessary by the users to implement the system in a high volume manufacturing environment. Furthermore, as PI materials are highly sensitive to sweller and reducer, further optimization may be necessary for the process to be effective for specific types of PI material.

Acknowledgement

The authors would like to express their sincere gratitude to Dr. Christian Rietmann, Eric Walch, and Andreas Gloeckner for their invaluable contribution to this study. Without their support, this study would not have been possible. **PCB**

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3. Flexible Circuit Design Guide, MINCO.

4. Flexible Circuit Design Guide, 4th Ed., Teledyne Electronic Technologies.

5. Publicly available technical datasheets for each type of PI substrate.

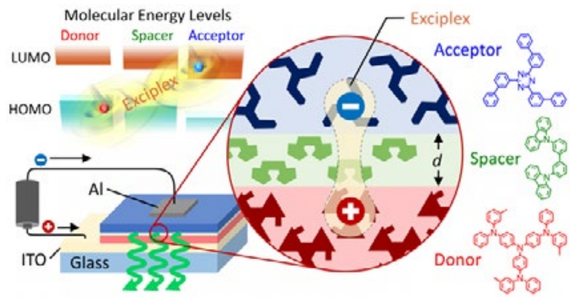
6. Flexible Circuit Technologies

Originally published in the proceedings of SMTA International, 2015.

(Left to right) **Dr. Rita Mohanty** is director of global R&D and project management; **Dr. Albert Angstenberge** is global application manager; **Dr. Melanie Rischka** is senior R&D chemist; **Mr. Han Verbunt** is a scientist. All co-authors are with MacDermid Enthone Electronics Solutions.

Artificial Control of Exciplexes Opens Possibilities for New Electronics

Demonstrating a strategy that could form the basis for a new class of electronic devices with uniquely tunable properties, researchers at Kyushu University were able to widely vary the emission color and efficiency of organic light-emitting diodes based on exciplexes simply by changing the distance between key molecules in the devices by a few nanometers.



This new way to control electrical properties by slightly changing the device thickness instead of the materials could lead to new kinds of organic electronic devices with switching behavior or light emission that reacts to external factors. Organic electronic devices such as OLEDs and organic solar cells use thin films of organic molecules for the electrically active materials, making flexible and low-cost devices possible.

A key factor determining the properties of organic devices is the behavior of packets of electrical energy called excitons, which consists of a negative electron attracted to a positive hole, and can be thought of as a missing electron. In OLEDs, the energy in these excitons is released as light when the electron loses energy and fills the vacancy of the hole. Varying the exciton energy, for example, will change the emission color.

"This is some of the first evidence that electrons and holes could still interact like this across such a long distance," commented Professor Adachi, "so this structure may also be a useful tool for studying and understanding the physics of excitons to design better OLEDs and organic solar cells in the future."

Electronics Industry News
Market Highlights

IoT Chip Market Worth $10.78B by 2022

The IoT chip market is expected to grow from USD 4.58 billion in 2015 to USD 10.78 billion by 2022, at a CAGR of 11.5% between 2016 and 2022.

Quantum Dot Solids: This Generation's Silicon Wafer?

Just as the single-crystal silicon wafer forever changed the nature of electronics 60 years ago, a group of Cornell researchers is hoping its work with quantum dot solids—crystals made out of crystals—can help usher in a new era in electronics.

Researchers Engineer an Electronics First, Opening Door to Flexible Electronics

An engineering research team at the University of Alberta has invented a new transistor that could revolutionize thin-film electronic devices. The team was exploring new uses for thin film transistors (TFT), which are most commonly found in low-power, low-frequency devices like the display screen you're reading from now.

Nanosheet Growth Technique Could Revolutionize Nanomaterial Production

After six years of painstaking effort, a group of University of Wisconsin, Madison materials scientists believe the tiny sheets of the semiconductor zinc oxide they're growing could have huge implications for the future of a host of electronic and biomedical devices.

Total Capital Expenditure of Top Three Semiconductor Manufacturers to Rise 5.4% YoY for 2016

The revenue of the global semiconductor foundry industry is projected to grow by just 2.1% year-on-year for 2016 on account of slowing end market demand and expanding supply, according to the global market research firm TrendForce.

