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GOOD FOR THE INDUSTRY

ENGINEERING SOLUTIONS FOR PCB MANUFACTURING

SMT® MAGAZINE

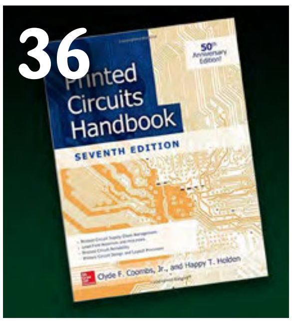
AUGUST 2016

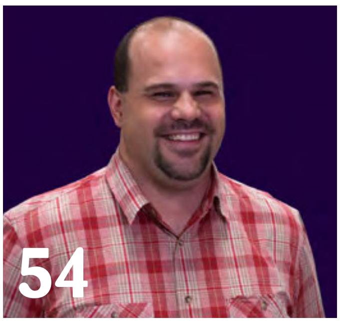
I-Connect007 GOOD FOR THE INDUSTRY AWARD

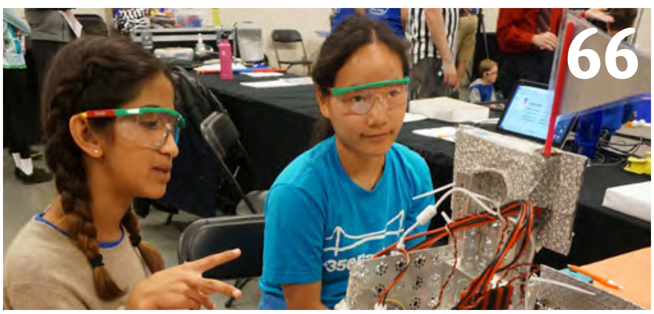
The very first recipient of this award is revealed on page 54

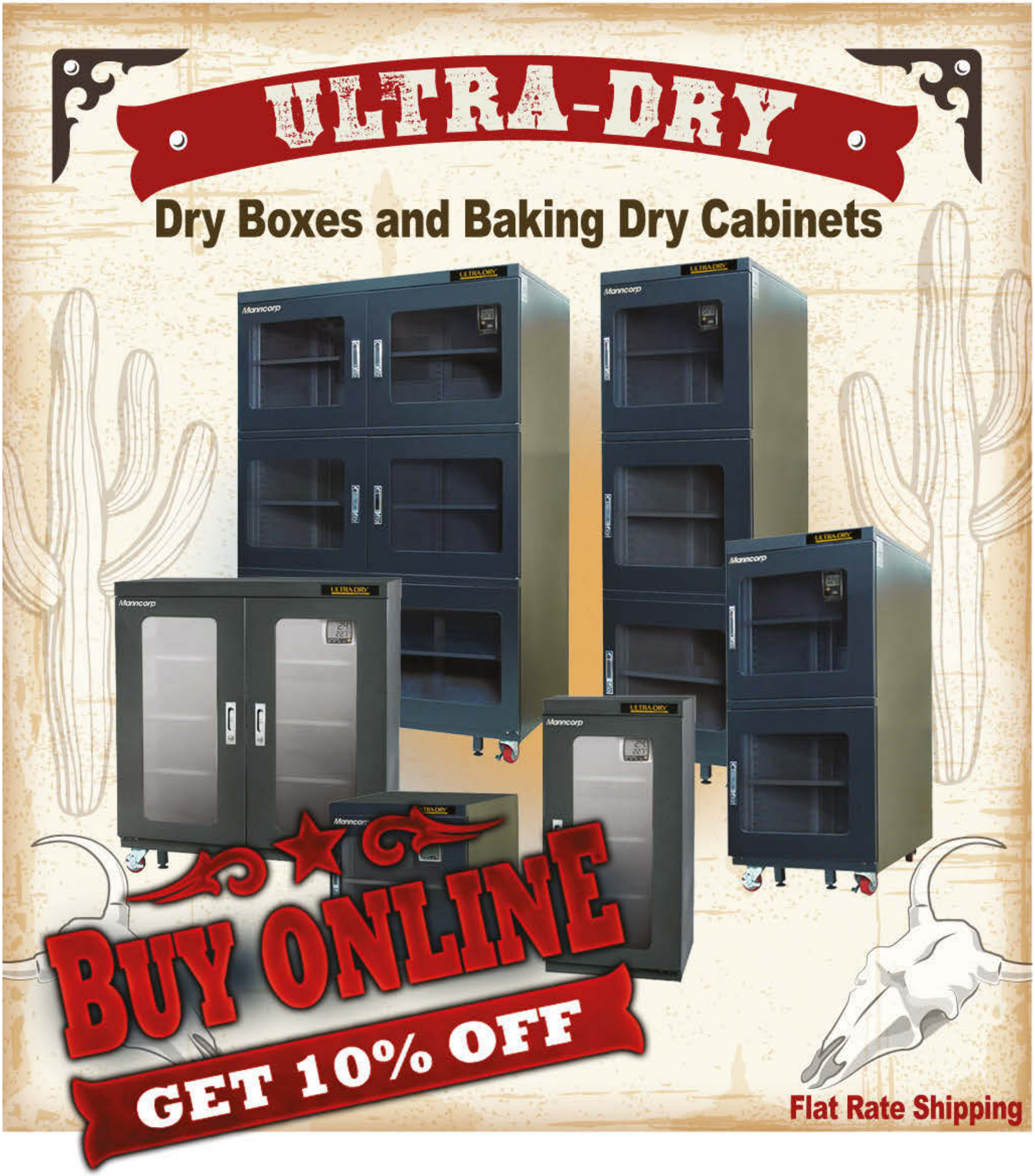
Voices of the Industry

In this issue of *SMT Magazine,* we take a pause from covering technology trends, challenges, and next-generation solutions. Instead, we are focusing on our readers—to give a voice to their thoughts on the industry, companies, jobs, interests, and even pain points.









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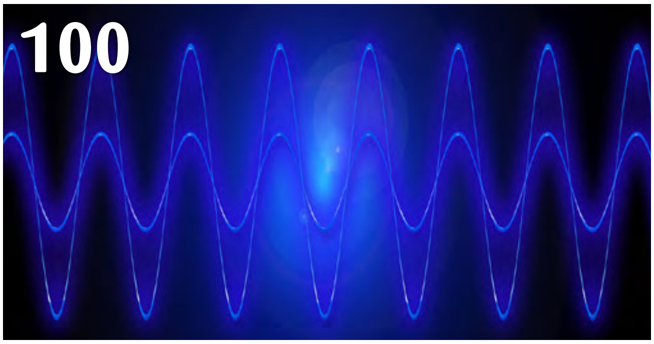

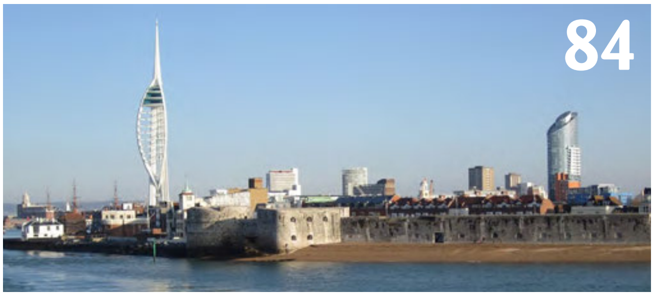

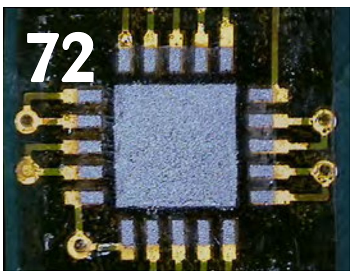

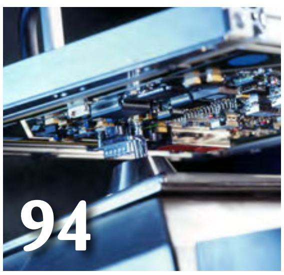

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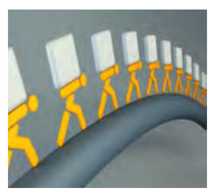


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The Industry Speaks

by Stephen Las Marias
I-CONNECT007

Every time I get to visit trade shows and exhibitions and see the amazing equipment and solutions on display, I think, "Wow, the guys who developed these systems are great." When I talk to the people responsible for creating those technologies, I marvel at how they blend their ideas and creativity with technology to foster innovation in this industry. Most of the time, I am in awe of how easily they could spearhead the next generation of solutions in their respective industries.

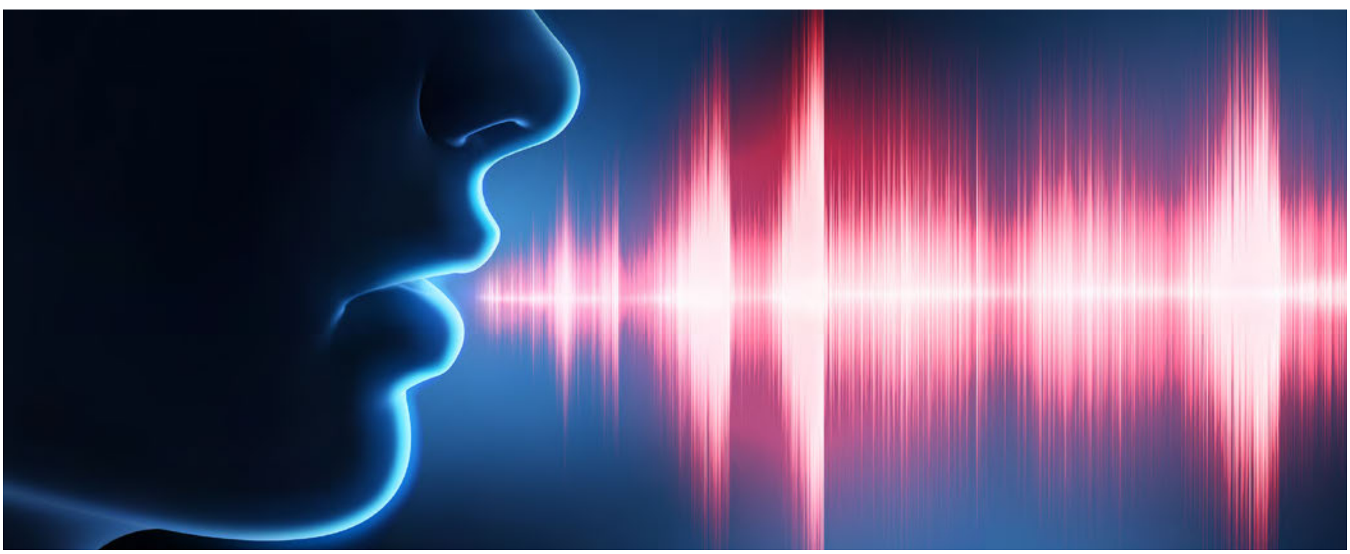
My job enables me to be at the forefront of these innovations, to know more about them and the people who created them, so that I can tell our readers the story behind these great technologies and how they are helping customers address their everyday manufacturing challenges. Over the past year, my colleagues and I have interviewed numerous engineers, key executives and industry experts. We have discussed their insights, mission, vision, and great ideas to help improve the electronics assembly and manufacturing industry. For those of you who might have missed any of these, in this issue we're providing an index of all of the interviews we've conducted with the industry's movers and shakers.

Meanwhile, we all remember times when co-workers have made personal comments—comments that we would like to keep off the record. Sometimes, they're about customers' ridiculous demands that often require months of all-nighters. Sometimes, they're about engineering teams that seem to be stuck in a rut doing the same thing over and over, even when the process yields average results. And sometimes, these comments are just related to wishing that tasks and processes could be done more inefficiently.

And then there are also comments about management seeming to be oblivious of what's really happening at the shop floor. Or they may reference a disconnect between the decision-makers and the engineers and operators.

We get many of these off-the-record comments during interviews and in our surveys' comments section. These comments are also important because they express the personal thoughts and feelings of the people involved in this great industry—the very same people who make these technology advancements possible.

Which is why in this issue of *SMT Magazine*, we take a pause from covering the latest tech-



nology trends, challenges, and solutions in the electronics manufacturing and assembly industry. Instead, we are focusing on our readers—to give a voice to their thoughts on the industry, companies, jobs, interests, and even pain points when it comes to their respective specialties.

Read what these engineers and experts from Keysight Technologies, Integrated Micro-Electronics, Datest Corp., Integrated Technologies Ltd, NEOTech, and Saline Lectronics, to name a few, have to say when it comes their problems, their happy thoughts, and great ideas. Some of them even provided their favorite tips and tricks when it comes to their jobs.

Our columnists Tom Borkes, Michael Ford and Robert Voigt also joined in the conversation. Read what they have to say inside.

This month, we also feature two initiatives aimed at strengthening the future of our industries. One is FIRST (For Inspiration and Recognition of Science and Technology), a program that aims to get kids more interested in STEM subjects through a variety of fun and interactive experiences. I-Connect007 Publisher Barry Matties spoke with Jill Wilker and Ken Johnson from FIRST during the recent Maker Faire in San Mateo to know more about FIRST and its vision.

The second one is the STEM program hosted at the recent International Microwave Symposium (IMS) show. In an interview with I-Connect007, IEEE MTT Education Committee STEM Lead Steven Lardizabal discusses the show's STEM outreach.

The seventh edition of the *Printed Circuits Handbook* was published this spring, which was also the 50th anniversary of the first edition. In line with our theme for this month's issue, we asked the many authors of the Handbook for their thoughts—their voices. One such contributor is a co-worker of mine, Managing Editor Andy Shaughnessy of *The PCB Design Magazine,* who has written the first-ever chapter on PCB design tools.

Meanwhile, we are proud to introduce the I-Connect007 *Good for the Industry* award. This new and prestigious award is bestowed upon individuals and companies that are good for the industry. Find out what we mean by good for the industry and why we selected Alex Stepinski as the first recipient of this honor.

Inside this issue, you will also find Dr. Barrie Dunn's review of the 7th Electronic Materials and Processes for Space Workshop, held last April at the University of Portsmouth in the UK.

And as always, *SMT Magazine* isn't complete without our columnists giving their take on what's happening around the electronics assembly and manufacturing industry. For his column, Robert Voigt concludes his series on selecting a selective soldering system by doing a quick wrap-up to remind potential buyers about some important considerations that affect the purchase decisions they make.

Bob Wettermann writes about the rework challenges with leadless devices and the types of rework methods available.

Tom Borkes, meanwhile, writes about paideia and why the current education system no longer provides enough learning for earning. He says the complexities of our technological world and global marketplace now demand the development of specific, saleable skills as part of the student-customer's educational process—and that the template for teaching these skills must be based in the real world.

Last but not least, Justin Zeng, Francoise Sarrazin, Jie Lian, Ph.D., Zhen (Jane) Feng, Ph.D., Lea Su, Dennis Willie, and David Geiger of Flextronics International Ltd; Masafumi Takada and Natsuki Sugaya of Hitachi Power Solutions Co. Ltd; and George Tint, Ph.D., of HDI Solutions Inc. write about nondestructive inspection of underfill layers stacked up in ceramics-organics-ceramics packages with scanning acoustic tomography.

I hope you'll enjoy this month's issue of *SMT Magazine*. Next month, we will talk about the challenges, technology trends, and the latest developments happening in the military and aerospace electronics manufacturing industry. Stay tuned! **SMT**

Stephen Las Marias is managing editor of *SMT Magazine.* He has been a technology editor for more than 12 years covering electronics, components, and industrial automation systems.

In this issue of *SMT Magazine,* we take a pause from covering the latest developments, technology trends, challenges, and next-generation solutions in the electronics manufacturing and assembly industry. Instead, we are focusing on our readers—to give a voice to their thoughts on the industry, companies, jobs, interests, and even pain points when it comes to their respective specialties. Read on to learn about their problems, happy thoughts, and great ideas. Enjoy!

Jun Balangue
Business Development Manager/Brand Manager, Electronic Industrial Solutions Group
KEYSIGHT TECHNOLOGIES

My favorite tip or trick to share is...
Listen to your customers.

One of the biggest challenges I face in my product marketing role is how to create a product that will make sense to the customers and when the product is available, convincing customers to buy my product. My tip is, *always listen to your customers!*

Listening to your customers is not only meant for customer-facing roles like call center, customer service, sales and applications engineers. It should be applied to all levels in the company from the CEO to every engineer and employee.

Listen to the following:

1. Understand what is working and what is not working

The word "understand" as defined in Dictionary.com means "grasp the idea of," which to me, is a very important way to improve your product. A customer who is willing to voice problems is a treasure because it enables us to understand how we can improve our product or give them a complete solution.

2. A complaining or angry customer doesn't mean a lost deal

This is always a very difficult situation and in most times, we tend to walk away. But in reality, if you are able to face an angry customer,

understand the reason behind their frustration and turn their problem into a solution, you will win their trust.

3. How good or bad is the competitor's product

Always listen to a customer who talks about the competitor's product. By listening, you are basically arming yourself with knowledge that may enable you to turn your product to a better one.

4. What is working now doesn't mean it will work in the future.

Have you ever heard the idiom "If it ain't broke, don't fix it"? This should not be applied to any products, even if customers are extremely happy and have no intention of changing. You will never know what you might find, which in turn may help customer save cost or improve their test coverage.

5. Know what is coming in the future in terms of technology advancement

Where do you find the newest technology? Your customer production floor, of course! Being in touch with your customer allows you to have access to all this information ahead of everyone. Being the first means you are always the one who offers the latest solution based on what the customer needs and knowing the challenges they face with the advancement of technology.

These are my tips on how I use every inch of customer feedback and turn it to the advantage of the test system that we offer to the market.

Frederick Blancas
Strategic Planning, Marketing and Sustainability Manager
INTEGRATED MICRO-ELECTRONICS INC.

What I like about the electronics industry now is its openness to collaborate. The government, academe, and private electronics companies are intensifying their collaboration to find solutions to problems that besiege society. Through their collective expertise and experience, they create synergy that leads to greater value for each of them as well as the public.

Imagine a world where medical equipment is inexpensive, allowing clinics and hospitals in impoverished regions to provide better healthcare for the masses. Imagine IoT or IoV devices helping decongest clogged streets, enabling people to spend more time at work and at home. The whole ecosystem has started to embrace the concept of sustainability—that businesses, with the support of government and academe, can engage in profitable endeavors while addressing social and environmental issues.

Robert Boguski
President
DATEST CORP.

Fear is a Lousy Motivator

With the dumbing down and banalization of English nowadays, problems have been banished from the lexicon and replaced by euphemisms—legislated away by popular acclaim. Instead, we call problems by their bastardized title: "issues."

Example: "We have a payment issue with our customer. A large, much-anticipated sum has been delayed. Hence we can't pay you, dear Supplier, for the one-day turnarounds you gave us recently (thanks for the superior service, by the way! Oh, and do we have your AS9100 certificate on file?)."

For most small businesses, that's a catastrophe, not an "issue." Imagine the subcontractor's General Manager telling her employees, "Gee guys, we hoped to run payroll this week, but since Behemoth Aerospace didn't pay us (because they can do that), and won't for 120 days (their stated terms), you'll have to wait awhile for your paycheck. Better news in October (said in July). Until then, chin up."

Do you think for one minute that Behemoth Aerospace waits 120 days for payment from the Feds?

Why is it that companies best able to pay and flush with cash, resist paying to time-hon-

ored Net 30 terms? Is this something taught in the vendor exploitation module at Harvard Business School? It's certainly not in any engineering syllabus I'm aware of. Ethics? What ethics?

Or this: "Yes we know you quoted this job last November, and now we're placing an order with you in April with additional, previously unknown requirements. However, we cannot accept your revised quote reflecting those new requirements because our customer has already placed their order with us. They would have issues with any changes (read price increases) now."

Right, but we have our own issues with your evident lack of a spinal column.

So the question is, why are suppliers so afraid in instances like these to speak the plain truth to their customers? Fear of losing face? Terrified of losing business? Avoidance of confrontation? Is obsequious sucking up some distorted, 2016 rite of passage? I fear invertebrate tendencies are becoming the new normal.

A fine, self-inflicted mess we find ourselves in. The irony is that upright customers will find the truth bracingly refreshing, and welcomed. They have endured B.S. aplenty.

Remember what FDR said about fear in 1932?

We are what we become.

Tom Borkes
Founder
THE JEFFERSON PROJECT

My favorite tip or trick to share...

Recognize that the robots are here! But don't look to the skies, look to the factories and point-of-sale services and products. The robots will be ubiquitous. Their disruptive introduction into the world of high-tech electronic product assembly is/will reduce labor content and remove the need for traditional labor intensive operators.

Looking at the social impact, the question will be what will these displaced workers do? From high tech product assembly to fast food workers, those without saleable skills will put incredible pressure on the social services of their respective governments.

The answer is a responsive educational system that has a strong "learning for earning" component—a system that is in direct touch with the quickly changing needs of industry. Alvin Toffler wrote a book in the '70s called *Future Shock*. His thesis was it wasn't the change, so much, that will cause the chaos and social unrest, but the rapid arrival of that change—so fasten your seat belts!

Jade Bridges
Global Technical Support Manager
ELECTROLUBE

What I really like about my company is the breadth of work that we are involved in. Having six different product divisions, we have the capability to assist in different areas of electronics manufacturing and offer complimentary solutions, tackling the problem as a whole. It is great to have this wide range of knowledge and to understand how the different elements can impact the overall problem raised and also to have the capability to do something about it!