What New Wearable Sensors can Reveal from Perspiration

When University of California, Berkeley engineers say they are going to make you sweat, it is all in the name of science. Specifically, it is for a flexible sensor system that can measure metabolites and electrolytes in sweat, calibrate the data based upon skin temperature and sync the results in real time to a smartphone.

India's Market Dynamics are Impacting Digital Business Implementation

Widespread failures in realizing return on investment (ROI) in digital technologies for customer experience could create a sense of distrust among buyers and decision makers in India about the potential for digital business, according to Gartner Inc.

New Bimetallic Alloy Nanoparticles for Printed Electronic Circuits

Printed electronics has the potential to enable low-cost fabrication of electronics on flexible or curved surfaces, which will lead to the use of electronics in more varied applications. We will be able to fabricate homemade mobile phones or smart watches using a printer in the future.

Outlook of Small Business Owners by Sector 2016

Most retailers are likely to say growth is the top priority for their business (86%). However, they are least likely to plan to make capital investments (67%) or hire staff (58%) over the next six months, even though they are most confident they would be able to access the funding needed for growth (97%).

Organic Crystals Allow Creating Flexible Electronic Devices

A team of researchers from Moscow State University, in cooperation with Russian and foreign colleagues, learnt to grow organic semiconductor crystals with extremely high light-emitting efficiency that promise a bright future for wet-processed organic optoelectronics.

Green Legislation and the Impact on Electronic Materials and Processes

by Karl H. Dietz
KARL DIETZ CONSULTING LLC

In a previous *Tech Talk,* I pointed out that "green" and "environmentally friendly" are ill-defined terms. In general, these terms refer to manufacturing that involves the replacement of toxic substances with less toxic materials, the elimination of materials or processing steps, less consumption of chemicals (i.e., more efficient or higher yield processing), reduction of water use, reduction of energy use, less space requirement (i.e., smaller equipment footprint), recycling, and on-site recovery of materials. The following list highlights critical regulations that impact electronic manufacturing.

A. An overview of regulations that impact materials and processes used in the fabrication of electronic devices.

RoHS:

The RoHS Directive stands for "the restriction of the use of certain hazardous substances in electrical and electronic equipment." This directive bans the placing on the EU market of new electrical and electronic equipment containing more than agreed levels of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) flame retardants.

Manufacturers need to understand the requirements of RoHS to ensure that their products, and their components, comply.

WEEE:

Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE). This regulation addresses the disposal and recycling of electronic equipment.

REACH:

REACH: Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18. December 2006 concerning the Registration, Evaluation, Authorisation and Restric-

tion of Chemicals (REACH),establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC.

REACH is administered out of Helsinki, Finland. The regulation encourages the sharing of data between applicants for the registration of the same substance to minimize cost and animal studies. Studies are assigned a monetary value that is used in computing the compensation owed to the owner of the data by other applicants who want to use such data in their application. The distinction between "chemical" and "article of commerce" in REACH may differ from OSHA regulations, and thus may require the registration of chemicals that compose an "article." REACH adopted the convention that polymeric substances are not registered as such, but that the monomers from which the polymer is derived need to be registered. This can lead to confusion as toxicity data of monomers may be associated with the properties of the polymer.

> "The regulation encourages the sharing of data between applicants for the registration of the same substance to minimize cost and animal studies."

China RoHS and China WEEE

China RoHS (Restriction of Hazardous Substances), officially known as Administrative Measure on the Control of Pollution Caused by Electronic Information Products is a Chinese government regulation to control certain materials, including lead.

All items shipped to China now have to be marked as to whether the items contained in the box are compliant or non-compliant. The Electronic Information Products (EIP) logo or other label is used to mark parts and assemblies that do not contain unacceptable amounts of substances identified by the regulations, and that are environmentally safe. Units that do contain hazardous substances are marked with the EIP logo including an Environment Friendly Use Period (EFUP) value in years.

There are currently six substances considered environmentally hazardous by the China RoHS directive.

- Lead
- Mercury
- Cadmium
- Hexavalent Chromium
- Polybrominated Biphenyls
- Polybrominated Diphenyl Ethers

China RoHS does not allow any technology exemptions unlike the EU RoHS 2 Directive. China RoHS includes the following elements:

- Prevention of pollution by eliminating pollutants and requiring recycling
- Cradle-to-grave scope
- Packaging must be non-toxic, biodegradable and recyclable
- Packaging must be marked with material content
- The RoHS 6 (Cd, Cr, Hg, Pb, PBB, PBDE) are banned from use
- Products must be labeled with:
  - Names, content levels, and recyclability of harmful materials
  - Recyclability
  - Product safety periods (date range product is safe to use)
  - Extraordinary exception permits labeling in product manuals or on packaging
- Producers must provide indices of product safety periods for publication
- Producers must contract with local recyclers to recover products after safety period
- Producers must finance recycling

- Entities and individuals may complain about pollution caused by electronic products
- Violators who fail to take corrective action as a result of complaints may have their permits revoked and their identities publicized
- Products not properly marked will not pass customs

Status of China WEEE (rules governing the recycling and disposal of waste electrical and electronic equipment). (Source: Analysis of the "China WEEE Directive": Characteristics, breakthroughs and challenges of the new WEEE legislation in China, by Hong Zhang.)

"In response to WEEE problems in China, the Chinese government has developed a variety of policies since 2000. But none of them issued before 2010 turns out to be a comprehensive WEEE-specific policy. These policies were not enough to guarantee a sound treatment of WEEE and construct an economic, environmental and ethical recycling and disposal system in China. On 1 January 2011, the Regulations for the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products (RAW), often referred to as the China WEEE Directive, was finally enacted. It aims to standardize the recovery and disposal of WEEE. Being the most important WEEE legislation in China, how RAW tries to overcome these weaknesses in earlier policies has not been studied systematically. Particularly, the breakthroughs, concerns and challenges of RAW together with the related reflections from stakeholders have not been analyzed."

"Being the most important WEEE legislation in China, how RAW tries to overcome these weaknesses in earlier policies has not been studied systematically."

Directive for Energy-using Products

Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council, Official Journal of the European Union L 191/21.

B. Effects of Lead-free Legislation on Electronic Materials, Processes, Equipment

- **Laminate (source: IPC)**

Manufacturers must work with their laminate suppliers to ensure they will be providing materials that will be able to withstand multiple reflows at higher processing temperatures. Two concerns with higher soldering temperatures are the Z-axis expansion and decomposition of the laminate.

Higher soldering temperatures result in greater Z-axis expansion, which may affect PTH reliability.

Decomposition, or breaking of polymeric bonds, can happen during high-temperature soldering. Although tests are conducted regularly for laminate, which call for the materials to survive a steady 288°C temperature for 15–20 minutes, mere seconds during a soldering operation could break polymeric bonds within the material.

In addition to these issues and the potential for increased warpage of the PCB, higher reflow temperatures can also affect inks, adhesives, and markings.

- **Finishes (source: IPC)**

Because it is important to protect the copper conductors on PCBs from degradation, PCBs finishes are applied via hot air solder leveling (HASL), electroless and immersion metal depositions, and organic solderability preservatives (OSPs). Because a fully lead-free electronic assembly will call for no lead in the finish, board fabricators must select an alternative rated on cost, reliability, shelf life, and customer specifications.

In conjunction with the U.S. Environmental Protection Agency (U.S. EPA), IPC conducted an evaluation of alternative solder finishes. Additionally, the EPA, IPC and EIA also conducted a life cycle assessment of lead free solders.

- **Lead-free Solder (source: IPC)**

A broad variety of solder alloys have been investigated as potential replacements for tin lead solder. While there is broad agreement that there will be no drop-in replacement for tin lead, alloys based on tin/silver/copper ("SAC") have emerged as the Sn/Pb replacements of choice.

- **Multilayer Bonders**

Multilayer bonders are coatings on innerlayer copper circuitry to enhance adhesion to prepreg during multilayer lamination. As dielectric resins had to be modified to better hold up to lead-free soldering temperatures, bonders had to be modified.

- **Thick Film Ceramic Pastes**

Glass frits containing lead had to be reformulated.

- **Desmear Chemistries**

Desmear chemistries are typically solvent swelling of dielectric resin followed by permanganate etching of the epoxy, to clean the drilled through-holes and/or to micro-roughen the dielectric surface. As base material resins needed to be modified for higher Tg to better hold up during lead-free solder reflow, the desmear chemistries had to be modified (made more aggressive).