Paul Brooker
Production Manager
INTEGRATED TECHNOLOGIES LTD

What I really like about the industry is...

The best thing about working in the medical device industry is knowing that the products we manufacture have a positive effect in people's lives. From handheld blood-glucose monitors to large scale retinal scanners, everything that we do, whether it's full device assembly or just PCB manufacturing, helps improve, enhance and save lives.

Healthcare is a dynamic sector and as a design and manufacturing company we get completely involved in the development and production of cutting-edge technology. It's great to be part of an industry driven, shaped and propelled by innovation.

A recent example of a product that we are working on is a DNA analysis system, allowing scientists to visualise single strands of DNA when diagnosing or even predicting illness. The people leading these companies are often the academics and clinicians that dedicated years of their lives to research in a particular area and their passion shines through when you meet them. We supplement their skills by helping them to take their ideas and concepts to real-life commercial products. There's something incredibly rewarding about that.

Lastly, I have a huge sense of pride about our industry and being part of it – some of the world's greatest minds have dedicated their lives to the medtech sector and together we bring about advancements that will shape medical treatment and affect future generations to come.

If I could change one thing...

One thing that we encounter as a subcontract manufacturer is an occasional lack of understanding of the value we add.

It is not uncommon for us to be asked 'how much cheaper can you make it than we can?' when the real consideration should be more along the lines of 'how much value is there in not having to worry about the investment, resources and knowledge required to manufacture a complex medical device?'

We have become quite adept in explaining to potential customers that outsourcing is not necessarily going to be 'cheaper' on a per unit basis but instead allows you to focus on your core competencies safe in the knowledge that your device is going to be manufactured to the required regulatory and quality standards.

The burden of overheads is an important factor in pricing manufacturing services where medical devices are concerned. It's not just labour costs, buildings, etc., but also the maintenance of quality management systems, component traceability, approved vendor lists and much more.

Promoting understanding about value added rather than money saved when it comes to outsourcing in the medtech industry would make a big difference and bring the focus back to how we can effectively work together to manufacture the best possible medical innovations.

Dave Busch
VP Medical
NEOTECH

Our ability to understand our medical customers' product concepts and transform them into affordable, finished medical devices that help heal people is what makes coming to work so rewarding. Two things are required to excel at the concept-to-finished medical device transformation process. First is operational excellence—working assets harder than the customer can as measured by ROIC—which is the basis of a cost-effective medical device. The second is SME in medical devices and the therapy they are to provide, which comes from your team of product designers, quality and regulatory experts and medical material experts. Working in such an environment is not only rewarding but exciting.

Rob Cooper
Pre-Production Engineer
SALINE LECTRONICS

It's most helpful when a customer provides clear stack-up information with the Gerber files—board thickness, copper weight, soldermask color, and final finish. Layer order is often omitted on multilayer boards. A good "read-me" file that lists all of this information—including a key to cryptic or default layer naming—is so helpful!

I recommend that customers provide a data sheet for any unusual or pre-release parts used. There are so many new parts introduced in this business, and sometimes a customer specifies one not yet in general circulation. Finding out process information on some of these exotic sensors is next to impossible without the right contacts, so please be transparent about the information available regarding new parts.

Dave Cusumano
VP Engineering
SALINE LECTRONICS

In a perfect situation, we would prefer that our customers supply ODB++ files with their Gerber files and a BoM in MS Excel format. This will allow us to be more efficient when developing the manufacturing process (with less chance for error) for each customer's assembly.

Barrie Dunn, PhD
Professor, School of Engineering
UNIVERSITY OF PORTSMOUTH

Companies engaged in the production of high-reliability electronics will have invested in capital equipment required for performing failure investigations and documenting findings as laboratory or technical reports. Laboratories and personnel tasked to carry out these activities also exist within the user industries. Suspect or 'non-conforming to specification' items received at in-coming inspection might be electrically tested then examined by visual, scanning electron microscopy, acoustic imaging or by a host of other non-destructive methods. It is essential to keep the findings as company reports. Such documents need to be stored in machine-readable and searchable formats. This is essential in order for lessons to be learnt and staff to be able to quickly retrieve data and eventually deduce a statistical record of defects and their possible causes. Samples may be subjected to metallography and other destructive tests, which will be often the most important when considering the disposition of hardware. These dispositions will often fall under the categories:

- Suitable for use
- Suitable for use only after article has been repaired or refurbished
- Not acceptable, return to supplier
- Not acceptable, scrap

Again, keep the records in a machine-readable and searchable format.

Hardware that has been deemed to fail in service may also be forwarded to the laboratory in order to try to establish the mode of failure; typically, these will fall under the broad headings:

- Material defect (poor choice of material, wrong composition, brittle inclusions in metallic alloys)
- Processing defects (soldering, brazing and welding defects, incorrect curing of organic materials)
- Human error (machining defects, poor workmanship, wrong units of measurement)
- Service defects (resulting from over testing, environmental mechanical loading (shock, vibration, thermal cycling fatigue, corrosion and eventually, wear-out at end of expected life)

The most important documents generated by the laboratory are the laboratory or technical reports. Again, keep the records in a machine-readable and searchable format.

Too often during material or failure review meetings between manufacturers, suppliers and customers, the sales or technical support staff are unable to provide data concerning acceptance or reject rates. When failures do occur in service there is often insufficient readily available data available for participants. Customers need to know the frequency of such failures, the probable failure modes and the environmental conditions that may have contributed;

and, how many times have they occurred in the past? What were the remedial actions and were they successful? Previously archived laboratory reports hold the key to such questions.

Satisfactory reporting is costly in terms of capital equipment and trained staff, whether they be electronics engineers, chemists or metallurgists.

Michael Ford
Senior Marketing Development Manager
MENTOR GRAPHICS CORPORATION VALOR DIVISION

What an extreme amount of time, effort, and money has been spent over the years on shop-floor communication, only to find that real value from the data remains elusive, of limited value, and, in some cases, completely useless. The communication revolution is now knocking at the door of the electronics industry, with such innovations as Industry 4.0 and smart factories, powered by the "Internet of Manufacturing." This is not just a fad or series of buzzwords. Some real values are to be obtained by having accurate and timely information from manufacturing machines, processes, and operations. Until now, however, everybody has been doing their own thing. Machine vendors with proprietary interfaces locking customers into a single equipment source, solution providers having to reinvent interfaces with every change of machine model or even version, and end-users having to do it themselves as they realize that they are the only people in the industry to have a real influence on machine vendors. This huge mess has caused such a lot of waste and lost opportunity. It is clearly time to stop and break this bad habit.

Shop-floor communication know-how and technology for both hardware and software is now at a stage whereby fluid communication on the shop-floor is feasible. The collective accumulation of said know-how in the industry is at such a stage as to allow a realistic definition of how added-value communication can be done, without having to compromise down to the lowest common denominator or by leaving the content to be defined by individual negotiation on a case-by-case basis. It is time to bring in a new regime, a new standard, a new specification for data acquisition and flow across the shop-floor.

The introduction of the Open Manufacturing Language (OML) captures these needs into a single specification that is free and open to use. The next step is to use OML to quickly, if not immediately, establish a standard for the industry driven by a recognized industry body such as the IPC. Rather than taking years to come up with and agree on a specification, let's take OML as a starting point and get this done in weeks rather than years. We have all been waiting for it; so let's all be a part of it.

Why is traceability still perceived as a burden? We should be seeing this as a great opportunity...

Those old enough to remember the "old days" of traceability will recall how much effort it took to record key items of data about production completion, test results, and material usage, mostly on paper, to be filed away until needed. We hoped the data wouldn't be needed, that is, only if there was a catastrophe such as the need for a product recall. These old days are actually still today for most companies in the industry, and I suspect that everyone reading this is old enough to remember. Today, compliance and conformance dictate the need for traceability, often with just a broad, almost casual, reference. That there has never been a real definition of traceability for the electronics industry is almost unbelievable. Virtually every single adoption of traceability is different from every other, having been negotiated case-by-case. No one wants to spend time and resources to record data that is not necessary. Nobody wants to be in a position, however, where they are faced with huge costs of poor quality without a way to establish the scope of the issue and, hence, to reduce the cost and effect.

The new days of traceability can start to happen now. IPC will introduce the first traceability standard specifically focused on the electronics industry. With this new standard, defined levels of data capture suit different classifications of products, ensuring that only and all the relevant data is captured no matter what the product is or what industry it falls into. Discussion and negotiation between EMS companies and their customers will be made far easier by simply agreeing which defined level of traceability should be adopted. If and when the traceability data is needed to help resolve a major market-quality issue, it will be known that the data can be relied on.

The IPC-1782 traceability standard, however, brings with it a whole new world of opportunity for traceability data. Rather than just being an insurance policy for when things go wrong, with the standard now in place, data acquisition from processes can be made more automated, reducing the cost of traceability data collection. By building in the traceability data gathering requirements as part of the process operation, compliance and conformance are introduced also in an automated way, further reducing the cost of ownership. On the other side of the equation, the uses of traceability data with the new standard can be broadly expanded, delivering active quality management, poka-yoke control, and counterfeit material, etc. within the manufacturing operation itself.

The traceability revolution in electronics is coming soon, and not before time. So be ready to embrace it for your own benefit.

Mark Haavisto
Component Engineer
SALINE LECTRONICS

In a perfect world, our customer would provide complete documentation. Missing information can cause manufacturing delays when things are unclear, including:

- Assembly drawings with notes. If unavailable, a simple list of assembly instructions/requirements is helpful.
- A BoM with sufficient information to correctly identify components—manufacturer names and part numbers are always preferred, but if the customer is not particular about certain parts, such as resistors and capacitors, complete descriptions are needed to ensure correct parts are procured. For basic resistors, include: resistance value, wattage, tolerance, package size. For capacitors, include: type (ceramic, tantalum, etc.), capacitance value, rated voltage, tolerance, temperature coefficient (if applicable), package size.
- Process requirements: This would include things like RoHS compliant versus SnPb solder process and aqueous versus no-clean solder process. Clearly state the IPC class (I, II, III) requirements.

Alex Johnson
Associate Engineer
SALINE LECTRONICS

Figuring out the proper orientation to polarity-sensitive components is sometimes difficult, so making it clear on the silkscreen, with markings visible after the parts have been placed, really alleviates any possible issue of a polarity-sensitive component being incorrectly installed.

I would recommend that engineers pay specific attention to copper balancing on 0402 and smaller-sized parts in order to help eliminate tombstoning on an assembly. This is a common occurrence that we see, and taking this into consideration could mean the difference between an assembly that runs through SMT with a few defects, to an assembly that runs flawlessly.

I am enthusiastic about the direction of the industry moving toward SMT technology; making an assembly entirely SMT by eliminating mixed-technology assemblies can really reduce the cost, and decrease the processing time for assemblies.

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The Geeks Speak!

"The event was great! The atmosphere seemed a bit more relaxed than a typical trade show. I noticed that those in attendance seemed more approachable than a typical trade show. Even those that I would consider "competitors" interacted a bit."

-Mike Brown, IDS

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Alistair Little
Global Business & Technical Director
ELECTROLUBE RESINS DIVISION

What I really like about the industry is the fact that the electronics industry is always pushing the boundaries of what is possible to bring forward the next generation of products to the market place. This constant push then drives forward developments in the supporting industries to enable the creative ideas of today to become the reality of tomorrow. The various industries that have grown up over the years to support the development and manufacture of electronics are, in my opinion, the perfect blend of chemistry, engineering and physics.

Rafael Mantaring
Head of Design and Development for Asia
INTEGRATED MICRO-ELECTRONICS INC.

The EMS industry is very challenging. We are squeezed by OEMs of every cent they can get out of us. So much so, the slightest mistake in execution can break the business. There is a great sense of fulfillment however when execution is done perfectly. This is what the EMS industry lives for.

Stefan Meissner
Head Corporate Communications
ULT AG

This is really stupid...but we do it all the time:

Everybody's talking about Industry 4.0. Hardly half of them know what it's all about, but predict to do so. Few people know most possible consequences and outcome. Is this sort of a question out of fashion? It seems nobody wants to be the last jumping on this train? But where will that train lead us to?

What I really like about the industry/my company is...

Electronics manufacturing industry is all challenging, surprising, astonishing, demanding, and gives so many extraordinary experiences. It's really extraordinary that so many people working in this field are basically traditional and conservative but act that progressive in order to develop and produce innovative and future solutions. Watching that market is quite enjoyable.

François Monette
VP Sales and Marketing
COGISCAN

Industry 4.0 is the major topic of discussion in 2016. While the industry is debating exactly what it means and how it should be implemented, everyone agrees that the main hurdle to enable a higher level of integration is the lack of connectivity between various machines, processes and systems. It may sound like a straightforward thing to do but, in practice, it represents a major challenge. One of the reasons why various industry standards have failed to gain widespread adoption is that a complete connectivity solution cannot rely on a simple one-size-fits-all kind of approach. Each production environment is unique and the specific requirements depend on the various elements of each product and assembly process.

During the past 15 years, Cogiscan has been working closely with the leading equipment and MES vendors in the SMT industry. As a result, we have developed a deep expertise on this topic and we now offer the largest library of interfaces for each brand of machine and software to account for a wide range of customer processes. This library, coupled with the Cogiscan TTC applications, represents a proven and practical connectivity approach that is available today to enable Industry 4.0.

Industry 4.0 is a journey, not a destination. It will not be delivered by a single vendor but

rather through an optimal combination of various machines, systems and software. We believe that it's not practical or cost-effective to implement new systems strictly for the sake of achieving a higher level of technology. As it has always been the case in the manufacturing industry, every project must be carefully evaluated to provide a tangible return on investment. This is why most manufacturers are still at the stage of implementing basic MES functions such as material control, traceability and analytics. These functions offer the greatest benefits, both internally in terms of increased productivity, and externally in terms of customer satisfaction.

Jayaramu Nagaraj
Manager
KAYNES TECHNOLOGY
INDIA PVT LTD

What I really like about the industry/ my company is...

Customer focus in delivery and service. Similarly, in India, there should be a good semiconductor policy required to boost the electronics industry.

Sujata Singh
Senior Firmware R&D Engineer
Electronic Industrial Solutions Group
KEYSIGHT TECHNOLOGIES

There are few products in our fast paced world that have endured as long as the In-Circuit tester (ICT) where the company logo on the 30-plus-year machine's front panel has changed a few times. Its software platform has moved from Unix to Windows and is still evolving. Many components on the hardware platform have changed several times to keep pace with current technologies and platforms. The look and feel of the ICT has undergone a few transformations to be in tune with customers' needs. One would think that such an established product would require minimum effort to maintain and have no need for innovation. However, that's not the case in R&D.

Working as an R&D engineer with the ICT team at Keysight technologies is a challenging job. The challenge is to be able to continuously upgrade the platform and ensure better performance every time. For a complex machine like ICT, it is not an easy feat to accomplish. It requires extreme sleuthing techniques to grasp its intricate machining before replacing any of its existing components with newer parts.

The landscape of electronic test boards has changed significantly over the last few decades. The boards are smaller and denser now, and the ICT has also evolved by adding more and more test methods in its repertoire to increase the coverage. Recent technologies such as Cover Extend and Boundary Scan have provided alternate test methods where conventional tests would not have been sufficient. The graphical interface is currently undergoing a full overhaul to make it easier for customers to use and interact.

I am privileged and thrilled to be given an opportunity to work in an environment that is challenging and yet gives plenty of room for innovation.

Steve Telgen
Pre-Production Engineer
SALINE LECTRONICS

Design software is not necessarily created for the manufacturability of assemblies. Component footprints, copper spacing, hole sizes should be reviewed to match the datasheet recommendations as opposed to the automated tools that come with the design software. Above all, design engineers should always review the design by re-loading output Gerbers into a simple free viewer. A visual review will help to catch many layout errors before the design is ever sent out for assembly.

Francis Stephen A. Vida
Customer-Focused Team Leader
INTEGRATED MICRO-ELECTRONICS INC.

What I really like about the electronics industry are the new technologies being applied to both product and process. This has kept me excited and interested in my work which is one of the reasons why I have been with the company for more than 20 years. During my free time, I enjoy TV programs and magazine articles that feature the latest technology on automotive and consumer products.

My favorite tip to share: Focus on innovation and continuous improvement. In a highly competitive industry, the only way to be on top is not to be satisfied with the current condition but to always find ways no matter how small the impact is, in improving the quality, cost and delivery of the product. For this to have a big impact to the company would depend on the participation of each level in the organization from the top-down. I always believe that the biggest room in the world is the room for improvement.

Sivakumar Vijayakumar
Technical Marketing Engineer, Electronic Industrial Solutions Group
KEYSIGHT TECHNOLOGIES

If I were in charge, for all boards, structural test has to be factored into the board test strategy.

As electronic designs advance across horizon of domains like semiconductors, board designs and PCB manufacturing, the challenge lies in enhancing the yield of the product with a good process to manufacture 'defect free and functional' product. A key aspect to this lies in designing a good test strategy that includes structural test.

On a SMT line, a good structural test upfront will help in filtering many issues and enhance the quality of the product, which ultimately leads to higher yield. The effectiveness of structural test is not about 'how many defects has the step caught' but instead, 'this step has ensured that no defects escape.' A defect escape that gets triggered at customer end can have a snowballing effect, which will dent the product brand.

In my opinion, review and development of structural test should start early at the design phase with the first schematic and netlist. With this, the project can be developed to analyze how well is the structural test coverage and, what should be covered in functional test. This helps in devising the optimal test strategy. With the development of structural test at proto-phase, it can be turned-on to run on the SMT lines for early production, leading to quicker product maturity and time-to-market.

Nowadays, many board structural testers offer features to help in integrating some basic functional tests on their testers. Exploiting the power of such features enables the effectiveness of the test and provides ample amount of coverage to catch defects during early design phase. Making the most of these board structural testers is definitely a winning formula to manufacture 'defect free and functional' product.

Robert Voigt
VP Sales
DDM NOVASTAR INC.

We spend a lot of time educating customers, but...

We don't mind being trusted consultants to the PCB assembly buyer, but we have the same conversations over and over with people who have misconceptions about what type of assembly technique to use. Most of these ideas are promulgated by manufacturers trying to push a specific technology.

Case in point: Companies that make a single technology, such as selective soldering systems, are strongly suggesting the idea that selective is better than other older assembly techniques, like wave soldering. The flaw here—and this is what we tell anyone who asks—is that selective was invented as a way to solder thru-hole components on a mixed technology board where wave is unable to accomplish it. In terms of speed and efficacy, nothing is faster or stronger than wave, so if you have a board with all thru-hole components, wave soldering would process your boards easily 5–10 times faster than selective. Wave has been around for decades, certainly, but it's still the fastest, least expensive and most reliable assembly method.

Tell a friend!

You get what you pay for! The U.S. market is flooded with value-added resellers of SMT assembly equipment coming out of Asia, driven largely by low cost. Regardless of the quality of the machines (some of which may be quite good), there's often a trade-off for low cost, manifesting as problems getting spare parts, support and maintenance. And what if you wanted a custom modification or programming? That machine is not so fast or inexpensive anymore.

Downtime is not just annoying, it's non-productive, so we encourage people to ask these questions before they buy: Who will support your new machine? Can you get spare parts from local inventory? Does the seller offer training and maintenance service in the US?

If you get a quote from a true USA manufacturer, answers to all these questions will undoubtedly be Yes.

Anonymous

Quality Manager

(CHINA)

If they would just do this...

Cost reduction, budget control, cost control will not go far.... Innovation needs to be in place.

If they would only listen to the customers and ignore the voice from the floor—disaster.

This is really stupid...but we do it all the time...

Lean for the sake of lean...Thousands of lean kaizen just for a number game.

If I were in charge...

We'll go back to the basics. Focus on our most valuable asset and competitiveness; less control, and even less management staff.

What I really like about the industry and my company is...

The people. People form the company. Whatever it is, we have to like all of them, guide them, coach them, and listen to them. If there is a bad apple, then remove them without hesitation, or else trust them.

My favorite tip or trick to share is...

...trust. Hire slow, fire fast. The right talents determine the future of the company.

Anonymous

Manufacturing Engineering Technician

(NORTH AMERICA)

If they would just do this...

Pay attention to the manufacturer's recommended PCB layouts when designing in a part.

Provide a neutral format CAD file (IPC-D-356, ODB++, IPC-2581 if they are feeling bold) with ALL Gerber ZIP files. Don't send them in a separate ZIP and DO include them.

If they would only listen...

QFNs aren't the most difficult parts any more. Flip-chip and castellated multi-chip modules are a much bigger target for IoT devices, and they are driving our defects.

This is really stupid...but we do it all the time...

Designs have to target a process. The PC layout engineer needs to understand how the board will be assembled while generating the layout and then that needs to be communicated to the production personnel to be executed properly. Designing in the "latest and greatest" part doesn't help if the targeted SMT process is not capable of handling it.

If I were in charge...

Quoting would be more automated and more accurate. We use a legacy Excel spreadsheet for quoting. It has been modified by a number of individuals over the years and it is mostly a "black box" at this point. Several suppliers provide more configurable and transparent quoting software but the price points are out of our comfort zone.

What I really like about the industry/my company is...