- **Soldermasks**

Soldermasks had to be modified to avoid outgassing, discoloration, blistering, and delamination at higher processing temperatures.

- **Other Concerns: Tin Whiskers (Source: IPC)**

(Note: Lead (Pb), even at low levels, is known to largely suppress tin whisker formation.)

A large area of concern with the use of tin-plated or pure tin component finishes is the occurrence of tin whiskers. This condition arises when tin begins to grow tiny filaments known as whiskers. A tin whisker is a spontaneous columnar or cylindrical filament, which can branch, of mono-crystalline tin emanating from the surface of a plating finish. Tin whiskers generally have an aspect ratio (length/width) greater than two; whiskers have been found to be over several mm in length in rare instances. The whiskers can be kinked, bent, or twisted and may be surrounded by striations/rings. These whiskers are very brittle therefore can lead to intermittent or permanent electrical shorts when broken and re-deposited upon the circuit's surface.

Ways of avoiding whiskers in actual field applications include:

- Not using pure tin, especially in a 'brightened' format.
- Reflow of the tin plating to re-fuse/re-crystallize and stress-relieve the deposit.
- Using barrier materials (over-plating or organic post-coatings) to encapsulate any whiskers which have formed since completion of the plating.

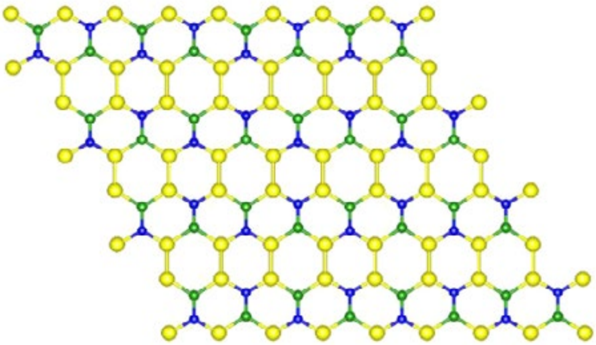
C. Examples of minimizing energy consumption, avoiding the use of toxic materials, recycling and re-use of materials

- Soldermask developer chemistry: use of polyalcohols.
- On-site copper recovery from acidic and alkaline etchants.
- Recovery of materials from copper-clad boards/scrap: Example: separation of metals, resins, and glass for re-use.
- Replacing electroless copper process with direct metallization processes: Avoids several process steps, reduces water consumption.

- Removing toxic materials from electroless copper baths: Example: Reducing agent formaldehyde, a suspect carcinogen, is replaced by hypophosphite reducing agent. EDTA complexing agent that interferes with heavy metal waste treatment, is replaced by tartrate complexing agent. Toxic stabilizing agent cyanide is replaced by citrate.
- Recycling of Mylar ® film (e.g., from dry film resist): Used Mylar® film and other PET products can be subjected to a pyrolysis or alcoholysis process. The polymer is broken down into its building blocks (e.g., terephthalate ester which can be used again as raw material for PET). The recycle volume needs to be substantial to make this process economical.
- Flame-retardant Issues: Although halogen-containing and phosphorous compound containing flame retardants are not included in the RoHS legislation, there is mounting pressure to get rid of these flame retardants, especially brominated flame retardants such as tetra-bromo-bisphenol A. The reasons are diverse: halogen-containing base materials are more expensive to recycle so that OEMs and fabricators see an incentive to get rid of them even without legislation. Studies are underway that are checking into the toxicity of bisphenol A, whether brominated or not. The aversion to phosphorus-derived flame-retardants is not well based on toxicity data. One approach to avoid these compounds and still retain V-0 rating is the use of resins with higher aromaticity content (more benzene rings). **PCB**

Karl Dietz is president of Karl Dietz Consulting LLC. He offers consulting services and tutorials in the field of circuit board and substrate fabrication technology. To view past columns or to reach Dietz, click here. Dietz may also be reached by phone at (001) 919-870-6230.

New 2D Material Could Upstage Graphene



A new one atom-thick flat material that could upstage the wonder material graphene and advance digital technology has been discovered by a physicist at the University of Kentucky working in collaboration with scientists from Daimler in Germany and the Institute for Electronic Structure and Laser (IESL) in Greece.