We rise to challenges.

My favorite tip or trick to share is...

Google.com **SMT**

The Many Voices Over the Past Year

The SMT007 Interview Index

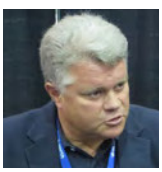
In line with our "Voices of the Industry" theme this month, we have interviews conducted over the past year that feature the insights, great ideas, and vision of the movers and shakers in the SMT and PCB assembly industries.

Mentor Graphics: The Past, Present and Future of Analytics
Farid Anani, Mentor Graphics Valor Division
December 21, 2015

Solder Paste Printing: A User's Perspective
Joemar Apolinario, Aurelio Bantigue and Rodney Bebe, Integrated Micro-Electronics Inc.
SMT Magazine June 2016

Saki America Wants to Dominate the Inspection Marketplace
Quintin Armstrong, Saki America
December 4, 2015

iNEMI: Leading the Way to Successful Electronics Manufacturing
Bill Bader, International Electronics Manufacturing Initiative (iNEMI)
SMT Magazine December 2015



SMTA: Working Hard for the Global Industry
Bill Barthel, Surface Mount Technology Association (SMTA)
SMT Magazine December 2015

EchoStar: The Future of Supply Chain Management Done Right
Les Beller, Andy Thomson and Micah Moore, EchoStar
SMT Magazine July 2015

Meeting High-Speed Demand with Optical Circuits
Felix Betschon, vario-optics ag
July 28, 2015

Inspection Innovations to Reduce Cycle Time
Guido Bornemann, Viscom AG
SMT Magazine October 2015

Inspection: The Last Line of Defense
Guido Bornemann, Viscom AG
SMT Magazine June 2015

The Jefferson Project: Educating the Next Generation in Applied Manufacturing Sciences
Tom Borkes, The Jefferson Project
SMT Magazine January 2016

Reducing Setup Time to Provide More Uptime in Production
Bob Bouchard, BTU International
SMT Magazine May 2016

Solder Jet Printing: Keeping Up with the Challenges
Thomas Bredin, Mycronic
SMT Magazine June 2016

The Many Voices Over the Past Year

SMART Group: The Guiding Influence in the Electronics Industry
Keith Bryant, SMART Group
SMT Magazine December 2015

SMTA West Penn Chapter Plans Manufacturing Boot Camp in August
Bill Capen, DRS Technologies
May 26, 2016

ITRI's Wang Talks Future of Soldering and Paste Printing
Wang Chao, ITRI Ltd
July 12, 2016

Beating the Supply Chain Challenge
Seth Choi, SMTC Corp.
SMT Magazine July 2015

Solder Jet Printing: Is It the Right Time?
Nico Coenen, Mycronic
May 11, 2015

The Launch of a Lifetime: Catching up with Barry Lee Cohen
Barry Lee Cohen, Launch Communications
May 4, 2016

Kester Highlights Strategies to Address High-Reliability Issues
Lynnette Colby, Kester
December 23, 2015

What's in a Name? ICAPE Group's Glenn Colescott Explains
Glenn Colescott, ICAPE USA
May 27, 2016

A Look at the High-Reliability Interconnect Market
Mark Cormier, Miraco Inc.
July 15, 2015

Making Systems Smarter to Gain Visibility, Traceability, and Reduce Handling Errors
Bjorn Dahle, KIC
SMT Magazine May 2016

K&S and Assembléon: A Perfect Marriage of Technology and Services
Jeroen de Groot and Chan Pin Chong, Kulicke & Soffa (K&S)
January 22, 2016

Ready to Hire! Blackfox Provides IPC Class 3 Training to Veterans
Al Dill, Blackfox Training Institute
March 16, 2015

A Look at the Latest Demands for Flying Probe Testing
Barbara Duval, Seica
May 18, 2015

Experience is Key
Bernd Enser, Sanmina Corp.
SMT Magazine September 2015

The Reliability Factor in Solder Paste Printing
Knoll Evangelista, EMS Components Assembly Inc.
SMT Magazine June 2016

The Pasternack Story
John Farley, Pasternack Enterprises
July 18, 2016

The Key to Understanding Industry 4.0: Show, Don't Tell!
Michael Ford, Mentor Graphics Valor Division
December 17, 2015

Mentor's Michael Ford on Lean for Surface Mount Processes
Michael Ford, Mentor Graphics Valor Division
November 25, 2015

iNEMI Managing Director: New, Disruptive Technology on the Horizon
May 28, 2015
Dr. Haley Fu, iNEMI

The Many Voices Over the Past Year

Alpha Talks Challenges of Solder Recycling
December 22, 2015
Jason Fullerton, Alpha

Solder Paste Dispensing: Breaking the Limits of Printing
Eric Gu, Nordson Asymtek China
SMT Magazine June 2016

Innovative New Uses for Ceramic Column Grid Arrays from TopLine
Martin Hart, TopLine
December 18, 2015

BGA or CGA: When Is It Right for You?
Martin Hart, TopLine
May 25, 2015

Super Dry Technology Helps Expand Market Share
Rich Heimsch, Super Dry-Totech
November 6, 2015

Quality is Key
Johnny Ho, Sanmina Kunshan
November 30, 2015

The Solder Paste Factor in Printing
Mitch Holtzer, Alpha Assembly Solutions
SMT Magazine June 2016

Industry 4.0: Creating a Standard
Dan Hoz and Ofer Lavi Ben David, Mentor Graphics Valor Division
December 31, 2015

Efficiency, Energy and Convenience: Driving New Solutions and Markets
Craig Hunter,
Vishay Intertechnology Inc.
SMT Magazine February 2016

Electrolube: We Like Problems (Chinese Style)
Ron Jakeman, Electrolube
SMT Magazine May 2016

Doing Business in India and China
Ron Jakeman, Electrolube
March 31, 2015

Honeywell Paper Investigates Avionics Vibration Durability
Dr. Joseph Juarez, Honeywell International
December 14, 2015

Electrolube Discusses Conformal Coating Innovations
Phil Kinner, Electrolube
November 27, 2015

Choosing the Right Conformal Coating
Phil Kinner, Electrolube
SMT Magazine September 2015

Cycle Time Reduction in the Eye of AOI
Norihiko Koike, Saki Co. Ltd
SMT Magazine October 2015

Addressing the Need for Reliable, Accurate Inspection Results
Norihiko Koike, Saki Co. Ltd
SMT Magazine September 2015

A Look at Saki's Approach to 2D, 3D and X-ray Technology
Norihiko Koike, Saki Co. Ltd
May 20, 2015

How Automotive Electronics are Driving AOI Developments
Jens Kokott, GOEPEL Electronic
SMT Magazine September 2015

Taking the Human Out of Hand Soldering: Is it a Must?
Hirofumi Kono, Japan Unix
June 15, 2015

To Clean or No Clean?
Mike Konrad, Aqueous Technologies
June 23, 2016

The Many Voices Over the Past Year

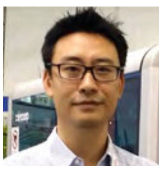
Enabling Process Innovation through Test and Measurement Solutions
Matej Kranjc, National Instruments
SMT Magazine April 2016

CyberOptics: Honing in on the High-Reliability Market with 3D AOI and SPI Platforms
Sean Langbridge, CyberOptics
May 14, 2015

Soldering Experts on Hand at SMTA's West Penn Chapter Expo & Tech Forum
Marilyn Lawrence, Conformance Technologies Inc.
May 25, 2016

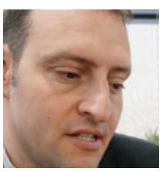
Supplier Spotlight: Transition Automation
Alden Lewis, Transition Automation
April 27, 2016

An Integrated PCB Producer's Approach to the Market
Andy Liu, NCAB
July 7, 2016



Is Automation the Answer to Cycle Time Reduction?
George Liu, Cencorp Automation
SMT Magazine October 2015

VDMA Productronics: Pushing Forward the German Electronics Manufacturing Industry
Dr. Eric Maiser, VDMA Productronics
SMT Magazine December 2015



Mentor Graphics' Oren Manor Explains Exactly What Industry 4.0 Brings to Manufacturing
Oren Manor, Mentor Graphics
SMT Magazine March 2016

A Closer Look at SMTA
Tanya Martin, Surface Mount Technology Association (SMTA)
SMT Magazine December 2015

Japan's Thermosetting Plastics Association Represents at IPC APEX EXPO 2015
Kazutaka Masaoka, Thermosetting Plastics Association (JTPIA)
March 19, 2015

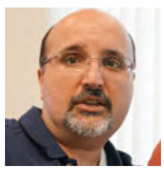
Creation Technologies on IMPACT Washington, D.C. 2016
Bhawnesh Mathur, Creation Technologies
SMT Magazine June 2016

Echostar Talks Impact of Quality Process Collaboration with Partners
Ron Meier, Echostar
November 24, 2015

Fairlight: An Iconic Name in Digital Audio
Emilijo Mihatov, Fairlight Instruments
August 3, 2015

IPC President John Mitchell Discusses IPC's Footprint in China
John Mitchell, IPC
June 20, 2016

IPC: Connecting Electronics Industries
John Mitchell, IPC
SMT Magazine December 2015



Improving Production Efficiencies with Better Data Strategies
Bill Moradkhan, Portus
SMT Magazine November 2015

Medical Electronics: Risks and Opportunities for Electronics Manufacturers
Brian Morrison, SMTC Corp.
SMT Magazine January 2016

Nordson EFD Discusses Dispensing Technologies, Solder Reliability and Innovation
Philippe Mysson, Nordson EFD
January 8, 2016

Strategies to Reduce Handling Errors in Your Rework Process
Donald Naugler, VJ Electronix
SMT Magazine May 2016

Choosing the Right Component to Reduce Cycle Times
Edward Neff, SMAC Moving Coil Actuators
SMT Magazine October 2015

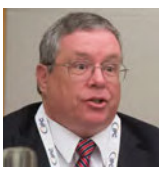
Mechatronics Innovations and Applications
Edward Neff, SMAC Moving Coil Actuators
August 6, 2015

Are the Robots Taking Over?
Esben Hallundbaek Ostergarrd, Universal Robots
April 13, 2015

A First-Timer's Perspective on IMPACT Washington, D.C. 2016
Faisal Pandit, Panasonic Factory Solutions Company
SMT Magazine June 2016

SPI Parameter Considerations for Tighter Tolerances
Jean-Marc Peallat and Chong Choon Hee, Vi Technology
SMT Magazine June 2016

The Demands on Automated Fluid Dispensing
Brad Perkins, Nordson ASYMTEK
SMT Magazine September 2015



Conversations with STI Electronics' Dave Raby at IPC IMPACT Washington, D.C.
Dave Raby, STI Electronics
SMT Magazine July 1, 2016

Alpha's Morgana Ribas on Advances in Lead-Free, High-Reliability Alloys
Morgana Ribas, Alpha Assembly Solutions
December 10, 2015

A Preview of the 2016 International Microwave Symposium
Amanda Scacchitti, IMS
May 19, 2016

Improving the Solder Paste Printing Cycle Times
Adam Sim, Speedline ITW EAE
SMT Magazine June 2016

AIM Solder Talks Innovations to Address Assembly, Reliability Issues
David Suraski, AIM Solder
December 7, 2015

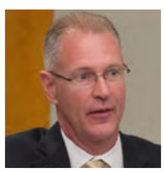
Hand Soldering: The Move Toward Automation
Domingo Taberner, JBC
June 29, 2016

Driving Innovation
Arthur Tan, Integrated Micro-Electronics Inc.
SMT Magazine September 2015

Automotive Electronics Driving Innovations in Test
Boon Khim Tan, Keysight Technologies Inc.
SMT Magazine September 2015

OEM Applications: MacDermid's OEM Director Embraces Renewed Focus
Lenora Toscano, MacDermid
SMT Magazine December 2015

Solder Paste Printing: Challenges and Best Practices
Watson Tseng, Shenmao America Inc.
SMT Magazine June 2016



Zentech's Matt Turpin on IMPACT Washington, D.C.'s Benefits
Matt Turpin, Zentech
SMT Magazine June 2016

Zentech: Expanding EMS Solutions and Supporting Innovation
Matt Turpin, Zentech
April 29, 2015

The Many Voices Over the Past Year

American Standard Circuits' Unique Offerings Contribute to Long-term Success
Anaya Vardya, American Standard Circuits
June 11, 2015

In 3D Inspection, can "Length = Height" Mean No Escapes?
Kobi Ventura, ALeader Europe
June 8, 2015

Reducing Cycle Times with Innovative Bonding Solutions
Gudrun Weigel, Delo Industrial Adhesives
SMT Magazine October 2015

Stencils: Why They Still Matter
Eric Weissmann, Photo Stencil
SMT Magazine August 2015

Process Improvements for Cycle Time Reduction
Randall Williams, B&P Automation Inc.
SMT Magazine October 2015

Valtronic Highlights Vital Components in Medical Electronics Manufacturing
Jay Wimer, Valtronic USA
SMT Magazine January 2016

What You Need to Know About Dispensing
Garrett Wong, Nordson ASYMTEK
January 19, 2016

Tremol SMD Talks EMS Trends and Industry Outlook
Kiril Yanneff, Tremol SMD
November 19, 2015

I-Connect Survey: Automation or Reducing Process Steps?

In our recent survey, we asked what is more important: automating a process or eliminating process steps.

What is more important to you?	
Automating a process	50%
Eliminating process steps	50%

Source: I-Connect007 Survey

Reducing a process step in an assembly line, which may result in a more efficient process—by taking the waste out of the value stream—is a key factor towards lean manufacturing. Automation, meanwhile, takes the manual aspect out of the process and replaces it with a system that works 24/7. Of course, automation requires heavy investment; and a challenge here, as pointed out in one of the responses in the survey, is justifying the need for automation.

Interestingly, the results are 50-50. Half of our respondents say automating a process is more important, while the remaining 50% consider eliminating a process step a key strategy.

One comment is that both are important—and that they go hand in hand. However, while automation can be done in most process areas, eliminating process steps is not possible in many areas. Also, in the case of smaller manufacturers, their facilities most of the time do not lend themselves well to either: some respondents say they have islands of automation rather than a real, end-to-end process automation.

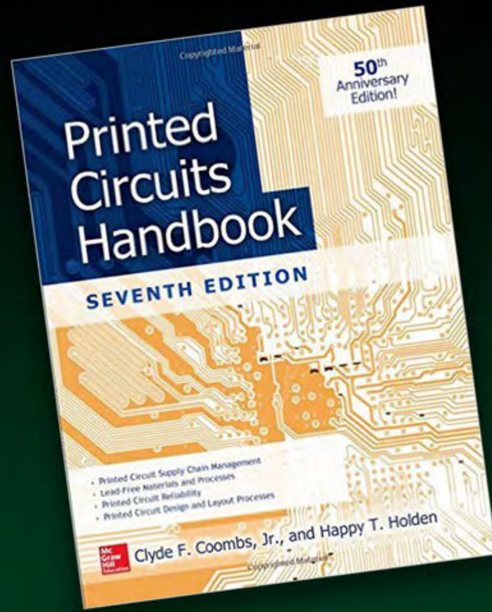
Reducing handling errors is one of the biggest factors that require the need for automation. This is followed by faster throughput and lower labor costs. Another reason to automate, according to the survey, is to deliver more consistent quality results.

Respondents highlighted some of the key processes that they consider important to automate: drilling and routing, installing fasteners, wet process, via fill, image transfer, lamination, and inspection, particularly AOI.

When it comes to eliminating process steps, the following are some of the key processes that respondents consider eliminating: plating, lamination, solder mask, repetitive measurements, and inventory management. Apart from eliminating steps in the process, respondents say reducing takt time is the next best thing.

Eliminating process steps, however, requires several justifications. Survey respondents highlight the ROI, cost, timeframe, and testing considerations when it comes to reducing process steps.

The Authors of the Printed Circuits Handbook "Speak"



Editor's Note: The seventh edition of the Printed Circuits Handbook *was published this spring, which was also the 50th anniversary of the first edition. For this issue—"Voices"—we asked the many authors of the Handbook for their thoughts—their voices. We asked a few questions to get them started; though not everyone spoke strictly about the Handbook, we found their comments interesting and thought-provoking, and we hope you do as well. We begin with a wonderful history of the Handbook by the main man himself, Clyde Coombs.*

Clyde Coombs

Editor-in-Chief
(Chapter 1)

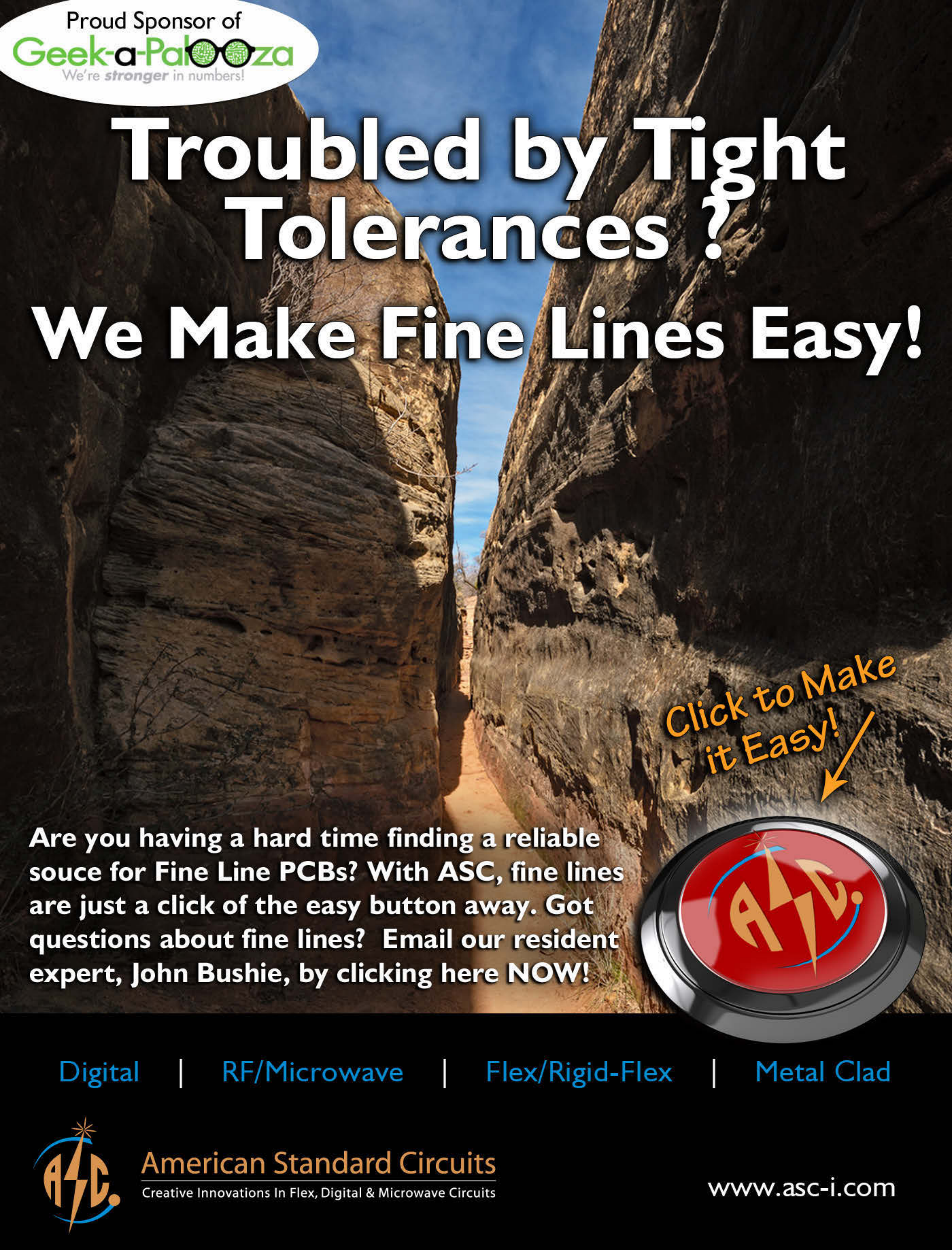
Background of the *Printed Circuits Handbook*

The *Printed Circuits Handbook* is now in its seventh edition, and we are observing the 50th anniversary of the publication of the first edition. This long-term level of importance in an industry is remarkable, but the need for this book seems obvious today. This is to put the concept of the book into the context of the industry when the first edition was published, and try to explain why there was a book in the first place, and what led to this long string of successful subsequent editions.

Touring a modern, technology- and capital-intensive, highly-automated printed circuit factory of today, supported by a staff of trained specialists, many with advanced degrees in science, engineering and systems, would be a totally different experience than touring a printed circuit shop of 1959. For the most part, those shops were the creation of entrepreneur artisan platers or silk screeners, and the facilities were called "bucket shops" for good reasons. With the exception of IBM, Collins Radio, RCA, and a few others, along with the founding members of IPC, the estimated several thousand shops in the United States (numbers at the time ranged from 4,000 to 7,000) were operated by rules of thumb, years of experience in related trades, and generally considered an art, not a technology.

Shops were divided into two categories: captives, which made boards as a part of a vertically integrated OEM, and independents, which made and sold boards to OEMs that did not make their own. Both categories of shops could be justified since it was generally accepted that it did not take significant technical skill, or a large capital expenditure to start a shop. However, in 1959, the printed circuit world was on the brink of a major revolution that few shops were prepared to cope with, and most shop managers did not understand. The spark for this was the sudden introduction, and swift adoption, of the transistor into electronic devices. As vacuum tubes disappeared, and more functionality was designed onto much smaller boards, there was a sudden need to be able to connect circuits on both sides of a board reliably.

Entire OEM futures were being staked on whether printed circuits would even serve as an interconnection system. National advertis-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Troubled by Tight Tolerances ?
We Make Fine Lines Easy!
Click to Make it Easy!
Are you having a hard time finding a reliable souce for Fine Line PCBs? With ASC, fine lines are just a click of the easy button away. Got questions about fine lines? Email our resident expert, John Bushie, by clicking here NOW!
Digital | RF/Microwave | Flex/Rigid-Flex | Metal Clad
American Standard Circuits
Creative Innovations In Flex, Digital & Microwave Circuits
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ing campaigns were focused on the fact that the product did not use printed circuits. Hewlett-Packard's first push into this process world was a disaster, which brought into question whether a superbly engineered product could be left to the questionable quality that would result if printed circuits were the foundation of its manufacturing. At the same time, it was also obvious that, with transistors being designed into all new products, hand soldering was not a viable option, even for the short term, let alone the entire new product line.

> "The first try at printed circuit assembly—crimping component leads onto board pads—was slow and unreliable."

The first try at printed circuit assembly—crimping component leads onto board pads—was slow and unreliable. The next step was the use of eyelets, which had some success on single-sided boards, and was proposed as the basis for two-side connection. It's almost impossible to describe the level of controversy that existed in the electronics industry of the time over whether eyelets or plated-through-holes were the best alternative. Today, that seems laughable, but the discussion was deadly serious at the time. The general betting seemed to be on eyelets. The reasoning went as follows: It was absurd on the face of it, that a process could be developed that would plate copper on a non-conductive surface, and do it in hundreds of small holes in a board—without missing even one—while eyelets were positively put in place and missing one would be obvious.

This environment of uncertainty spawned a furious search for an alternate circuit packaging technology and resulted in some very creative proposed solutions. Most were developed for specific products, or types of products, but were often put forward as general purpose packaging solutions. Most are now lost even to history.

As a recent graduate in electrical engineering and a new HP hire, with three years of experience in the United States Navy, my first assignment was to sort this out, propose, and develop a process that would be reliable and cost-effective, and could be integrated into the manufacturing capabilities of the company. I soon realized that they had assigned the wrong person. Instead of an EE, who could communicate with product developers, and board designers, what they really needed was a chemical engineer who could understand the chemical issues of plating and board materials. However, I had the job and needed to do a lot of learning.

First, however, I quickly eliminated eyelets, which HP was using successfully on single-sided, low volume boards, because 1) the difference in the coefficient of thermal expansion between the eyelet and the board material meant that after soldering, the two no longer could be counted on for an intimate contact, leading to potential intermittent, or open, circuits and required considerable touch-up with soldering irons; 2) eyelets had to be installed one at a time; and 3) the smaller eyelets needed for transistor interconnection were more expensive and even harder to install. That left plated through-holes, but the question remained: How could they be done reliably and consistently?

I went to the corporate library and found two books that claimed to be on printed circuits. One was really about silk screening, and the other was a high-level discussion with no real, or useful, information. The only actions left were to evaluate commercially available chemicals, and to see how others were doing it.

Giving some support to the concerns about the possibility of developing a reliable through-hole plating process was the problem that early chemical processes for reducing copper ions were very unstable. It was quite common for the solution to "go critical" and all the copper ions in solution suddenly reduce to a lump of copper at the bottom of the tank. In addition, there was a distinct interface between the copper that was deposited and the copper laminated to the base material. This required a separate sanding process to remove the copper deposited on the surface, leaving only the holes with new copper.

The result was no standard and low confidence.

Rising to meet these issues, however, a series of patents filed in the early 1960s introduced a chemistry that had a time-controlled reduction and resulted in copper deposited on the surface that did not require a sanding process. I've always felt that this was one of the most important technical advances of the twentieth century, and also the least appreciated. It became a commercial product from Shipley Chemical. We made two instruments with boards plated with this chemistry, and after full stress testing and evaluation, all discussion of eyelets stopped, and within six months all HP active boards were being made this way. The rest of the electronics industry took a little longer, but the plated through-hole has been at the heart of almost all electronic devices ever since.

At this time, the San Francisco Bay area was dominated by relatively large captive shops, with a number of small independents. I took this opportunity to leverage the Hewlett-Packard name and get invitations to visit as many of these shops as possible. The captives were just proud to show what they could do, while the independents saw us as a possible customer, but, in any case, not competitors. As a result, people were quite candid in telling me what they were doing. After a few visits, it became obvious that everybody was doing it the same way, thinking they had something unique. But it also became clear that what we were talking about was just chemistry, and of course it was basically the same. Since the people I had met did not feel competitive, I suggested that printed circuit association for our area might offer an opportunity for suppliers and users to get together to discuss technology issues confronting each. The result was the California Circuits Association (CCA). I had no idea how this would play out, but it grew from the five charter members in the Bay Area to three chapters, including two in Southern California, and more than 150 members at its peak. The biggest thing for me, however, was that I got to know who was doing what, and, more important, who really knew what.

One of the early efforts by the CCA was to hold a one-day seminar on all aspects of through-hole plating, featuring a PhD from Stanford Research Institute, Ed Duffek, and his technical assistant, Ernie Armstrong. It included the chemistry of getting a reliable coating down in the holes. The event sold out immediately, and we could have used a much bigger auditorium and charged much more. That's how hungry people were for real information. As part of the cost of admission, we provided a summary of all the information Ed and Ernie presented (this later became the basis for the chapter on plating in the first edition).

With the success of the Plating Seminar, we asked if there were other parts of the printed circuit process that would yield similar interest and we decided that just about all parts of the process would get a big reception. However, being a volunteer organization, we did not have the resources to repeat this effort very often, and we decided to concentrate on monthly meetings.

"Every book that was available was done by a single author and tended to concentrate on that person's field."

The need for real information was still there, however, and those with expertise in each process step were clear, so I decided that it was time to rectify the problem that there was no authoritative book on printed circuits in print. Every book that was available was done by a single author and tended to concentrate on that person's field. I felt that a contributed handbook, which is a McGraw-Hill specialty, could allow the use of a leader in each area. I made a formal proposal to McGraw-Hill based on this approach, and they sent it to a board of review for comment. One reviewer said he thought it would be OK, another said it represented a discussion of an unimportant issue and would be a huge mistake, a third said it was a great idea and McGraw-Hill would probably find they couldn't print them fast enough. The third reviewer was right.

When the book was published it went through printings as fast as McGraw-Hill could order them. Obviously, printed circuits were a very important issue, with a big, unsatisfied need for information to help technologists understand it. Large companies were buying the books by the hundreds and giving them to their entire technical teams. Small companies were using them as cookbooks. An authorized Japanese translation was quickly published, and an unauthorized reprinting appeared in Taiwan. I started getting mail and invitations to visit facilities around the world. That was 50 years ago, and the book has maintained its position as the industry's best source of information on all things printed circuits ever since. Also, as the Industry has changed,, so has the book, with new editions bringing new developments into focus and continuing to answer real questions. It's still a useful book about an important subject.

Looking back, I think that the key to the success of the book, from the first edition to the seventh, is the convergence of a series of points: 1) the printed circuit is the basic building block of electronic devices, and rather than receding in importance as components have seen more and higher levels of integration, it has become even more important as an application specific interconnection system; 2) it covers the entire process; 3) each chapter contains real information on how to perform processes and how things work; 4) as the need for information has developed in many parts of a company beyond manufacturing, we have put the same level of information on design and engineering issues.

Will there be an eighth edition? I can't say, but the challenges in the electronics industry haven't abated.

Happy Holden

Editor

(Chapters 1, 5, 16, 25, 26, 27, 43, 58, 65, 66)

***Q:** What would you do differently for this Handbook (if you could do it over again)?*

A: There is nothing I would do differently, but I do have regrets. It is sad that we had to remove chapters and content in order to meet the publisher's size requirement and add all the new content that required a new edition. That is always a trade-off with a hardbound, published book. That's one reason I like e-books: they can be longer, in color, with hypertext connections and electronic searches. I have totaled the pages from the 1st edition of the handbook through the 7th. More than 1,200 pages have been removed. Most of that content was not obsolete, but used less often, or not in current practice or interest or covered in other publications that are readily available. Newcomers to our industry may never know these technologies or techniques.

The handbook also focuses on practice, not theory. So you may not understand the WHY when an author talks about the best practice. My regret is that I have nearly 35 boxes in my basement full of PCB information collected over my 45 years in the industry and very little of that found its way into the handbook. There was just too much information—most of it not available on the Internet.

Finally, we don't have a chapter called "Neat Stuff." I would love to have added a chapter on the neat stuff created over the last 45 years by printed circuit innovators. The AT&T/Western Electric metal-core additive of early rotary phone days; Pete Peligrino's flow-motion plating that would deposit a mil of copper in 15 minutes; plated-post technology that created microvias twenty years before laser drilling; Kollmorgen's Multiwire® and Microwire® boards; the unique properties of tin/nickel plating instead of nickel plating as a barrier metal; and landless vias!

***Q:** Is there going to be an eighth edition?*

A: Well somebody will write it, and maybe I will edit it—if I'm still around. Most assuredly, it will be an e-Book. This industry is always changing. There will always be a need for a Handbook. Future Printed Circuit Handbooks will probably include printed electronics; metal inserts/wires and cavities for power dissipation; 3D laser-shaped circuitry on molded plastics, embedded components and new methods of optical wiring.

My concern: who is going to write the chapters? Clyde and I found it very difficult to find the new authors for the 7th Edition. Those with the most expertise were also the busiest, and maybe didn't have time to write a chapter. Fortunately, we found those experts and they made time to help us. We are eternally grateful that they took time to help the industry. Next time, the selection may be much smaller—or for me—not English speaking.

***Q:** Is there going to be enough new technology to justify an eighth edition?*

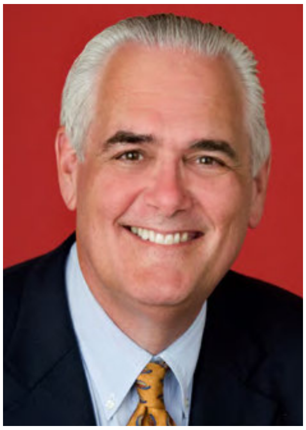
A: There is probably enough new technology now to start an eighth edition. The growth of digital imaging alone would need its own chapter. Not just laser direct imaging, but the use of powerful LEDs as light sources and TI's DMD micro-mirrors have started to proliferate. Inkjet printing of etch, plating, solder mask and legends is also growing. Given the use of these techniques at the new Whelen Engineering PCB fab facility, we also should bring back green technology (as it saved them a lot of money and "no permits required"). I like to call this new captive facility a "Lean plus Green" example. Lean is emphasized and results in a panel cost half that of China but with a two-day turnaround time instead of six weeks. These Lean concepts have simplified the entire PCB manufacturing process. They used horizontal pulse electroplating technology to reuse the copper from their etching process as well as other novel techniques to totally recycle all their rinse waters. It is also significant that all the technology came out of the U.S. or Europe, not Asia. But now that the cat is out of the bag, we may see more of it implemented in Asia. One key attribute is the less than three-year return on investment. Hopefully, this will now interest banks and other loaning institutions in financing more PCB factory growth in North America.

***Q:** How will the Handbook be used by newcomers to the PCB profession?*

A: We now have a generation in college, and more coming up through K–12 schooling, that have grown up with digital devices, video gaming, mobile phones and social networking. The effect of all of this has changed the nature of how they learn. To continue their education in electronics manufacturing—and specifically printed circuit fabrication and surface mounted assembly—we will have to adjust our training and education to this new generation of learners. For someone as old as I am, the challenge is to adapt my style of teaching to this new digital learner. I would like to work with the IPC to create a comprehensive, online, self-paced two-year and four-year degree in engineering (or at least a certificate of completion) for manufacturing in electronics that has the 7th edition of the Printed Circuits Handbook as one of its texts. PCB007 has other very good free e-books that can also be tapped in making up this new course. Given the work to create this, an eighth edition of the Handbook would have to wait until the coursework is finished.

Tim Rodgers

Adjunct Professor,
University of Colorado
(Chapters 3, 4, 6, 7, 8)



One area that I would have liked to explore in more detail in the latest edition of the *Printed Circuits Handbook* is the topic of supplier performance. A lot of people seem to think that the most effective way to ensure high performance is to threaten suppliers with legal action or the loss of future business. A supplier who works to avoid negative consequences may achieve a minimum level of performance, but probably not much more than that. If you expect your supplier to represent your interests when you're not actively observing their performance, you have to provide a reason for them to do so. What's in it for them?

A supplier is more likely to behave as a partner if they get something more out of the relationship than money for services rendered. What do suppliers want? The answer varies, but here are some examples:

• Large, well-known customers that they can use in their advertising to attract new customers. This is especially valuable for smaller suppliers that are looking for revenue growth.

• Technical capabilities that can be leveraged to other customers. If the customer's requirements drive the supplier to develop new technology, then the supplier will be able to attract other customers.

• Entry into new markets. Suppliers that focus on specific markets (e.g., consumer electronics, semiconductors, automotive, aerospace) are at risk due to economic and demand cycles. A diversified portfolio of customers and markets provides more stability.

• Predictable demand for better asset utilization. Suppliers are just like any other business—they like being able to confidently plan into the future. This is so important that some suppliers are willing to give a discount if the customer is willing to commit to use a fixed level of their capacity over a period of time.

Most suppliers operate with very small profit margins, and if they are in a position to choose their customers, they have to consider the cost to service each customer. If you can't give them a reason to value your business, then you shouldn't be surprised or disappointed if they don't go the extra mile.

Andy Shaughnessy

Managing Editor, I-Connect007
(Chapter 18)

When Happy Holden asked me to contribute to the 7th edition of the *Printed Circuits Handbook,* I jumped at the chance. I still have an older edition of the book that I was given when I first started covering this industry, and just being associated with the movers and shakers of the PCB world is a real honor. I've edited Happy's articles for 17 years, so it was a little bit of a role reversal to have him editing my content. But Happy and Clyde couldn't have been easier to work with, and they really have this process down to a science.

They were great about dealing with my schedule. I still don't know how I found the time to put this chapter together. I remember working on weekends, and on Thanksgiving before and after our turkey dinner. But it was a lot of fun. Have you ever been on a video conference with Clyde and Happy?

Much of this chapter focuses on tools by the "big guys" of EDA, since they do have the lion's share of the market. But I was struck by the number of inexpensive and free PCB design software tools available. And these are solid tools that actually work well. Some of these free and budget tools are robust enough that the big EDA companies may be getting a little worried!

I'm glad to see the handbook expanding to include EDA tools and supply chain management. I think Clyde Coombs and Happy Holden deserve all the credit for updating this "Bible of the industry." If they ask for my help on the next edition, count me in.

Bill Hargin

President, Z-zero—PCB Signal & Power Solutions
(Chapter 20)

***Q:** What would you have done differently in this Handbook?*

A: I do believe that the chapter Mark Montrose and I created adequately captures introductory educational material that's well-suited for people just getting into signal integrity, power integrity, and EMC. I've been doing that since the mid-'90s, and Mark, an EMC consultant, has been doing it even longer than that. I do wish there was more time to revamp the mechanical design section. That may be the focus for the next spin.

With the aging of baby boomers, like myself, I see educational materials like this book, which I use myself sometimes, as filling a critical need in the PCB design and fabrication world. In fact, my own company, which is an electronic-design software startup, is targeted, in part, to bridge that gap—taking about 20 years of lessons learned, and putting it in a software tool.

I will say that it was tough to carve out the time to create something meaningful. I felt like I was in college again, cranking out pages and graphics into the evenings and on weekends as the deadline approached. But, it's done, and I think it'll be a helpful introduction to signal integrity.

***Q:** Is there going to be an eighth edition?*

A: Heck if I know, but if there is, I'll probably double down on updating and improving the mechanical section.

Suzy Webb

Sr. PCB Designer, Design Science
(Chapter 21)

As PCB designers, we have the responsibility to bring order and inclusion to the chaotic needs of all the groups we work with. Those groups include the circuit design, mechanical design, fabrication, assembly, test, reliability, EMI issues, data sheet and model requirements, industry standards, industry specifications, and so on. In short, we have much to understand, and many hats to wear! All that, and it is our responsibility to prevent problems as much as possible, so that the product will perform as expected, will not need re-design, and will reach the market in a timely manner.

Many of us understand these principals because we have been around the business a very long time. Unfortunately, that body of knowledge may be fading away from the newer designers. The recent recession thinned the designer ranks considerably, and other long-time designers are getting near retirement age. There are no schools or engineering classes that teach the nuances of PCB design. There are no books or classes that can teach all of the ramifications of choosing this issue over that (although The Printed Circuits Handbook and books on specific topics are a very good start). Some of us try to share our knowledge with newer designers by leading classes, writing articles, speaking at conferences, and consulting at businesses. We encourage others to share their knowledge through user forums, software group meetings, and Designers Council meetings. Whether a designer is relatively new to the business, or an engineer is designing his own boards, we encourage him to read those articles or forums. Attend those classes, workshops, and conferences even if you must do it on your own time. (Many of us did it too.) Now is the time to be pro-active about your career! You will need a good foundation because there are many new challenges coming.

Michael Carano

VP Technology and Business Development, RBP Chemical Technology
(Chapter 32)

As an industry veteran with 36-plus years of experience, I have come full circle in my belief as to how the North American electronics industry can compete in today's global economy. Many years ago I felt strongly that the North American electronics industry in general and the printed circuit board industry in particular were second to none. Then, as OEMs shifted to an outsourcing model, much of the expertise and know-how went with it. As I traveled globally I experienced this trend first hand.

First the migration of cellphones then smartphones, television sets, even semiconductors were finding a home outside of the United States. What would be the future? Well, a few data points recently allowed my belief to complete the circle. As an example, last October (2015), IPC hosted the HDI/Flex Conference in Minneapolis. The two-day event was well attended by over 115 participants. The latest information on via filling, reliability, materials and solderable finishes flowed from the experts to the audience. The PCB fabricators in attendance were some of the biggest and the best: Multek, TTM, and FTG. And all North American headquartered. Very impressive. All have a large manufacturing footprint on the continent.

Then fast forward to the recent publication of the Printed Circuits Handbook! Just take a look and see the vast quality of information presented in this latest volume. You can't help but recognize that the reader would be getting a priceless education from the authors of the various chapters in the book. And just take a look and note where all these authors and editors reside. Yes, the North American electronics and printed circuit board industry is in good hands.

George Milad

National Accounts Manager for Technology, Uyemura USA

(Chapters 33, 35)

I think that OEMs should discontinue specific process qualification and concentrate on specifying the attributes that they desire in the finished product.

The OEM may run a battery of tests on a specific vendor product and it may pass and then they specify the qualified vendor. Among the drawbacks of this method is that, defective parts may still occur as a result from variations in the processing conditions, that the manufacturer or the OEM, may not be aware of. In addition, new processes with a wider operating window may be available that the manufacturer may want to try but feels trapped in the qualified process.

Another advantage of specifying the attributes that they desire in the finished product is that the responsibility for the delivered parts remains with the manufacturer. In this case the manufacturer chooses the process that fits his shop conditions and may choose a vendor that he feels is knowledgeable and offers him the best service and problem resolution as the need arises. Some of the qualification procedures may be so extensive and cumbersome that they impede the progress of the industry as it comes up with better more robust processes that have not undergone qualification.

Jason Keeping

Corporate Engineering Analyst, Celestica, Inc.

(Chapter 44)

Q: How was the experience of putting together your chapter of the Handbook?

A: As a technology leader for our organization, I have written documents for industry in the past; however, this was my first opportunity to have information put into hard copy book not as a document but as a book, and it was a great pleasure. As the content of this chapter had not changed much in the past decade based on the legacy of information that was already available, my real goal was to find content that was new that could enhance this section for readers. With recent work that I had completed for the IPC-HDBK-830 Conformal Coating Handbook, I had this fairly easily available and just needed to confirm all aspects and have them incorporated into this handbook. After this was done the overall flow and images just needed to be amended and put more into the current century. With current industry progress on nano materials and new developments, the next time this section may have new material types as well as content to empower its readers both in hardcopy and digital form.

With the speed that our industry is developing at the moment, the amount of changes that were encountered within this edition will most likely be exponential and not linear, just to maintain a parallel path to these market innovations and changes.

Q: Do you see any challenges in PCBs in general or PCB education in particular?

A: Within my role I work with all market segments between military/aerospace, industrial, telecommunication and even consumer covering all aspects of ruggedization from assembly cleaning, staking, edge/corner/complete underfill, and selective/atomized/vapour/dip deposited conformal coating and even component encapsulation and full assembly potting technologies. However, these technology sectors are continuously in development due to newer material research and cost pressures to compensate for newer harsh environments than previous designs and/or even legal requirements such as RoHS and/or even local requirements connected to emission either into the air or down the drain.