Reported in *Physical Review B, Rapid Communication,* the new material is made up of silicon, boron and nitrogen—all light, inexpensive and earth abundant elements—and is extremely stable, a property many other graphene alternatives lack.

"We used simulations to see if the bonds would break or disintegrate—it didn't happen," said Madhu Menon, a physicist in the UK Center for Computational Sciences. "We heated the material up to 1,000°C and it still didn't break."

Using state-of-the-art theoretical computations, Menon and his collaborators Ernst Richter from Daimler and a former UK Department of Physics and Astronomy post-doctoral research associate, and Antonis Andriotis from IESL, have demonstrated that by combining the three elements, it is possible to obtain a one atom-thick, truly 2D material with properties that can be fine-tuned to suit various applications beyond what is possible with graphene.

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PCB shops in Brazil: Are you kidding me?

by Renato Peres
CIRCUIBRAS

Let´s face facts: Who would ever think of listening to an opinion about the PCB industry coming from someone in Brazil?

In 2011, when I first came to the U.S. for a training session at an electrical test company, I heard things like: “Brazil is bigger than Texas? WOW!” and “Brazil is almost the same size as the U.S.?” and even this: “Are there cockroaches the size of my hand in Brazil?” People were also very curious about the location of places like Rio de Janeiro and the Amazon rainforest.

It wasn’t any better when I went to a PCB show in Suzhou, China, two years ago. The Chinese people I talked with said they had never heard of Brazil.

Brazilian Economy: Briefing

Brazil is the fifth-largest country and the fifth most-populated nation in the world, with approximately 205 million inhabitants. The country ranks among the top 10 richest countries in the world, but its future is not so clear.

Economic Outlook - Brazil					
Subject Descriptor	**Units**	**Scale**	**2014**	**2015 (1)**	**2016 (1)**
GDP, current prices	U.S. dollars	Billions	2,346.58	1,799.61	1,672.90
GDP per capita, current prices	U.S. dollars	Units	11,572.70	8,802.17	8,117.65
Total investment	Percent of GDP		20,030	18,032	16,681
Unemployment rate	Percent of total labor force		4,842	6,598	8,570
Population	Persons	Millions	202,769	204,451	206,082

(1) IMF staff estimates

Source: International Monetary Fund, World Economic Outlook Database, October 2015

Table 1: Economic Outlook—Brazil.

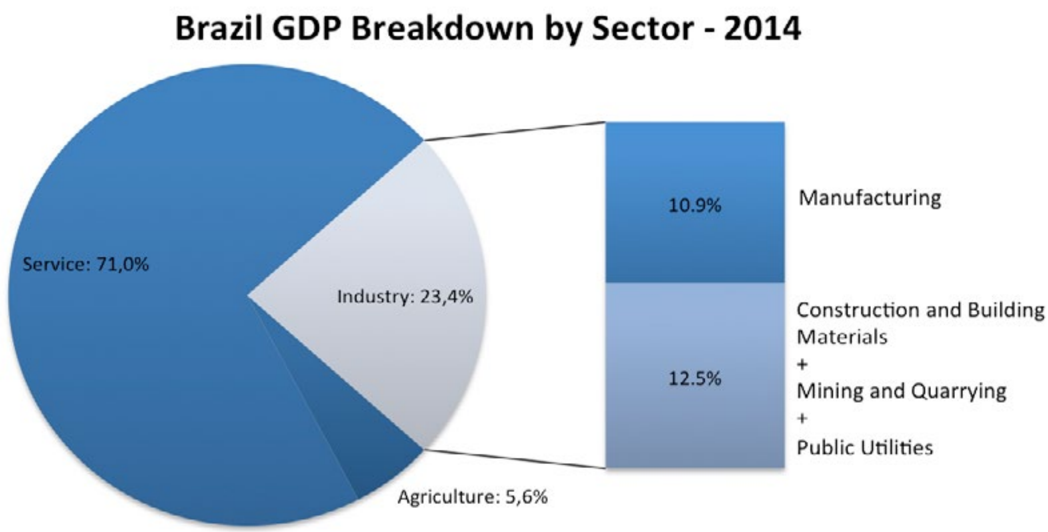


Figure 1: Brazil GDP breakdown by sector, 2014.