With this all stated, one aspect that is a hot topic—depending on whom you discuss with—is no-clean. From the information that I have obtained over the years, this was a great marketing term; however, is not true if you have the perception that no-clean means that assembly cleaning is not required. For the bare PCB this may be true; however after you run a PCB via the SMT process, add manually and/or via automated equipment components for a wave soldering process, then perform various manual touch points such as handling for test and/or inspection, the resulting ionic levels at this point usually do not mean the assembly is clean—yet all materials are "no clean." At this point the challenge is what the next step should be? This would be a challenge that I see coming that the industry will need to understand and what test methods and guidelines should be used and followed.

Laura Turbini

International Reliability Consultant
(Chapters 45, 59)

Q: What do you really enjoy about the industry?

A: I have had the privilege of working in the electronics industry for almost 40 years, starting in 1977 when I joined Western Electric's Engineering Research Center. As one of the early women in the industry, I was treated with respect and support by my many male associates. One thing that always impressed me in my colleagues is the way they worked together and helped each other. Over the years I had a chance to learn from the industry's leading thinkers. The insights I received from them led me into the area of research related to failure modes in printed circuit boards—particularly to the study of CAF (conductive anodic filament) formation. "Standing on the shoulders of giants" enabled me and my students to identify the chemical nature of CAF and how it is formed.

I was first asked by Clyde Coombs to contribute to the 4th edition, which published in 1996, and subsequently to the 5th, 6th and 7th editions. The present 7th edition was very important as a central resource for lead-free soldering. Writing a technical book chapter took a great deal of time to compose it in a clear manner and to make sure there were no errors—but I had learned to do that early in my career when I was the editor of the Western Electric Engineer. I am pleased to have been a participant in this book and I hope my former students will pick up where I left off.

Reza Ghaffarian

Principal Engineer, Jet Propulsion Laboratory, California Institute of Technology (or JPL/NASA, CIT)
(Chapters 60, 61)

Q: Why did you decide to write two chapters on PCB reliability for the **Printed Circuits Handbook?**

A: Well, when I look back, I find it to be interesting, even maybe amusing, as how a simple request by Happy, a dear long-time colleague friend and a co-editor, caused me months of hard work followed by a final proud moment of accomplishment. I am not joking since this for me is another extra activity, only work during weekend since I have a day job to do and that also put additional burden of as what I can publish. Well, I said OK to a simple request of review and republish with minor modification of a previously written chapter on PCB reliability. I thought a few weekends would be OK, especially knowing the Christmas holiday of 2014 was on the way. A few weeks became more than six months of nonstop weekend work and now a feeling of relief and accomplishment and I am concentrating on other activities. Rather just minor modification, I made a complete face-lift and one chapter becomes two, one on PTH reliability and the other on a new topic of micro reliability. My intention always has been to pay back to the industry, but this became a hefty one even though I am proud of it. I am proud to be able to add the most updated research on PCB reliability. Again, just a contribution to technical community with no financial gain.

***Q:** It has only been a few months since the Handbook was published, but have you received any input from the industry?*

A: Just this month I received two emails, one asking for a good reference on PCBs and the other one had comments after review of the chapter on microvia reliability, especially on drawback of current coupon testing. Even

> "Just this month I received two emails, one asking for a good reference on PCBs and the other one had comments after review of the chapter on microvia reliability, especially on drawback of current coupon testing."

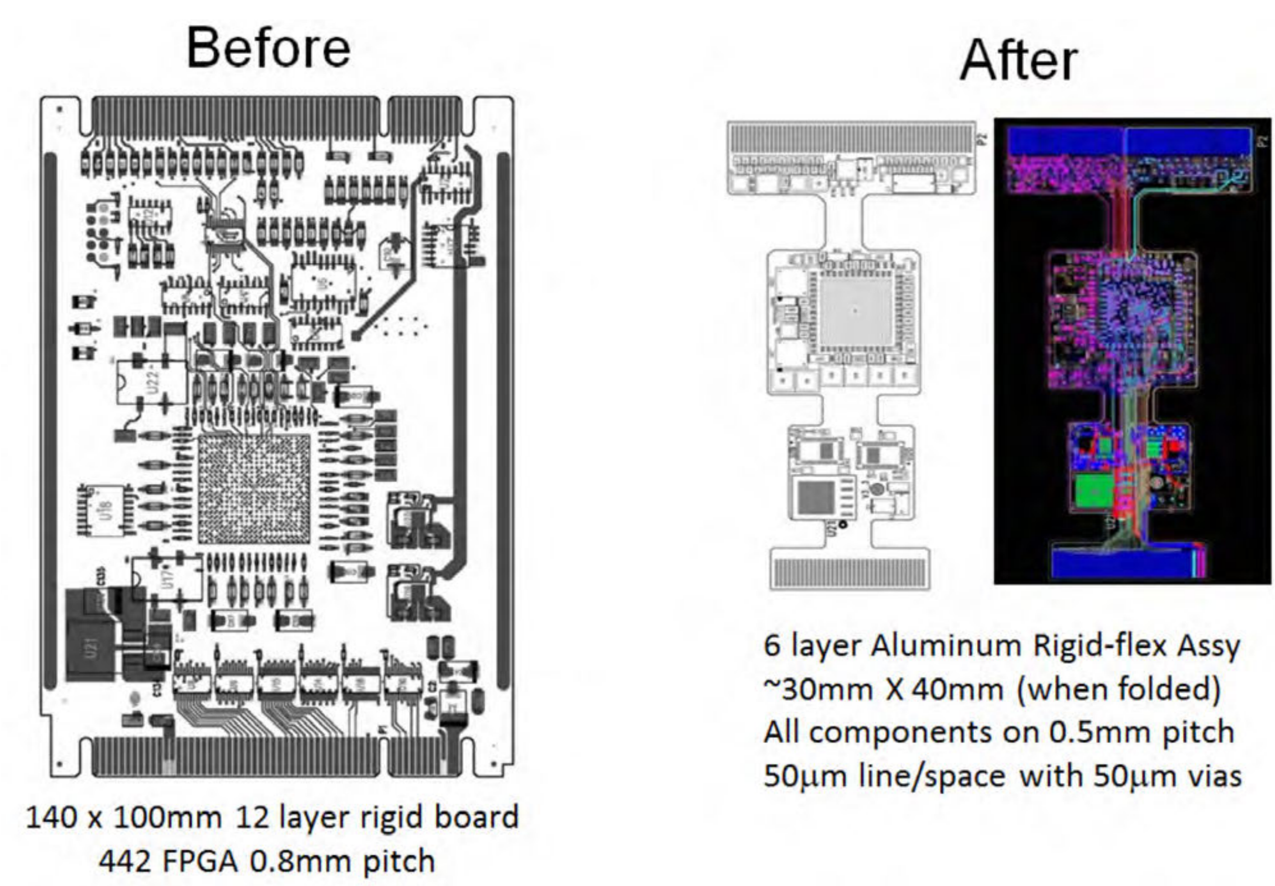
though I have heard similar comments during IPC Thermal Stress Test Methodology Subcommittee meetings, but this is on the stack microvia which is an interesting one and I like to share since it is timely too. Jerry Magera wrote that for stacked microvias, they have observed that opens may occur at temperature above the PCB Tg (glass transition temperature), more typically around 220°C, it stays open through the peak temperature, followed by reconnect/closure during cooling. They have tested these types of failures to thermal cycling, -40°C to 125°C, and found that such latent defects were undetectable. Solder float tests also does not detect these failures. They also found that current induced testing is not appropriate for acceptance test and also unable to detect microvia issues. He recommends that "the current induced test coupons should be used by PCB manufacturers to monitor their process for PTHs." So the two chapters on PCB reliability need to be revisited to include new technologies and requirements when the co-editors decided to publish the 8th edition. I want to send my sincere appreciation to the two well-known coeditors of the 7th *Printed Circuits Handbook* for their tireless effort to put together such an invaluable new edition.

Joe Fjelstad
Verdant Electronics
(Chapters 67, 68, 69, 71)

Electronic Assembly... Is it time to remove the "training wheels"?

Many children learn how to ride a bicycle by using training wheels—two extra wheels attached to the rear axle to allow them to keep upright as they learn how to ride. The down side of training wheels is that they slow the rider down and impede changes in direction. In many ways, solder is the training wheels of electronic assembly. It slows down manufacturing and impedes the industry's ability change direction when it comes to making products that are better, more reliable and less expensive. However, in order to gain those benefits, as with riding a bike, the would-be user has to exercise balance, discipline and good judgement. To illustrate, consider the following example.

Below are images of two electronic assemblies, they are identical in function and were designed by the same designer, Darren Smith[1], using the same general design rules. Yet as can be seen, one is substantially larger than the other and has twice the number of circuit layers. What makes that possible? Three things: the



Elimination of solder makes possible significant improvements in design efficiency.

first is the elimination of solder; the second is the placement of all components (fully tested and burned in) beneath the surface with terminations facing up; and the third is selecting only components that have terminations on a common grid pitch. The combination of these three simple principles makes it all possible.

Consider first the elimination (or at least the minimization or possible replacement) of the use of solder. Solder pads take up a significant amount of space on the outer layers of a circuit assembly leaving little room for routing circuits. The fact that hundreds of millions of dollars are arguably wasted annually, inspecting, testing of PCBs and assemblies, x-raying and repairing defective solder joints seems, if one reflects without prejudice, a reasonable thing to try and eliminate. However, there is also the cleaning process which is getting ever more difficult as lead pitches shrink. Eliminate (or replace) solder and you eliminate all of these wasted steps.

The elimination of solder is made possible (with the least number of steps) by the second item from above. That is the building of the components into the board and then applying the circuits. More succinctly, rather than building a circuit board and soldering components to the surface, build a "component board" and then build up the circuits on them. Some might consider this impractical but it can be done and fortunately while using nearly all of the current infrastructure. Circling back to the analogy that bikes work better without training wheels, the manufacturing process can as well.

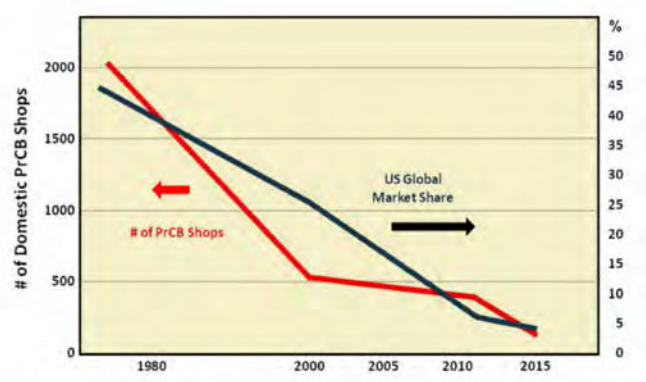
The last item is perhaps the most challenging because components come with leads on many different sizes, shapes, pitches and lead forms. J-leads, gull wing leads, though-hole leads, radial leads, pins, balls and even no leads for QFNs and LGAs. It is these latter two that are of greatest interest and value because they are well-suited to getting to a standard grid (e.g., 0.5 mm). Moreover, in a solderless assembly they require no solder on their terminations. Less manufacturing steps and the elimination of high-temperature excursions which can impact long term reliability are both good things. The common grid pitch simplifies design by making routing more predictable. When all three of the principles suggested are combined, well, the results are self-evident above. It needs to be conceded here that some components cannot be easily adapted to the concept in their present configurations, but they are what they are because there were no real physical constraints when they were introduced.

In summary, it is possible to eliminate solder from numerous applications and minimize its use in countless others, and by doing so, enjoy significant benefits in design and manufacture. Not every company will be comfortable without the training wheels. They will worry about falling and it can be argued they will be less nimble as a result. Yes, eliminating the "training wheels" from electronic assembly requires some risk-taking but it is through taking risks that progress is made. It is the combined discipline of design, procurement and manufacturing that will carry the day. From experience it can be found that a key guiding principle of excellence in manufacturing is to first do the right things and then do those things right.

P. Marc Carter

Printed Circuit Engineer
(Appendix)

Those of us who deal with other aspects of electronic production realize how fortunate the printed circuit world is to have long-recognized, centralized resources like the Printed Circuits Handbook. The Handbook (and a few other consensus resources, like IPC) allow us to



speak in a common language. Often as not, we ARGUE, but at least we argue from a common starting point. Historically, assembly and microelectronics haven't enjoyed that same common tongue.

It is now a truly international business, and the shift of much of the fabrication base out of North America has resulted in (for an English-language resource of finite length at least) a necessary de-emphasis on fabrication details, and an increased emphasis on assembly, and securing printed circuit boards from remote sources. Another reviewer commented that an e-book that allowed the reader to focus on those areas that were of particular interest in their case might be preferable. The only other way I can think of to deal with that issue would be a two-or three-volume PC Handbook, each volume addressing the needs of a particular segment. **SMT**

To read a book review by Karl Dietz, click here.

References

1. Darren Smith may be reached by clicking here.

Supply Lines Highlights

[To Clean or No Clean?]

The addition of a cleaning process to your manufacturing line will amount to an added 5–6 cents per board produced. Mike Konrad of Aqueous Technologies believes that is a small price to pay for the added value, testing, and reduced liability and insurance that a cleaning solution can provide; however, he admits cleaning isn't for everyone.

Hand Soldering: The Move Toward Automation

At the recent NEPCON event in Shanghai, JBC's Domingo Taberner discussed with I-Connect007's Barry Matties the hand soldering market in China, the move towards automation, the greatest challenges their customers have in soldering, and what to know about choosing the right temperature and tip.

ACE to Host Solderability and Lead Tinning Workshop in Arizona on August 10

ACE Production Technologies Inc.'s ACE Component Services group, in conjunction with Phase 4 Inc., will host a solderability testing and component lead tinning workshop in Arizona on August 10.

Hisco Partners with Alpha Assembly Solutions on New Soldering Webinar Series

Hisco, an employee-owned, specialty distribution company serving the electronics, aerospace, defense and medical device markets, has partnered with Alpha Assembly Solutions for a series of free soldering webinars.

KIC's MB Allen to Present "Optimization of the Reflow Profile to Minimize Voiding"

KIC's Marybeth (MB) Allen will present "Optimization of the Reflow Profile to Minimize Voiding" at the upcoming SMTA Carolinas Chapter Tech Session, scheduled to take place August 18 in Greenville, South Carolina.

Electrolube Appoints New Distributor for North Africa

Electrolube has appointed Adelec International to support and promote its range of conformal coatings, thermal management solutions, encapsulation resins, contact lubricants and service and maintenance aids across North Africa.

Indium Features Indium8.9HF, Indium10.1 Solder Pastes at NEPCON South China

Indium Corporation will feature its Indium10.1 and Indium8.9HF solder pastes at NEPCON South China 2016, scheduled to take place from August 30 to September 1 in Shenzhen, China.

BEST to Hold Workshop for PCB Inspection at SMTAI

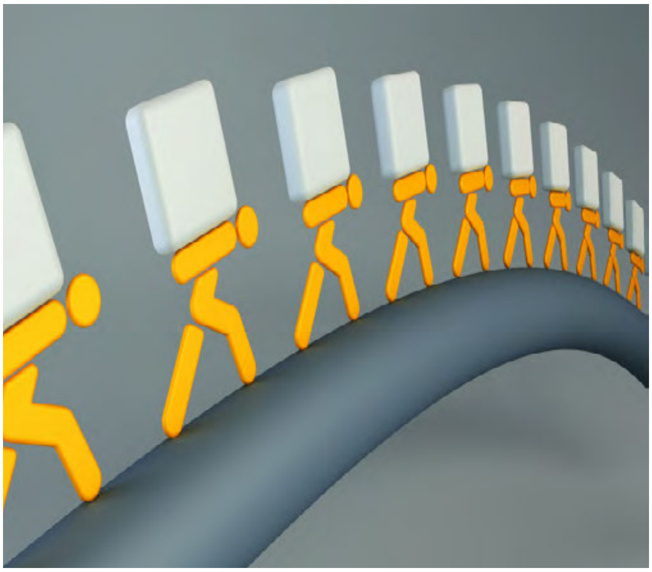
BEST will be holding the first ever "Inspection of Printed Circuit Board Assemblies" hands-on workshop at the upcoming SMTA International trade show in September in Rosemont, Illinois.

Mycronic Reports Strong First Half-year Results

Mycronic has reported a strong first half-year results, with sales growing by 37% on earnings of SEK 137 million.

Rehm Expands Worldwide Sales Network

Rehm Thermal Systems has expanded its sales team with the addition of Carsten Kramer as global solar director and director for Southeast Asia, and Dr. Klaus Brodt as sales for reflow condensation soldering systems and special systems.



Alex Stepinski, Our First Recipient of the Good for the Industry Award

I-Connect007 is proud to introduce the *I-Connect007 Good for the Industry* award. This new and prestigious award is bestowed upon individuals and companies that are good for the industry.

What exactly does "good for the industry" mean?

At I-Connect007 we believe it means helping the industry improve cycle time, lower cost, increase yields, build better products, increase profitability, reduce waste, become overall more efficient, do things differently, and motivate and inspire others to do the same—all things that are good for the industry.

This is what we at I-Connect007 do every day...we believe in this, and we know others do, too. We want to recognize those people that are good for the industry and share their stories.

Our goal is to consistently bring our readers fresh new content related to those characteristics listed above. Throughout the past year, the I-Connect007 team has done this by conducting interviews all over the world with hundreds of people from the industry, from congressmen to electrical engineering teenage prodigies to some of the top PCB executives. These interviews have given us a unique perspective into the industry as we have met all sorts of people and listened to, and then shared their stories. We hope they're as much fun to read as they are to conduct.

It was through one of these interviews that we first caught wind of a revolutionary new automated PCB fabrication shop in New Hampshire, being built as a captive facility—Whelen Engineering. The man behind the innovative design is Alex Stepinski.

Why is Alex Stepinski good for the industry?

Alex Stepinski is good for the industry because of his first-of-a-kind, proof-of-concept creation—a fully automated PCB factory with zero waste water discharge—and his and Whelen Engineering's will-

ingness to open the doors and share their new captive manufacturing facility for others to learn from.

When designing and building the factory, Alex did not rely on the status quo. Instead, with a clear mission and a new way of thinking, he sought out and adopted leading-edge automated technology that would substantially cut manufacturing cycle time and the need for costly labor. Alex's innovative factory design has fewer than 20 people operating it on all shifts and has caught the attention of and gained recognition from some of the industry's biggest names. When I-Connect007 sat down with Gene Weiner at the most recent HKPCA show, he had this to say of the Whelen factory:

"The idea of the containment of the operating equipment, the maintenance, the effluent, and the central control overlooking the whole thing that forms a circle, from which you can side-step to do ENIG or some other special process or finish, is sheer genius in the way it was designed and built. Several pieces of equipment were created especially for that line as well as the waste treatment, such as digitizing the use of a plasma system for desmearing that uses oxygen instead of an organic. There are a lot of innovative things at Whelen."

The Whelen factory represents the first fully automated PCB facility to open up on United States soil in decades, which is fitting because Whelen is a very pro-American company that manufactures sirens and indicator lights. Rather than continuing to spend $7 million a year on product in China, for a little under $12 million they were able to set up Alex's manufacturing line and start building their boards in-house. Taking chances on unproven technology and automation paid off in a big way and allowed Alex to significantly cut costs and reduce ROI. The Whelen factory offers American manufacturers evidence that adopting advanced technologies can pay off with even more opportunities in the future.

Of course, it's risky to take chances on expensive new technology when you're struggling to get by, which makes Whelen's openness even more admirable. They've offered to let anyone come in and look under the hood to see what they're doing. They want to share this technology and their unique approach with American companies.

The benefits and scope of Alex's design go beyond just North America, however. During our short visit at Whelen, a gentleman from the UK was examining the factory with hopes of setting up a similar facility in Europe. And these techniques and solutions aren't just beneficial to the West; it's expected many Asian manufacturers will be interested in Whelen's waste treatment system as environmental regulations continue to get ramped up in China. Veteran PCB expert Happy Holden summed it up:

“Every couple of decades a “perfect storm” of opportunity presents itself to our industry. What Alex Stepinski has done at Whelen is that perfect storm! I like to call it, “LEAN PLUS GREEN.” Putting together a number of new innovations like inkjet printing, horizontal plating and conductive polymer metalization, along with his own innovations in water and chemical regeneration/recycling, he has cut the labor, environmental and chemical costs out of the PCB equation. This allows PCB merchants and OEMs alike to relook at the concept of re-shoring and captive production here in the USA, since waste emissions and labor costs are no longer relevant.

I congratulate Alex and his team for earning this first I-Connect007 Good for the Industry award.”

Alex designed a factory that accomplished a number of firsts, and it looks like it could be adding more soon related to plating on plastics. It is for these ongoing accomplishments and continued innovation, as well as the willingness to share this information to further advance the industry as a whole, that we present Alex Stepinski with our *Good for the Industry* award. We've spent some time with Alex, and we've found that he is a genuinely nice guy.

If you get a chance, tour Whelen Engineering's new PCB manufacturing facility in New Hampshire. Once you meet him, you will agree that Alex Stepinski is good for the industry.

To read the full story on Whelen Engineering and Alex Stepinski, click here.

The I-Connect007 team is on a constant search for people or companies that can be considered good for the industry. If you know of someone like Alex who is *good for the industry,* let us know why, and perhaps one day it will be them being recognized in one of our magazines. **SMT**

Drone footage capturing Whelan Engineering's fully automated PCB factory.