ELECTRONIC INDUSTRY REVENUE (US$ million)	2014	Var % (2)	2015 (1)	Var % (2)	2016 (1)	Var % (2)
Computers	15,993	-26.6%	9,602	-40.0%	7,594	-20.9%
Telecommunications	12,567	1.7%	8,677	-31.0%	7,372	-15.0%
Industrial Equipments	10,922	0.0%	8,121	-25.6%	7,041	-13.3%
Household Appliances	8,715	0.9%	5,522	-36.6%	4,574	-17.2%
Electric Power Generation, Transmission and Distribution	6,685	-11.0%	4,733	-29.2%	3,861	-18.4%
Electric & Electronic Components	4,404	-11.1%	3,084	-30.0%	2,587	-16.1%
Electrical Installation Material	4,115	-6.2%	2,532	-38.5%	2,023	-20.1%
Industrial Automation	1,921	-5.0%	1,355	-29.5%	1,166	-13.9%
Total	65,322	-10.0%	43,628	-33.2%	36,218	-17.0%

(1) Estimates updated on December 2015

(2) Comparison with the previous year

Source: ABINEE (Associação Brasileira da Indústria Elétrica e Eletrônica

Table 2: Electronic industry revenue, in US$ million.

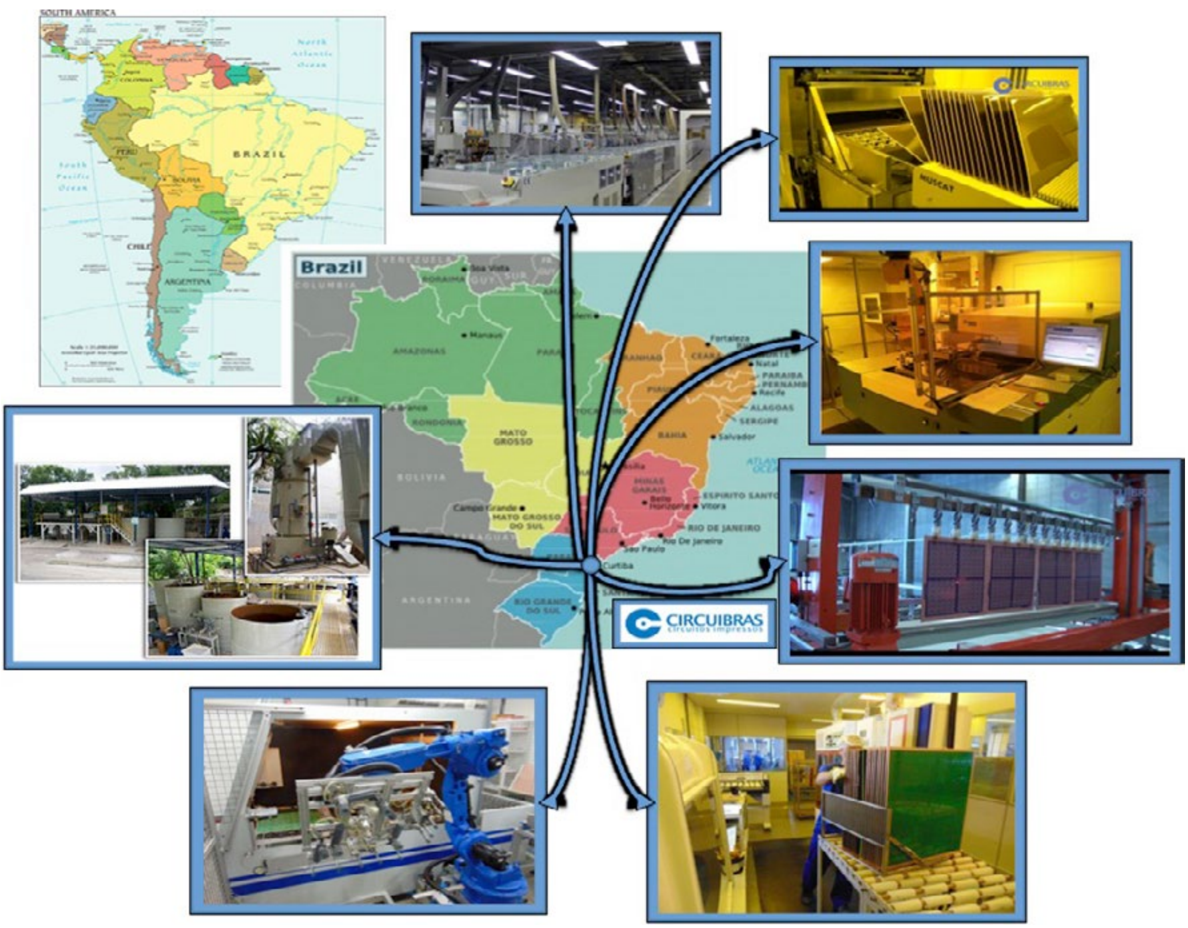


Figure 2: Brazil—The Circuibras facility and location in Brazil.

Brazil is heading toward one of its toughest recessions in the recent history, mainly due to political instability.

Abinee, the Brazilian Electrical and Electronics Industry Association, estimate a drop of 10% in real income (RS) in 2015 compared to 2014, and 6% in 2016, compared to last year. This industry is responsible for approximately 2.5% of the national GDP and it is divided into eight major segments as shown in Table 2.

The bad news is that there are enormous challenges Brazil must conquer to survive in

this arena. The good news is we are ready for battle.

What´s the point of following this column?

Although Brazilian PCB manufacturers' revenue represents a small share of the country´s GDP, and consequently has no big influence worldwide, we deal with some of the biggest players in the international electronics industry.

Quick-turn production, small- and medium-size batches, high-tech PCBs, severe environmental laws, lack of a specialized labor force and lots of customer requirements, are just some of the issues we need to deal with in our everyday lives.

My goals for this new column—Made in Brazil—are to present Brazil in a different way from the one I was introduced to when I was abroad, and to share the knowledge I have gained in the PCB industry during the last, almost 10 years I have been part of the Circuibras team, working and leading people in different areas—electrical test, drilling, routing, lamination, process engineering, dry film, AOI and visual inspection.

Going forward in this column, I will write about process and industrial engineering, as well as management and leadership, from a Brazilian worldview.

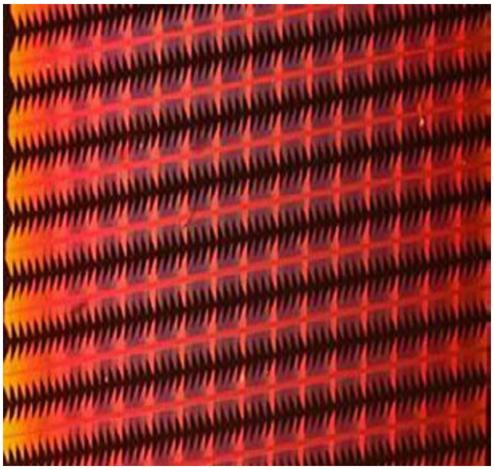
In my next column, I will bring some news on process engineering: what customer demands we face and why you should care about it, and I will also discuss DMAIC, a powerful tool that may help you improve your processes.

It is going to be a pleasure to offer my insights, and I hope to hear from you, learn your thoughts and talk about the thing that challenges us every day: printed circuit boards.

I hope you enjoy it! **PCB**

Renato Peres is an industrial engineer and production coordinator with Circuibras Circuitos Impressos Profissionais.

Physicists Promise a Copper Revolution in Nanophotonics



Researchers from the Moscow Institute of Physics and Technology (MIPT) have for the first time experimentally demonstrated that copper nanophotonic components can operate successfully in photonic devices. Copper components are not only just as good as components based on noble metals, but, unlike them, they can easily be implemented in integrated circuits using industry-standard fabrication processes. "This is a kind of revolution—using copper will solve one of the main problems in nanophotonics," say the authors of the paper. The results have been published in the scientific journal *Nano Letters*.

The discovery, which is revolutionary for photonics and the computers of the future, was made by researchers from the Laboratory of Nanooptics and Plasmonics at MIPT's Centre of Nanoscale Optoelectronics. They have succeeded, for the first time, in producing copper nanophotonic components, whose characteristics are just as good as that of gold components. The scientists fabricated the copper components using the process compatible with the industry-standard manufacturing technologies that are used today to produce modern integrated circuits. This means that in the very near future, copper nanophotonic components will form a basis for the development of energy-efficient light sources, ultra-sensitive sensors, as well as high-performance optoelectronic processors with several thousand cores.