Moving Beyond Paideia: Learning for Earning

by Tom Borkes
THE JEFFERSON PROJECT

The easy and sometimes only way we have to react to a problem is to criticize, carp and blame. A citizen may be declaring her disgust over the result of a government social engineering initiative, or a consumer may be slamming a poorly engineered consumer product that costs too much or is unreliable. The citizen and consumer have several tools in their respective toolboxes to register their disfavor. In a free society, freedom of the press and free speech are two of those important tools. It has been said that the antidote to irresponsible or ill-founded free speech is contained in more free speech. In an authoritarian-based society, the wrong free speech often leads to the tag of not being a team player or, worse, becoming an enemy of the state.

Another more direct tool of change for the citizens living in countries with a republican (note the small "r") form of government, where elected representatives are charged with doing the will of the people, is the individual's vote.

The United Kingdom is technically a constitutional monarchy. However, it is a representative republic in the sense that an elected parliament is charged with doing the will of the people—the queen is a traditional symbol with no law-making authority. Last month, the world watched as citizens in the U.K. voted directly in a referendum to be extricated from the European Union—a vote that directly rebuked the members of parliament they had elected to represent them. Here in the states, Mr. Jefferson would be pleased. He believed in the collective wisdom of the people. He recognized that the people will make errors in judgment from time to time, but if left free would correct those errors. Jefferson's nemesis, Alexander Hamilton, believed that the people were the beast, and it was the government's job to control the beast.

Thomas Jefferson believed that education is what transformed the beast into productive citizens who could govern themselves. He had a fervent belief in each man's education as a nec-

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essary component in the success of the American experiment in self-government.

In a free society, vigorous verbal and written discourse, whether in our role as citizens or consumers, are important tools in affecting change. In 1839, the English author Edward Bulwer-Lytton wrote, “the pen is mightier than the sword.” In 2016, social media has created an ether of sorts that has many of us wallowing and flailing about in a big data soup that permeates our existence. In an ironic way we are confronted with a new challenge: there is so much data to wade through, much of it from dubious sources, that we are confronted with the task of separating the wheat from the chaff. As we used to say in the seventies “Is it real or is it Memorex™?” In today’s world of big data it’s often difficult to know what’s real and what’s not. How do we establish the veracity of what we are reading, or the goodness of the data we use to determine a cause and effect relationship—remember red wine as a preventer of heart disease or eggs as a cause of heart disease—for all those years, all wrong!

“How do we decide what variable data are significant in controlling the process? Huge amounts of real time data are available.”

Big data in high-tech electronic product assembly provide a similar challenge. How do we decide what variable data are significant in controlling the process? Huge amounts of real time data are available. We need to understand the physics and statistics involved in the process to construct an assembly operation’s infrastructure that will best maximize yields and minimize rework. Design of experiments (DOE) is a useful tool, as are process capability studies. The point is that this is undergraduate level engineering work. These skills need to be taught during a person’s post-secondary educational process.

At one time, we called the ability to criticize and persuade the skill of rhetoric. This skill was actually taught in schools—not so much anymore unless you are studying to be a lawyer. This course has been replaced by classes such as diversity training and learning how not to hurt other people’s feelings. And, the word rhetoric has taken on a pejorative meaning, connoting pretentiousness or empty talk.

Civics and diplomacy were taught at one time, as well. These subjects gave us an understanding of how our government worked and how to criticize a policy we disagreed with in a civilized (civil) way, but without the need to pull any punches. In the real world or even on college campuses (purportedly the sanctuary of free and diverse thought), this art form has been largely replaced with ad hominem attacks meant to destroy our adversary, personally as well as politically. Or, the opposite: such extreme political correctness, we fear our words being termed as a micro-aggression as much as we fear a terrorist act. Further, what we once called stereotyping—the assigning of characteristics and behaviors across groups, not an individual’s behavior—we have added the appellation of identity politics. Our positions on issues are now defined by others, using the demographic groups we occupy: economic, class, religion, ethnicity, etc., as the bucket in which we are placed. Finally, while our educational system tries to teach us to raise the level of our argument, not the level of our voice, our society has embraced a win at all costs objective. Just look at today’s sports landscape: Cheating is okay as long as you don’t get caught. Why? Well, everybody does it, don’t they? This is the antithesis of virtue. As a culture and a society, embracing this sort of anything goes worldview puts us on the slippery slope to perdition. Here, Mr. Jefferson would be deeply concerned as he recognized that virtue was a necessary individual quality needed for the survival of self-government. To close the loop: each individual’s liberal (note the small “l”) education was one vehicle to each individual’s virtue. Individual virtue permitted self-government, and self-government permitted an individual’s liberal education. (As opposed to an authoritarian education where you learned, or were reeducated, to what the state wanted you to learn—purportedly, for the benefit of the collective—ah, Utopia!)

How about the private-product sector?

What is the most important weapon available to consumers in the private product sector? It's one that's analogous to their vote as citizens on the government side. It's the power of their purse in a competitive free market. You've probably heard the expression "I vote with my feet." In other words, as consumers we have traditionally addressed product discontent in the market sector by simply not buying the product. Now we can add to rejection at the cash register, sharing our view with the world through online product reviews.

The closest we come as citizens to "not buying the product" in the government sector is in the voting booth.

Just look at the current U.S. election year spectacle in which we are immersed and it doesn't take long to conclude that the candidates are long on criticizing and short on solutions. Ah, politics!

But what if we change the role we play from a product consumer to product developer or assembler. We are given the direct responsibility for designing a product, solving problems associated with a product or creating and maintaining an assembly process that exceeds the consumers' expectations both in price and performance—like the role many of us play or have played in the companies we work for. Whether we work for an OPD or an EMS, we have a direct impact in the performance and cost of those products.

One of the reassuring things about science and technology is its language. Unlike politics, mathematics does not prevaricate. The assumptions and work forming the context in which mathematics is used may be faulty, but the mathematics itself is unassailable. .

We have an educational system whose tenets were formed centuries ago. Whether the problem we are confronting is sociological or technical, our educational system's goal is to produce people who can solve open-form problems—those where there are more unknowns than equations. It seems that the educational system does a fairly good job in producing an entry level engineering workforce that can solve problems with closed-form solutions. But, unfortunately most of the problems we are confronted with in the real world are of the open form type, requiring judgment skills to arrive at what is probably the best solution. Judgment skills are acquired in the real world not the ivory tower. So, I criticize, carp and blame.

However, when I criticize our post-secondary educational system, it is incumbent on me to complement the criticism with my proposed solution(s) to the problem.

Academia has not traditionally been good at the learning for earning part. They have been happy to largely leave that to the private sector.

This brings us to this month's topic: Moving Beyond Paideia: Learning for Earning.

The word "paideia" comes from the ancient Greek, meaning the process of educating a youth into a citizen—a functioning citizen who becomes a productive part of the city-state, the polis.

It was recognized that the student youth was best served by being exposed to the best our species has created. Teaching and observing that which is "beautiful and good" was the goal.

Further, the educational process was a blend of the philosophical (the humanities) and practical (science and mathematics).

Mortimer Adler used this Greek idea to suggest the way we were educating in the 20th century was ineffective. He suggested that the primary and secondary compulsory educational years (grades 1–12) should be organized in three columns representing these goals:

1. Acquisition of Organized Knowledge
2. Development of Intellectual Skills-Skills of Learning
3. Enlarged Understanding of Ideas and Values[1]

I have addressed in past SMT Magazine columns that post-secondary education should have as its objective providing the student with a balance of learning for learning and learning for earning. If this part of the educational pipeline is fed with students that have a learning foundation built on Alder's three columns, it is a natural extension to continue the process in the learning for learning area through the Great Books program[2] and other humanities-based courses.

However, in the world of high-tech product design and assembly and other professions, this is not enough. For most of the 20th century, what we did in the electronic product assembly business was considered a trade to be taught in a trade school. Soldering, for example—a trade skill.

> A process for assembling a circuit board—a trade skill, community college stuff at best.

A process for assembling a circuit board—a trade skill, community college stuff at best. Production engineering, okay, but why all the math? Even time and motion studies—do they really warrant calculus and differential equations?

SMT started to change this in the early '80s. Global competition and the need to reduce labor content through automation, micron-level pitches for direct die attach, nano-technology, meta-process control[3], solder paste and cleaning chemistries, and many other advancements have all created a level of complexity that requires the attention of personnel that have an engineering level education.

Although I think paideia is essential as an educational foundation, in today's world it does not provide enough learning for earning. Mortimer Adler believed that a student's preparation for earning a living is not the primary objective of educational process. I suggest we now need to think beyond paideia. Why? Paideia provides the skills of how to learn, exposure to the great ideas found in the humanities, and basic skills of reading, writing and arithmetic. The complexities of our technological world and global marketplace now demand the development of specific, saleable skills as part of the student-customer's educational process—it is in their best interest. The template for teaching these skills must be based in the real world.

It used to be that a company would hire a person with a good liberal higher education who had majored in one of the engineering disciplines: electrical, mechanical, or industrial. Then, invested in bringing the new hire up a two-year or more learning curve to teach the employee what they really needed them to know to be successful at their job—the learning curve essentially being the real world experience the entry level person received. We can't afford this anymore.

Once you accept this thesis, then the question becomes what the most efficient and effective way to provide the learning for earning in an academic setting is. My proposed solution is Concurrent Education—more on this next month.

Hey, what do YOU say? I'd like to hear your thoughts. **SMT**

Next Month: The Child is Father to the Man—Turning the Relationship Between the Electronic Product Assembly Employer and Recent Graduates Upside Down

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1. *The Paideia Proposal – An Educational Manifesto,* by Mortimer J. Adler, 1982, Macmillan Publishing

2. *Great Ideas from Great Books,* by Mortimer Adler, 1969, Pocket Books

3. *Reducing Labor Content as a Strategy to Improve Competitiveness – An Analysis that Addresses the Value of Designing for Automation and an Empirical Analysis that Exploits the Automation Using META Process Control,* by Tom Borkes and Lawrence Groves, Trans-Tec Yamaha, First presented at SMTA International, Chicago, IL, September 30, 2015

Tom Borkes is the founder of The Jefferson Project and the forthcoming Jefferson Institute of Technology. To reach Borkes, click here.

MilAero007 Highlights

Zentech Manufacturing Awarded Prime SeaPort-e Contract by U.S Navy
Zentech Manufacturing Inc. has received a prime contract from the U.S. Navy for the SeaPort-e contract vehicle.

Libra Industries Renews ITAR Registration for All Manufacturing Facilities
Libra Industries has renewed its ITAR registration for its Dallas and Ohio facilities.

STI Receives Prime Contract Award for SeaPort-e
EMS firm STI Electronics Inc. has received a prime contract award for SeaPort-e.

Orbit International's Electronics Group Receives Letter Contract for New Order
Orbit International Corp.'s Electronics Group has received a letter contract from a major prime contractor for $275,000, authorizing it to commence the procurement of material for switch panels, while negotiations for the final purchase order are being concluded.

Plexus Continues to Invest in UK
As part of its continued program of growth within EMEA, Plexus Corp. will be investing in a dedicated building and equipment for Environmental Stress Screening at its Kelso, Scotland, manufacturing facility.

Kitron Officially Opens Kilsund Facility
Kitron ASA has officially opened its upgraded, state-of-the-art facility at Kilsund in Arendal, Norway.

Kimball Electronics Acquires Aircom Manufacturing
Kimball Electronics has announced the acquisition of the assets of Indianapolis-based contract manufacturing company Aircom Manufacturing Inc.

Sparton Earns Fourth Consecutive 5-Star Supplier Excellence Award from Raytheon
Sparton Corp. was recognized for its outstanding performance as a supplier to Raytheon Integrated Defense Systems (IDS) at the Supplier Excellence Conference held in Danvers, Massachusetts on June 7, 2016.

Rocket EMS Purchases Fortus 3D Production System from Stratasys
Rocket EMS Inc. has enhanced its design and production capabilities with the purchase of the Fortus 3D Production System.

Cobham Lands $13M Electronics Assembly Order for an Advanced Processing Project
Cobham recently received an approximately $13 million order for electronics manufacturing services from a leading research organization for an advanced processing project.

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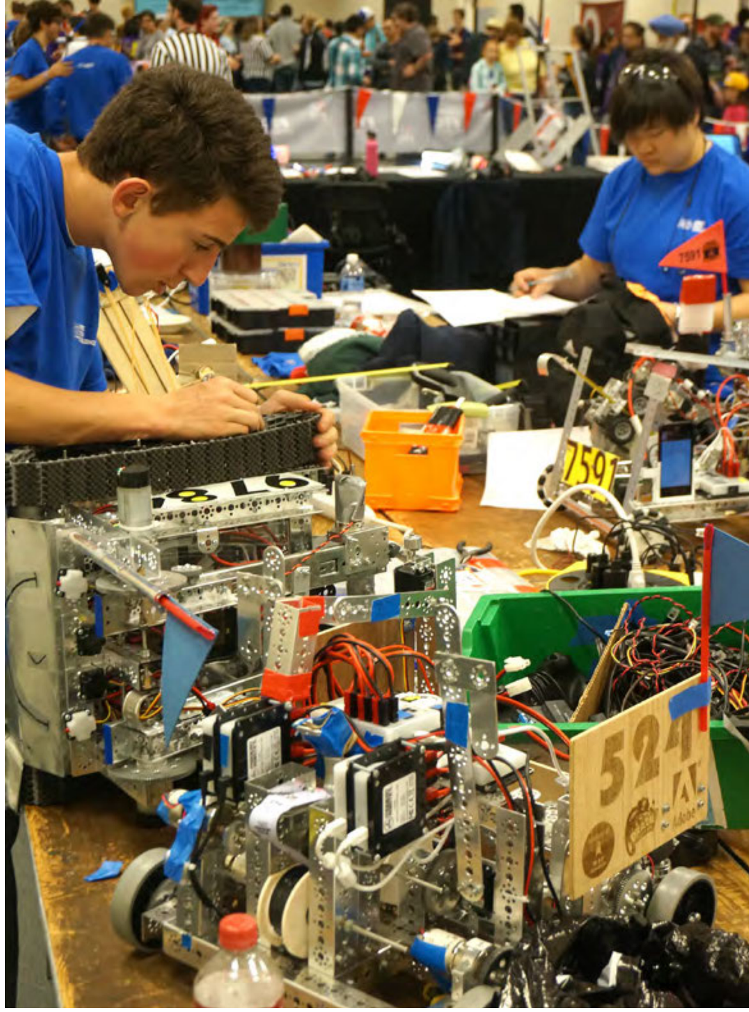


By Barry Matties
I-CONNECT007

FIRST (For Inspiration and Recognition of Science and Technology) is a massive initiative taking place around the world that is aimed at getting kids more interested in STEM subjects through a variety of fun and interactive experiences. Many FIRST challenges and competitions took place at a recent Maker Faire in San Mateo, where I met with Jill Wilker and Ken Johnson from FIRST, who helped illustrate FIRST's truly inspirational mission and vision.

***Barry Matties:** Jill, tell me a little about what you are doing here at this event.*

Jill Wilker: We have a whole hall here at Maker Faire, where we are demonstrating the FIRST programs. We have three of the FIRST programs represented, with kids from high school through elementary school. We have FIRST LEGO League with our elementary kids where they build a LEGO robot, all autonomous, and solve a problem. The problem this past year was based around trash, so getting young middle school kids to think about why we are creating so much trash in the world and what can we do about it. It really makes them problem solvers along the way while playing with LEGOs, which is always a natural attracter for the kids.

Then we have FIRST Tech Challenge represented, where we're actually running an off-season competition. We have 14 of our local teams here who signed up to come back for a post-season event to replay FIRST Res-Q, where they're learning about issues around what happens in an avalanche. Things like, how do you save climbers and clean up debris after an avalanche? It gets the kids really thinking about real-world problems.

Then we have FIRST Robotics Competition, where last year they played a game around storming a castle, FIRST Stronghold, and now they're here demoing their robots all together and showing the progression of the programs. With me is Ken Johnson, who is also with the FIRST Tech Challenge program.

***Matties:** Ken, you're out of New Hampshire? Welcome to California, first of all.*

Ken Johnson: Thank you. It's beautiful out here.

***Matties:** You're the director of the FIRST Tech Challenge. Tell me about that please.*

Jill Wilker and Ken Johnson

Johnson: FIRST is headquartered and founded out of New Hampshire, but we are global. We have about 400,000 students annually participating in our programs, with about 150,000 volunteers that make it all work. Jill and Mark Edelman run FIRST programs for Northern California. I am responsible for FIRST Tech Challenges all over. We've got over 5,000 teams now in 18 different countries. The growth has been phenomenal.

The big thing this year is the all new control system based on the Android operating system running on Android cell phones and tablets. That has allowed us to really make the program accessible to a whole range of students that otherwise might have been a little intimated by jumping into the robotics deep end. We're really happy with the way that the platform is coming together. We worked with Qualcomm as our corporate sponsor partner to be able to develop this, and it's been really well accepted this year.

Matties: The technology I'm seeing here on the show floor, the battle floor if you will, looks elaborate and expensive. How is all this being funded?

Johnson: I can speak specifically for the FIRST Tech Challenge, but the way that our non-profit is built is through a combination of registration fees from teams and corporate sponsorships. Frankly, most of our budget is covered by team registration fees. Those registrations are oftentimes augmented by sponsors themselves who would like to sponsor teams joining our programs, and who fully support the development of the next generation of science and technology leaders.

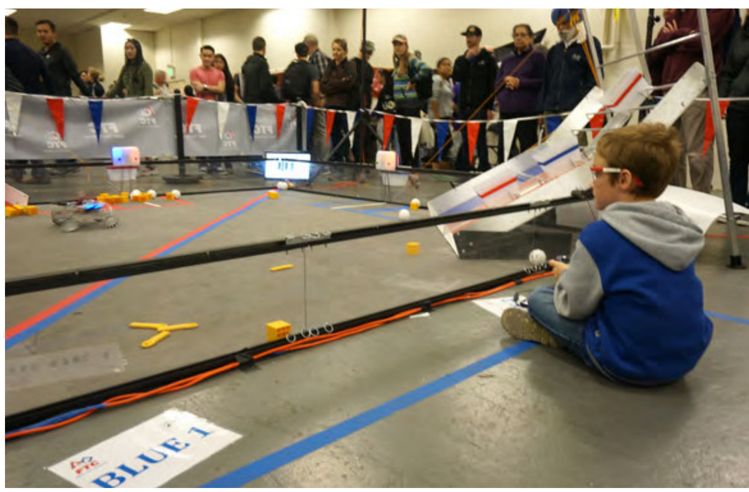
It's a win-win for everybody. It helps grow our program, it helps grow the people that are involved, but it really is creating this next generation of people that the sponsors will need to work in their companies. Qualcomm, NASA, BAE Systems, Rockwell Collins, PTC, really are looking at future consumers, but more importantly, future people that can push their technology forward.

Matties: Exactly. Are there any mentorships that come out of those sponsorships? Do they bring people in and work at that level?

Johnson: Definitely. Interacting with FIRST is really a wonderful thing for sponsors because they can get involved at a bunch of different levels. To start, they can simply apply their employees as volunteers.

Wilker: At events, like one-day kind of events. Come in, get trained up and you interact with the kids in a very controlled, one-day commitment kind of experience. We have a lot of corporate teams that like to come in and they'll give me a dozen volunteers for the day and they come in as a group.

Johnson: They can volunteer for a single day, as kind of a shallow dive. They can get their stu-



dents, their kids involved, and it's a nice way for a corporation to not just give back to the community, but also directly get their employees and their students involved. They can also get involved at, of course, at the sponsorship level. They can help sponsor teams for simple things like registration all the way up to overall headquarter sponsorship. We've got a wonderful group of sponsors that span the range from technology companies, like the ones that you'd expect, Google and Apple, for example, to companies like Coca-Cola. We've got really a nice broad range of sponsors. It's not just technology companies.

***Matties:* What's the goal of FIRST?**

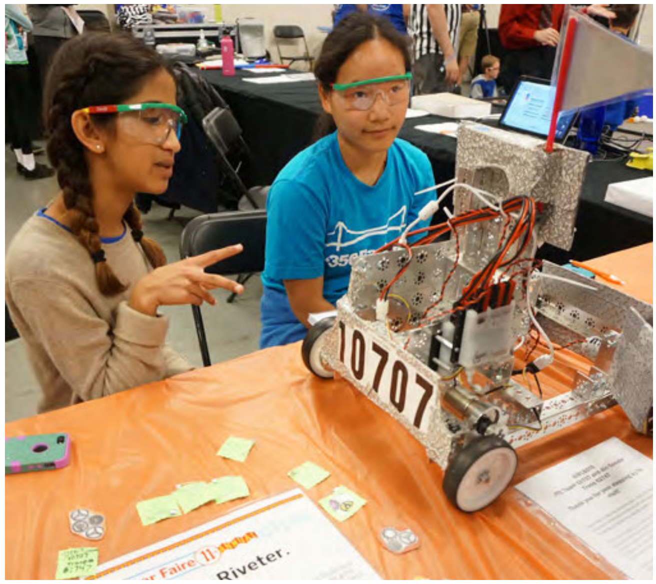
Johnson: The goal of FIRST is to change the culture to celebrate accomplishments of scientists and technologists and show that it's a fun, meaningful and accessible way to create a wonderful future for you as a student and really, to create the kind of behavior that we need to fix the really big problems that are upon us. Not just from a technology standpoint, but also from a cooperation standpoint. That really is the goal of FIRST. It's no smaller than changing the world.