Recent Highlights from PCB007

1 Happy's Essential Skills: The Need for Total Quality Control (Six Sigma and Statistical Tools), Part 2

The statistical representation of Six Sigma describes quantitatively how a process is performing. To achieve Six Sigma, a process must not produce more than 3.4 defects per million opportunities. A Six Sigma defect is defined as anything outside of customer specifications.

2 What a Long, Strange Trip it's Been—and It's a Long Way from Being Over


Harvey Miller

Harvey Miller has been in the PCB industry for more than 40 years, and he's probably seen it all. I recently sat down with Harvey at a wine bar in Palo Alto to learn more about his history in the industry and where he sees it going forward. Harvey arrived wearing jogging shorts and running shoes. No surprise after what his doctor recently shared with him.

3 Graphic PLC Receives Training Awards

The awards recognise exceptional training and development in organisations across the South West; celebrating companies that develop their staff through training and have as a result seen exceptional business success.

4 TTM Technologies Reports Sales Growth in Q4 and FY 2015

"Our solid fourth quarter execution combined with seasonal growth in the cellular phone end market and robust demand in the automotive and aerospace and defense end markets drove our sequential increases in gross margin, operating profit and strong free cash flow generation," said Tom Edman, CEO of TTM.

5 Conflict Minerals: Negotiations Begin in Europe on Proposed Legislation

Informal negotiations between the EU Council, Commission and Parliament (trialogue) started on the conflict minerals dossier on February 1, 2016. The trialogue is an informal, closed-door process in which the Council and the Parliament try to reach to a compromise on a legislative proposal.

6 New Year, New Outlook for the Electronics Manufacturing Industry

As an advocate for the electronics manufacturing industry, my job is to educate and encourage policymakers to create a favorable legislative and regulatory environment for advanced manufacturing to grow and succeed. From that perspective, I think we should be proud of the significant progress we made in several areas in 2015.

7 In Memoriam—Dennis (Denny) J. Cantwell

Long-time IPC member, Dennis (Denny) J. Cantwell, 74, passed away on November 12, 2015. Denny was a very active member of the IPC Flexible Circuits Base Materials Committee until his retirement from Printed Circuits Inc. in 2009.

8 Robots, Wearables and Implanted Devices in the Age of Bionic Health

If you are an electronics manufacturer and you ask your business bankers where their market research suggests growth will come from, they will almost certainly identify medical electronics as a key growth area.

9 How North American Fabricators Benefit from Attending HKPCA

Two New Englanders in Shenzhen. It sounds like the title of a play, doesn't it? Headlining the bill is Peter Bigelow of IMI, who explains to me why even small American manufacturers benefit from attending large Chinese shows like the HKPCA. He's joined by fellow New Englander Alex Stepinski of Whelen Engineering, who discusses drill concepts and the transition to zero discharge.

10 Mr. Laminate Tells All: CEM-3 Reinvents Itself (Again)—or, Atari Game Boards on eBay?

CEM-3 was unusual as the reinforcement was a combination of woven fiber-glass fabric and fiber-glass paper. The resin system was a dicy-cured epoxy resin yielding a Tg the same as FR-4 at the time, of 110–120°C range. Because it was all epoxy and all fiberglass, the properties were electrically identical to those of FR-4.

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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.

IPC APEX EXPO 2016
March 13–17, 2016
Las Vegas, Nevada, USA

25th China International PCB & Assembly Show 2016 (CPCA)
March 15–17, 2016
Shanghai, China

2016 Annual Foundation Course (ICT)
April 11–14, 2016
Loughborough, England

Thailand PCB Expo 2016
April 19–22, 2016
Bangkok, Thailand

KPCA Show 2016
April 26–28, 2016
KINTEX, Gyeonggi-do, S. Korea

JPCA Show 2016
June 1–3, 2016
Tokyo, Japan

IPCA EXPO 2016
August, 2016
India

IPC Fall Meetings
September 24–30, 2016
Rosemont, Illinois, USA

SMTA International 2016
September 25–29, 2016
Rosemont, Illinois, USA

electronicAsia
October 13–16, 2016
Hong Kong

Electronica
November 8–11, 2016
Munich, Germany

International Printed Circuit & Apex South China Fair (HKPCA)
December 7–9, 2016
Shenzhen, China

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