***Matties:* That's a lofty goal and I can see by the kids' faces here that you're achieving that to a degree right now already.**

Wilker: They're our wonderful ambassadors. We have today, for example, on the FIRST Tech Challenge, an all-female rookie team who wanted to come. They literally just registered, built a robot and came out. They're working with the Girl Scouts and some corporate sponsors.

***Matties:* I saw that. It's great.**

Wilker: We also have teams here that competed at the world championships. So some very high performing teams that have got their act together, and then we have everything else in between. In the FIRST LEGO League this afternoon, we have teams that basically decided that they love this program and they came back to share their robot and their project. Again, some more teams that just are wonderful ambassadors. Talking with the kids really is how the program spreads. Word of mouth is the best medicine. It's really contagious.



***Matties:* It's contagious for sure. These kids are excited. What about public schools? Are they embracing your programs? Are they incorporating this into their curriculum in any way?**

Johnson: They are. It's interesting. I know across the board, an average of 65% of our coaches are teachers. In what has really been a pull from the coaches' side to bring it into the classroom, we started FIRST as a STEM extension activity really designed to be done outside the classroom, but with the high percentage of coaches that are teachers and the whole movement towards more project-based learning, which is perfectly aligned with Makers, that pull has really been strong in the last few years.

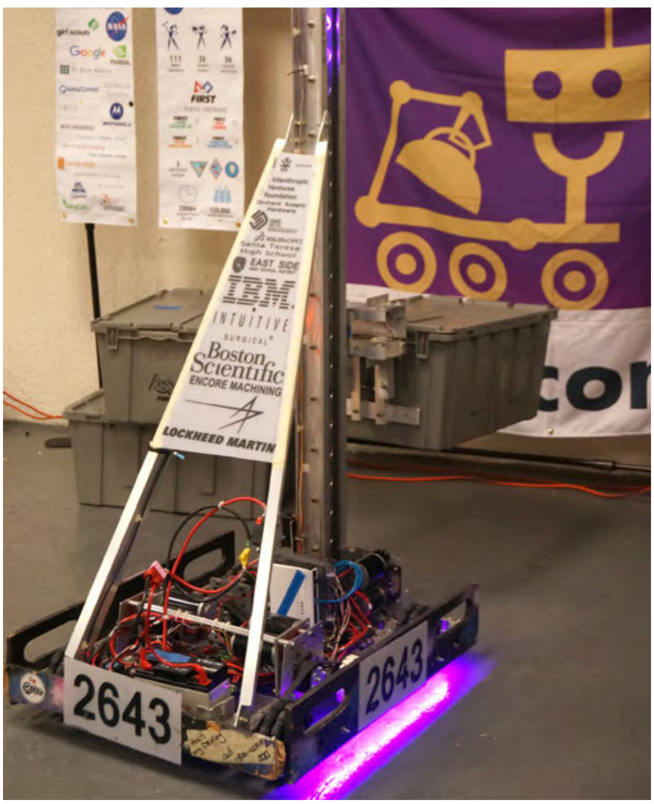
We are working and do work with curriculum developers. We developed some curriculum ourselves. We also have a lot of early adopter teachers who have brought it into the classroom in a guerrilla style, bringing it in and using it to really augment the types of things that they're already teaching.

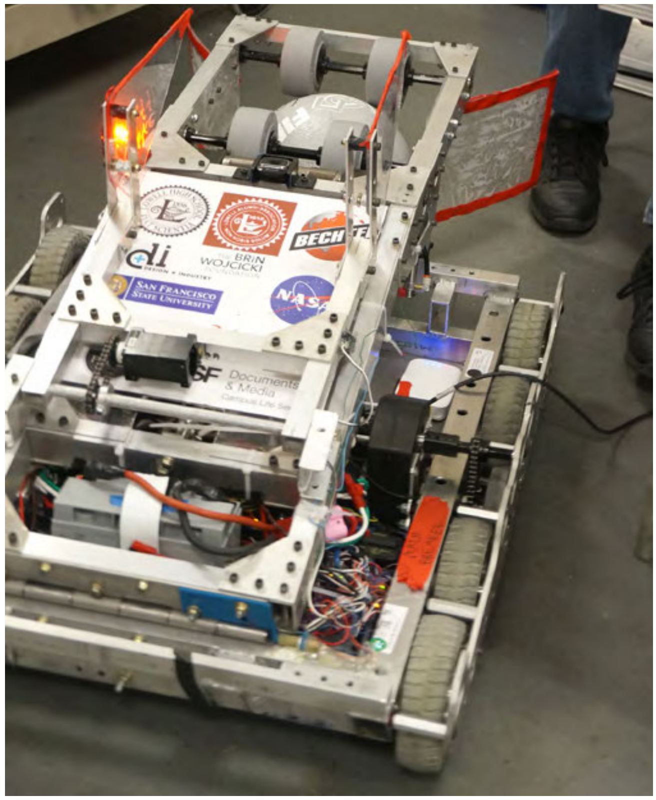
***Matties:* That's great. Experiential learning is really a lot of fun for these kids. Is there anything else that we should mention that we haven't talked about?**

Wilker: To me, the big differentiators are around, as you mentioned, changing the culture and behaviors. There's an ethics to the program. As an engineer myself, I like technology. I'm attracted to technology, but a lot of girls maybe are not. Technology for technology's sake outside of any reason to just play a game is not as exciting as, "I'm actually solving problems that are meaningful and I'm teaching people to behave nicely and well." There's a concept called Gracious Professionalism. It's basically embodied in the core of FIRST, which is, "I am going to compete like mad, but I can be gracious. I don't have to be in your face and have the kind of over bravado and aggressive behaviors."

Matties: Like we see on our baseball fields recently.

Wilker: Exactly. I can be a professional about that. I can be respectful and treat people well and extend that to the rest of the community. Actually, as a working engineer, I want everyone to embody that. To me, that is the backstory of FIRST. It's not just a technology program, but really, as Ken mentioned, it's changing the world and changing the values of technologists and engineers that sometimes have some of the worst parts of sports and not the best parts. They do the teamwork part, but they also bring some of the other stuff that honestly I don't want all in my workplace. I want a well-oiled team that I'm working with as a technologist myself, but in a way that's collaborative and where actually everyone wins. Not where one person wins at the expense of everyone else.





Matties: Very well stated. Ken, any final thoughts?

Johnson: No, I think Jill did a great job of summing it up. The only thought I would leave it with is I think all of your readers should get involved in FIRST as a volunteer, get their students involved, or sponsor. It's good for them, and it's good for the world.

Wilker: It's everywhere you want to be. FIRST is in 80 countries.

Matties: Excellent. Thank you so much.

Wilker: Thank you. **SMT**

Bumping of QFNs/LGAs and Other Leadless Devices for More Consistent Rework

by Bob Wettermann
BEST INC.

The Challenge

Leadless devices are now the greatest package style by volume (Yole Development Market Survey) being placed by electronics assemblers worldwide. These packages, due to a variety of factors, are challenging to rework. Among the greatest challenges this package presents are the solder voiding primarily on the ground plane, the inability to clean underneath the devices post rework, and the difficulty in getting similar standoff heights on both the IO and center ground. These challenges along with their increasing complexity and ever smaller package sizes challenge even the most skilled rework technicians.

In addition to the above rework challenges, the package style itself remains very difficult to inspect post reflow for a variety of reasons. As there are rarely any visible solder joints due to in most instances a lack of a solderable sidewall on the IO pads of the device, as well as the very low standoff distances between the bottom of the device and the PCB, there is very little visual inspection which can occur. This means that the reliance on a skilled x-ray technician as well as a capable x-ray system is in order.

Types of Rework Methods Available

Of the various methods for reworking leadless devices, the bumping method (Figure 1), when appropriate for the board and part at hand, is the process with the greatest first pass yield, the one with the greatest standoff distance for cleaning flux residue from underneath the device and the one with the greatest assurance of minimizing voiding.

"Bumped" 2 x 2mm QFN Package, 0.5mm pitch, 0.2mm Wide Pads

There are numerous methods being used to rework leadless devices; either guided by the older IPC 7711 5.4.1 process guidelines or by the newest stenciling techniques. The older of these methods includes solder paste printing on the site location of the PCB followed by the placement and reflow of the device. The newer methods including IPC 7711 procedures 5.8.1.1 and 5.8.1.2 includes the device pads being "bumped" followed by their placement. The device, post "bumping", can be placed using a rework system using paste flux or with a properly-designed "capture" stencil which has apertures that can locate and capture the "bumps" on the PCB.

Both of these latter methods for reworking leadless devices were popularized using polyimide stencils. In these methods, a polyimide stencil is placed over the land patterns on the bottom of the device. Solder paste is then squeegeed in to the apertures. The device is then reflowed. Post reflow, the stencil is peeled off leaving "bumps" on the bottom of the device (mini metal stencils can also be used when appropriate). Because the reflow is done in air, the flux volatiles can escape, thereby having the "bumped" part nearly free of voids. In ad-

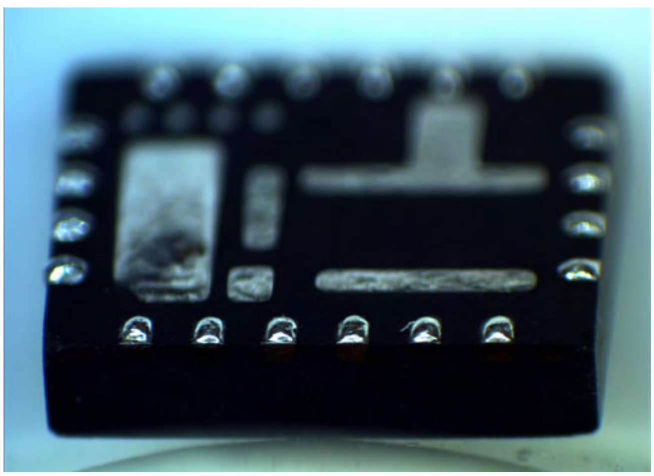


Figure 1: Bumped leadless device prior to placement.

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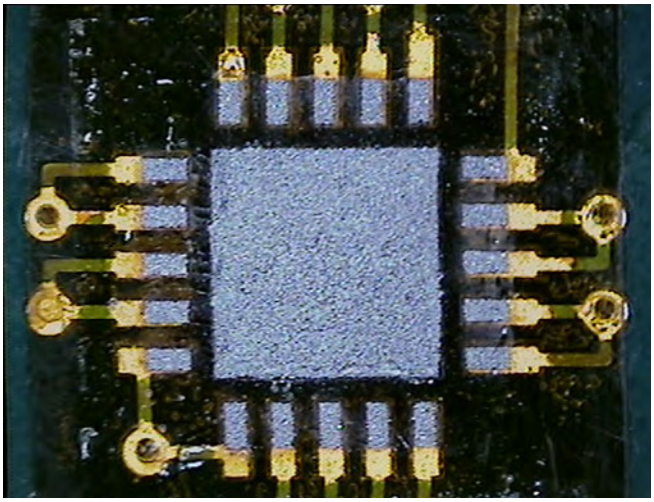


Figure 2: Typical polyimide receiver stencil on PCB accepts the "bumps" of the leadless device.

dition, these stencils are thicker than the initial manufacturing stencils meaning that the final standoff height is greater when compared to traditional printing and placement. This bumping technique also greatly simplifies placement of the leadless device as a lower-skilled technician or even first-timer, when following the instructions properly, can produce the "bumps" for placement.

Best First Pass Yield

The "bumping" rework process, whether the placement is done via a receiver stencil (Figure 2) on the PCB or via a split vision rework system, presents the rework technician with the greatest leadless device first pass yield percentage. This method, along with its limitations and nuisances described above, presents a leadless device with consistent, nearly void-free "bumps" ready for attachment onto the PCB. As the outcome of the bumping process produces a nearly void-free center ground (the escaping volatiles of the flux burn off and have somewhere to go during the "bumping" process), one of the rejection criteria, namely a too great of a voiding in the resultant pads of the device, is greatly reduced. The placement accuracy in the "receiving" stencil placed onto the PCB, assuming it is properly aligned, presents a means of mechanical alignment of the replacement device onto the PCB. If a split vision rework system is used to place the "bumped" device, then placement accuracy is zeroed in on by the rework systems' vision system. In both cases, what is overcome is the high dexterity required in paste printing of the site location as well as the outgassing of the expired flux volatiles (which may lead to solder voiding), which may not meet the acceptability requirements of the inspection criteria.

Greatest Standoff Distance

In addition to the highest first pass yields, the bumping process, when done properly, presents a leadless device which has a higher standoff distance when compared with other rework techniques allowing for a better opportunity to clean off contaminants from underneath the device. If selective printing were to be completed on the PCB using the same stencil thickness as in the original manufacturing process, then there may not be enough room underneath the device to properly clean the unwanted soils from underneath the device. For example, assuming that a 7.5 x 7.5mm package were to be reworked using the original 4 mil thickness stencil, the standoff height between the bottom of the device and the PCB would

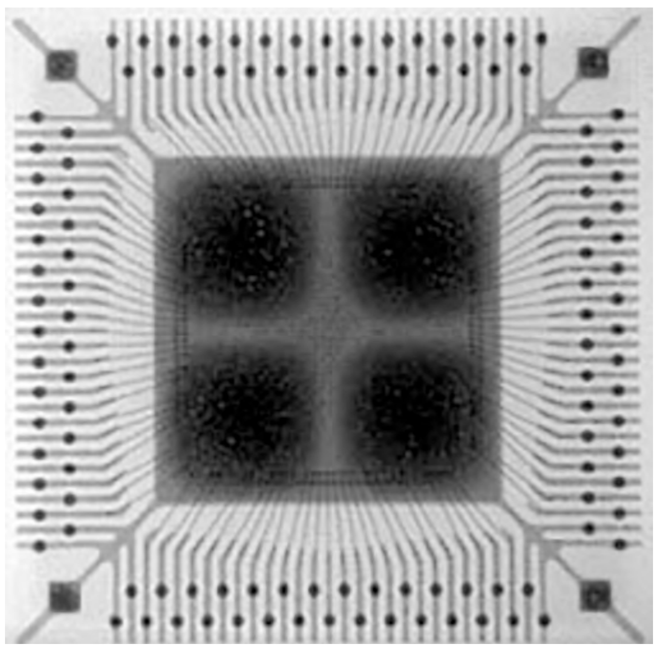


Figure 3: X-ray image of bumped QFN reflow on to PCB location which has been "bumped".

be approximately 2 mils in thickness. For most cleaning systems, this is just not enough of a standoff to get the cleaning agents underneath. A bumped device would be at the 4 mil height, thereby allowing the cleaning agents a better chance to do their job.

Best Chance to Minimize Voids

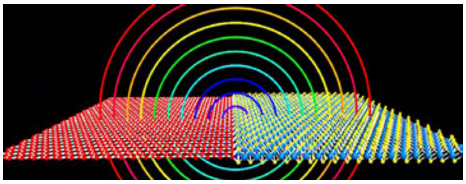
Another advantage of the bumping rework process allows for the outgassing of the flux volatiles thereby presenting a nearly void-free device post rework. When the device has been selectively solder paste printed and is sent through a reflow profile, the volatiles have a chance to escape as the device is in an open environment. Contrast this to the case where the site location is printed and the volatiles can be entrapped creating solder voids. A typical bumped part x-ray is shown in Figure 3 demonstrates this.

Conclusion

When a leadless device such as a QFN, LGA or LCC needs to be taken off and then replaced, the bumping technique is one in which the device can be routinely replaced without a high degree of skill required, one that offers a greater standoff height for more complete under package cleaning and most importantly one that reduces the amount of voiding on placement. This is a well-proven IPC rework procedure and is gaining wide acceptance in small-medium rework jobs. **SMT**

Bob Wettermann is the principal of BEST Inc., a contract rework and repair facility in Chicago.

Ultra-flat Circuits Will Have Unique Properties



The old rules don't necessarily apply when building electronic components out of two-dimensional materials, according to scientists at Rice University. The Rice lab of theoretical physicist Boris Yakobson analyzed hybrids that put 2-D materials like graphene and boron nitride side by side to see what happens at the border. They found that the electronic characteristics of such "co-planar" hybrids differ from bulkier components.

Shrinking electronics means shrinking their components. Academic labs and industries are studying how materials like graphene may enable the ultimate in thin devices by building all the necessary circuits into an atom-thick layer.

The researchers led by Rice graduate student Henry Yu built computer simulations that analyze charge transfer between atom-thick materials.

Yakobson said 3-D materials have a narrow region for charge transfer at the positive and negative (or p/n) junction. But the researchers found that 2-D interfaces created "a highly nonlocalized charge transfer" — and an electric field along with it — that greatly increased the junction size. That could give them an advantage in photovoltaic applications like solar cells.

The lab built a simulation of a hybrid of graphene and molybdenum disulfide and also considered graphene-boron nitride and graphene in which half was doped to create a p/n junction. Their calculations predicted the presence of an electric field should make 2-D Schottky (one-way) devices like transistors and diodes more tunable based on the size of the device itself.

Yakobson said the principles put forth by the new paper will apply to patterned hybrids of two or more 2-D patches. "There's no reason we can't build 2-D rectifiers, transistors or memory elements," he said. "They'll be the same as we use routinely in devices now. But unless we develop a proper fundamental knowledge of the physics, they may fail to do what we design or plan."

Rice postdoctoral research associate Alex Kutana is a co-author of the paper. Yakobson is the Karl F. Hasselmann Professor of Materials Science and NanoEngineering and a professor of chemistry.

The Office of Naval Research supported the research.

Electronics Industry News
Market Highlights

DRAM Contract Prices Stabilized in June and Are Expected to Rise in Q3
DRAMeXchange expects DRAM contract prices, after being on a downtrend for almost two years, will go up in the third quarter by about 4% to 8%.

Automotive Telematics Revenue Will Soar to $4.2B Globally in 2021
Global revenue from automotive telematics systems will grow at a CAGR of more than 19% to $4.2 billion by the end of 2021, according to new forecasts from IHS Inc.

3D Printing Industry Expected to Top $6.5B in Revenue in 2016
A new report from Semico Research, '3D Printing: The Next Industrial Revolution 2016 Update', forecasts that revenues for the industry—including printers, services, and materials—will eclipse $6.5 billion in 2016. That figure will almost triple by 2021.

Automotive Semiconductor Market Grows Slightly in 2015
Despite slower growth for the automotive industry and exchange rate fluctuations, the automotive semiconductor market grew at a modest 0.2% year over year, reaching $29 billion in 2015, according to IHS Inc.

IoT Communication Protocol Market Worth $15.8B by 2022
The IoT communication protocol market size in terms of value is expected to grow from $11.44 billion in 2015 to $15.8 billion by 2022, at a CAGR of 4.7% between 2016 and 2022.

World Record: 248,000 Industrial Robots Revolutionizing the Global Economy
The worldwide sales of industrial robots achieved a new record number of 248,000 units in 2015, according to the International Federation of Robotics.

Machine Vision Market to Hit 9.1% CAGR to 2020
The machine vision market size is estimated to grow from $8.08 billion in 2015 to $12.49 billion by 2020, at an estimated CAGR of 9.1% from 2015 to 2020.

Global Demand for Smart Weapons Accelerating Growth to Top $41.8 Billion by 2025
A renewed emphasis on advancing Smart Weapon capabilities to counter evolving threats such as A2/AD (anti-access Area Denial) envelopes, combined with on-going demand from asymmetric wars and continued force modernizations in emerging countries is driving spending across the full range of Smart Weapons, according to Strategy Analytics.

N.A. Semiconductor Equipment Industry Posts May 2016 Book-to-Bill Ratio of 1.09
North America-based manufacturers of semiconductor equipment posted $1.75 billion in orders worldwide in May 2016 and a book-to-bill ratio of 1.09, according to SEMI.

China IoT Market Worth $121.45B by 2022
The China IoT market is expected to reach $121.45 billion by 2022, at a CAGR of 41.1% between 2016 and 2022, mainly driven by the growing demand for smartphone and other connecting devices, the increasing internet penetration, rising trends of industrial automation, and mainstream adoption of cloud computing, according to MarketsandMarkets.

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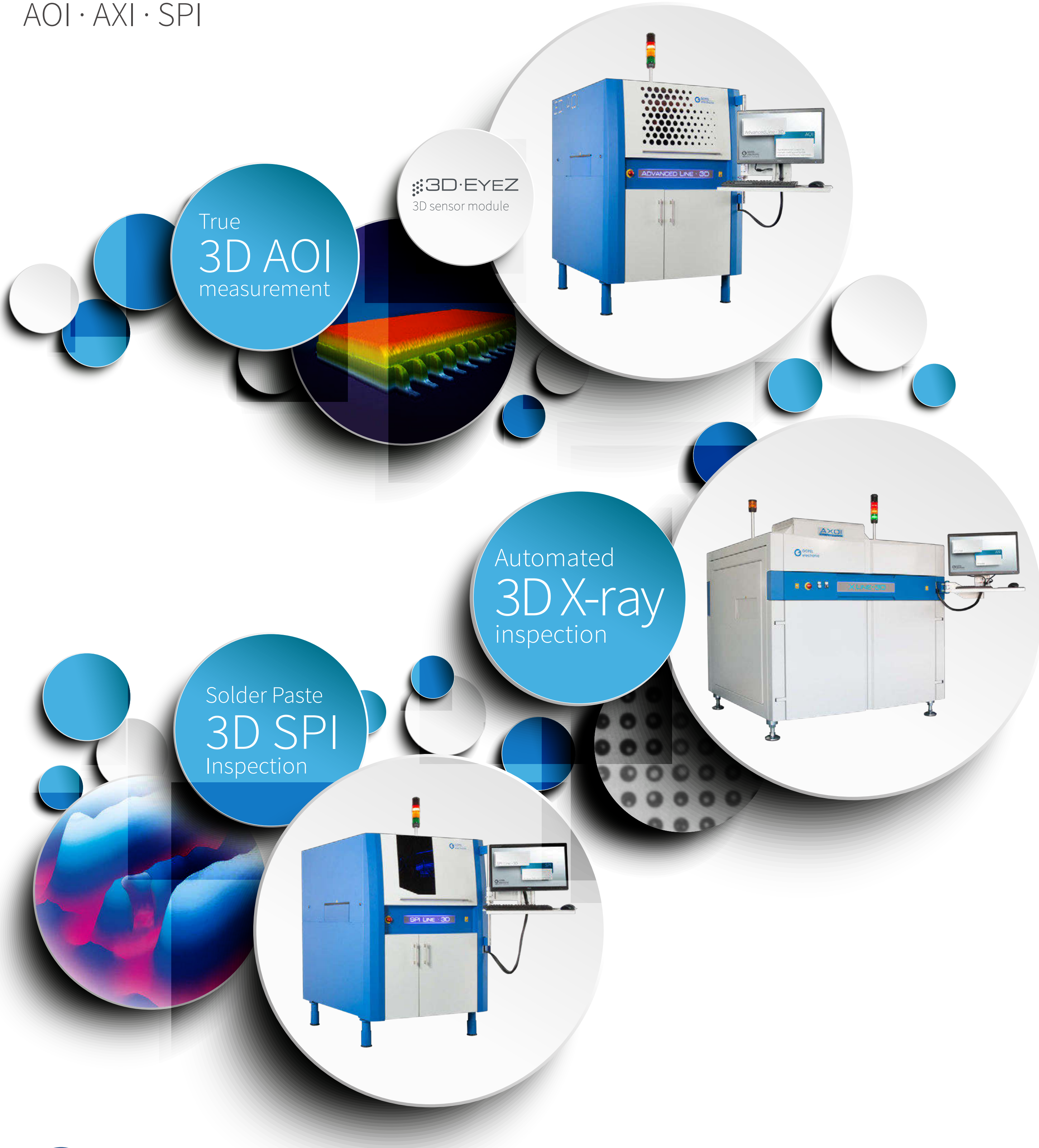

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IMS and STEM: Building a Stronger Future

by Barry Matties
I-CONNECT007

Every year, the International Microwave Symposium (IMS) show hosts a STEM program and invites young students to take in the sights and sounds of the microwave symposium. At this year's show, I met with IEEE MTT Education Committee STEM Lead Steven Lardizabal to learn more about the show's STEM outreach.

***Barry Matties:** Steven, you're a part of the educational program, and today the kids are here attending the STEM program. Tell me a little bit about the educational program and what that means.*

Steven Lardizabal: The student education program for IMS is actually something that's envisioned by the MTT Education Committee. It's a way to not only get graduate students involved in actually being researchers and not just reviewing what's going on, but getting actively involved and talking to other researchers and getting that all the way down to the STEM area, which is down to middle schools and elementary schools.

Steven Lardizabal

***Matties:** A very critical part of our future, right?*

Lardizabal: Yes. The national focus on STEM is really middle schools. In middle school, students start getting distracted. They get history class and civics, so they start learning about their world, and they start doing a lot of different things, like studying literature, and math is only one piece of that. Science actually doesn't come until high school, so if the students don't pick up those abstract concepts early, you lose them. It's really hard beyond eighth grade to get focused. It's not to say that they're not going to become great writers or even doctors, but they're probably not going to design integrated circuits. That's where we're really focused.

***Matties:** How long have you been part of the educational program?*

Lardizabal: I've been part of the educational program within my company for almost a decade, and with IMS and the IEEE for the last three years.

***Matties:** We have what looks like maybe 75–100 kids here today, right in that area. I'm curious. Out of the past kids who attended, how many have you followed that have gone on into the programs? Do you have any of that data?*

Lardizabal: We have a lot of data on the graduate students and how they follow through. Last year, we had over 150 middle school and high school students, because there's a very active IEEE-supported STEM education group there in the Phoenix area.

***Matties:** Yeah, I was quite impressed with that. It was a large group. Of the graduates, what sort of people come out? Of the 75–100, would you expect five to ten percent to go on into the technology field from this?*

Lardizabal: I would like to get one. It's becoming rich by making a penny. We know we'll touch more, but if I can get one of these kids really inspired to say, "You know what? I want to invent the next iPhone. I want to save the environment, and technology is the way I'm going to do it." It's that gem of knowledge that gets them going. In truth, that one is every one of them is how I like to say it. One at a time, but all of them.

***Matties:** One can be a lofty goal.*

Lardizabal: Exactly.

***Matties:** It sounds counterintuitive with 100 kids here, but you keyed in on it earlier. There's a lot of distractions in a child's life.*

Lardizabal: Yes. There are a lot of other things to do.

***Matties:** To get them inspired in something like this so early, you're going to have to find a special student. How do these kids get here? Is this a choice for them to be here, or is this just a class that does this as a field trip?*

Lardizabal: Recruiting for the event is one of the most difficult, because typically IMS happens when school lets out. Getting the local school to understand what IMS is all about is part of our challenge, and it's part of our outreach. It is a fairly select group. Not that we're selective, but there may be only a certain pool available. We have to work with that, but we also want it to be outreach to the broader community. In Phoenix, we had a groups of Native

Americans invited, and next year in Hawaii, it's going to be a similar case where we hope for a very diverse audience.

***Matties:** There are quite a few females and males in this group today, which is great to see, as one of your speakers noted earlier. They're going to go on a tour today. What's the hope that they get out of this tour?*

Lardizabal: What you get out of a tour, you find out that an engineer is a real person, and actually they love to talk about what they live and do for their life, and they want you to know more about that and how you can affect the world around you. I like to tell them there are people here walking these halls who have created things that fly out in space, things that we use in our everyday life in the wireless world and things that defend us.

***Matties:** A view of technology that they don't otherwise get.*

Lardizabal: That's right. They might see it on the news and you're more than one step removed, and here it's actually the pieces of equipment and the people who make them and make that happen.

***Matties:** Last year, you had Joey Hudy as a keynote speaker for these kids. Are you following the same format with the keynote speaker here as well?*

Lardizabal: There are a couple of keynote speakers. It's a little different this year. One focus that the San Francisco leaders (Kelvin Yuk and Mike Chapman) had keyed in on was having people who have a non-traditional background. The speaker right now, John Chapman, designs lighting systems for large projects like skyscrapers, but he's got a very diverse background. He's an active surfer, who works in a cool engineering field, and he's a normal person. That's what we want to get them to know.

***Matties:** How is a program like this funded?*

Lardizabal: It's funded very enthusiastically by the exhibitors here at IMS, for the most part.

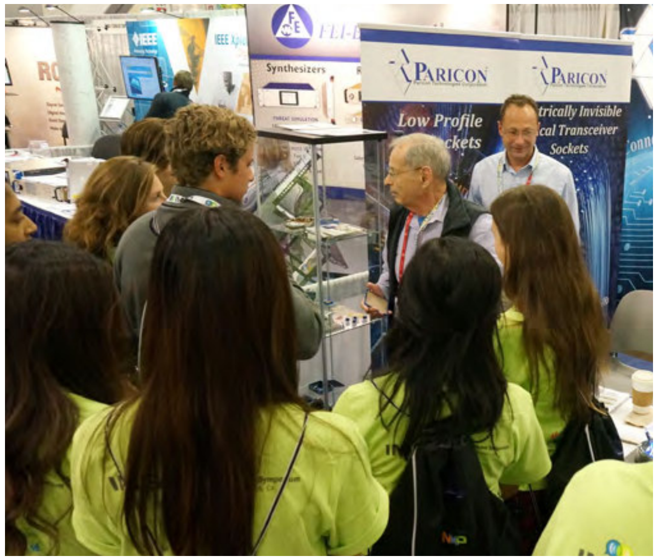
They contribute their support at different levels of sponsorship, and that's what's kept the program going, and they're never not there. There's always more each year. We sometimes have some funding from the National Science Foundation, too.

***Matties:** Past the event and the show today, what kind of work does your group do in between the shows?*

Lardizabal: In between the shows, the MTT group is actively involved in student programs with IEEE chapters throughout the country and around the world. There are student design competitions and a number of outreach efforts.

***Matties:** A lot of meetings that they can go and attend to keep the energy. Is there online interaction with the kids as well and websites for these kids?*

Lardizabal: For the college students there is a strong presence, and for the younger students the Internet is, I almost expect, an outlet for exciting and continuing interests. I see one route where that may happen. The IEEE may have a website available for continuity for IMS from year to year where the different cities can communicate. What's important there is actually so the students can communicate and see what was done at the other IMS shows, and as the teachers learn about where they can get information about STEM, if we can connect these



cities that IMS visits through these high school and middle school teachers, I think that's kind of an interesting area that we could be helping out on.

Matties: ***I know STEM is getting a lot of attention in the media from a lot of different places, the Maker Faire and so on, and just in general people are talking about it. If a company wants to be more active in supporting the STEM program, what should they do?***

Lardizabal: Certainly support us here at IMS at the different sponsorship levels, and find people within your company who want to come and volunteer. In 2015, we had over 50 volunteers from supporting companies, and a number of other companies coming out and supporting us as our STEM event. We encourage the volunteers and the industry presenters to provide an interactive day with an engineer and learn about not just the exhibits they'll be seeing, but what it is like to attend a scientific conference where ideas are shared. Certainly, they have more questions about the engineers themselves than they can handle.

Matties: ***Yes, I would think so. This is great. Thank you for all your efforts in this. I know you're making a difference one student at a time.***

Lardizabal: Thank you, and particular thanks to Kelvin Yuk and Mike Chapman who worked so hard to continue the IMS STEM program in 2016.

Matties: ***It's a great goal and it does make a difference, so thank you. Are there any final thoughts that you would want to share?***

Lardizabal: I think the most important thing I've seen in working on the STEM programs over these last few years is—and just earlier someone was talking about homeschooling, and really the focus there isn't the difference in what the teaching is—it's that the teaching is not teaching to a test. It's real life. You can do that in school too, and you can do that here at IMS at the symposium.

Matties: ***That is Excellent, Steven. Thank you so much.***

Lardizabal: Thank you. **SMT**

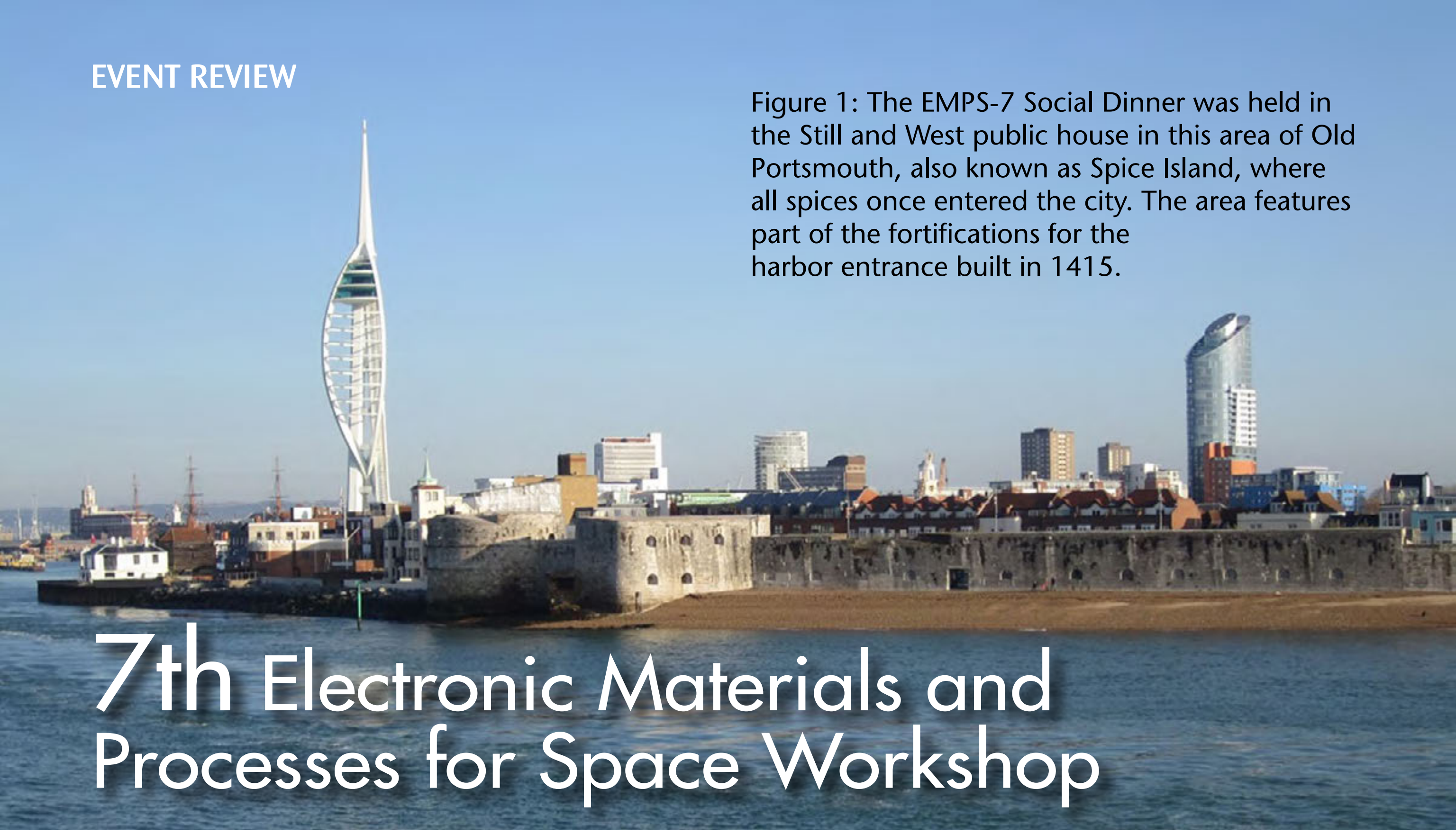


Figure 1: The EMPS-7 Social Dinner was held in the Still and West public house in this area of Old Portsmouth, also known as Spice Island, where all spices once entered the city. The area features part of the fortifications for the harbor entrance built in 1415.

7th Electronic Materials and Processes for Space Workshop

by Barrie Dunn
UNIVERSITY OF PORTSMOUTH

The EMPS-7 Workshop was held at the University of Portsmouth (UoP), UK on 13–14 April 2016. This Workshop followed on from an IPC/UoP Lead-free Risk Management (PERM) meeting at the same venue—convenient for participants attending both events and arriving from continental Europe and the U.S.

The Organizing Committee of EMPS-7 consisted of Jussi Hokka, European Space Agency (ESA) and Misha Filip, UoP. The Programme Committee consisted of Barrie Dunn; Jussi Hokka; Bill Strachan, ASTA Technology; and Martin Wickham, National Physics Laboratory.

A brief welcome and introduction to the EMPS-7 Workshop was given by Jussi Hokka and Barrie Dunn. This was followed by the opening address provided by Professor Graham Galbraith, vice chancellor of the UoP. Ninety-five delegates from industry, space agencies and academia attended this two-day workshop which was held in the magnificent Portland Building auditorium (Figures 1 and 2).

The participants this year represented 16 countries and included engineers from the U.S. and China. Prof. Galbraith was proud to note that this workshop had been founded by the University in 2010 and has continued each year at a different European venue.

Portsmouth is a dynamic and vibrant waterfront city and is unique being the UK's only island city and is noted for its links to the British navy, shipbuilding and in recent years it has become a hub to Space industries such as Astrium-Airbus, Spur Electron and BAE Systems. These companies rely on advanced materials for high strength/low weight spacecraft structures—many are based on carbon fibre technology. Coincidentally, these CFRP materials are also selected by the Ben Ainslie Racing team for the fabrication, in Portsmouth, of world

Figure 2: Some participants to EMPS-7 (photo thanks to Leo Schöberle).

class racing yachts. Summer 2016 will see these yachts take part in the Americas Cup which is being hosted by the City of Portsmouth, and it is here where the Land Rover BAR team is on a mission to bring the America's Cup back to British waters!

The first Workshop session concerned PCBs and circuit technologies. Maartin Cauwe from the Centre for Microsystems Technology, Belgium, presented the results of an extensive study into the embedding of passive components into PCBs for space applications. The reliability of such embedded passive components has been evaluated and a functional demonstrator manufactured. It was found the embedded technology samples performed almost as well as surface mount technology (SMT) counterparts environmentally tested in parallel. It was only the embedded 0201 resistors that had a minor impact on component reliability. At present, standarised testing of such technology is challenging as there are no design rules for space products and, as required by spacecraft contracts, there is no possibility for component replacement or repair with this new technology. Dr. Cauwe considered further embedding activities should include MOSFETs, power components and more complex modules.

> "It was found the embedded technology samples performed almost as well as surface mount technology (SMT) counterparts environmentally tested in parallel."

The next presentation concerned the development of new PCB surface finishes using "deep eutectic solvents" (DESs) based on environmentally benign liquids with remarkably high salt content. This work was described by Karl Ryder from the University of Leicester. DESs have found many applications related to electroplating, electro-polishing, immersion coatings, metal recycling and energy storage. DES technology has enabled the plating of PCB copper tracks with silver, nickel, tin and gold. A so-called "universal surface finish" has been developed by the Leicester team. Its plating chemistry and main successes were detailed by Dr. Ryder. The main PCB finishes comprise of electro-less nickel, immersion palladium and immersion gold (ENIPIG)—these potential space PCB finishes have uniform coverage combined with excellent planarity. The DES processes are free from acids and cyanides, have little effect (dissolution) on the substrate copper and were stated to result in highly solderable surfaces.

The reliability of flexible PCBs for aerospace applications was discussed by Hans-Peter Klein of Dyconex AG, Switzerland. Interconnect mechanical stress testing and exposure to extensive temperature cycling was performed on microvias having a diameter of less than 100 microns. It was found that flex materials having a low Tg could be subject to early in-service damage and their failure mechanisms were described in detail. Materials with a high Tg were recommended as they are not subject to either the assembly stresses caused by solder-assembly or the conventional spacecraft in-service life stresses. Flexible circuits with a high Tg can undergo rapid acceptance testing and provide meaningful predictions of service life.

Other research performed at Swera IVF, Sweden focused on the cracks that may form in PCB laminate during the thermal cycling of assembled electronic components. It was noted by Per-Erik Tegehall that tin-silver-copper (SAC) alloys are far stiffer than the tin-lead solders they are replacing. One effect, during large delta T thermal cycling of area grid array (AGA) packages mounted to PCBs, is that the SAC solders stress the solder pads far more than the "compliant" SnPb solders and this can cause cracks to develop beneath the copper pad terminations. Many reliability tests have been performed at Swera, particularly related to Ball Grid Arrays assembled onto daisy chained monitoring circuits within PCBs. In general, the reliability of the SnPb solders was found to be "lower" than that of the SAC alloys, but it is only when detailed metallography is performed that defects are observed in both configurations. It is essential that any micro-sectioning of solder joints assemblies, after completion of environmental testing, includes the removal of all flux residues followed by mounting the samples in a room temperature hardening epoxy (under low vacuum). When a fluorescent agent is added to the molding resin fine cracks can be observed during optical inspection under UV light. SnPb solders degrade by thermal fatigue within the solder alloy, however it was surprising to find that the SAC soldered assemblies can also degrade in two distinct failure modes. Some SAC joints become completely recrystallized, and comprise of single grains. These are very strong in the Z direction and cause extensive pad lifting and fracture in the resin below the pad. Beneath the same AGA some SAC joints are seen to be multi-grained and these were noted to fail at the solder to pad interface. Figure 3 shows images of SAC solder joints taken with Electron Back Scatter Diffraction (EBSD) after thermal cycling—the left-hand image shows a single grain of random orientation (other single-grained balls had different orientations) and there is no crack within this grain, only a lifted pad. The right hand ball is multi-grained and here the failure is within the solder.

Dr. Tegehall concluded that cracks forming in the PCB laminate might improve the fatigue life of SAC joints, but they can lead to an over-estimation of the fatigue life of such joints by at least a factor of three.

Jussi Hokka outlined the roadmap identified by ESA-Estec, the Netherlands for advancing technologies related to PCBs and several assembly technologies until 2020. He detailed the activities of several ESA-Industry working groups actively engaged with SMT and PCBs

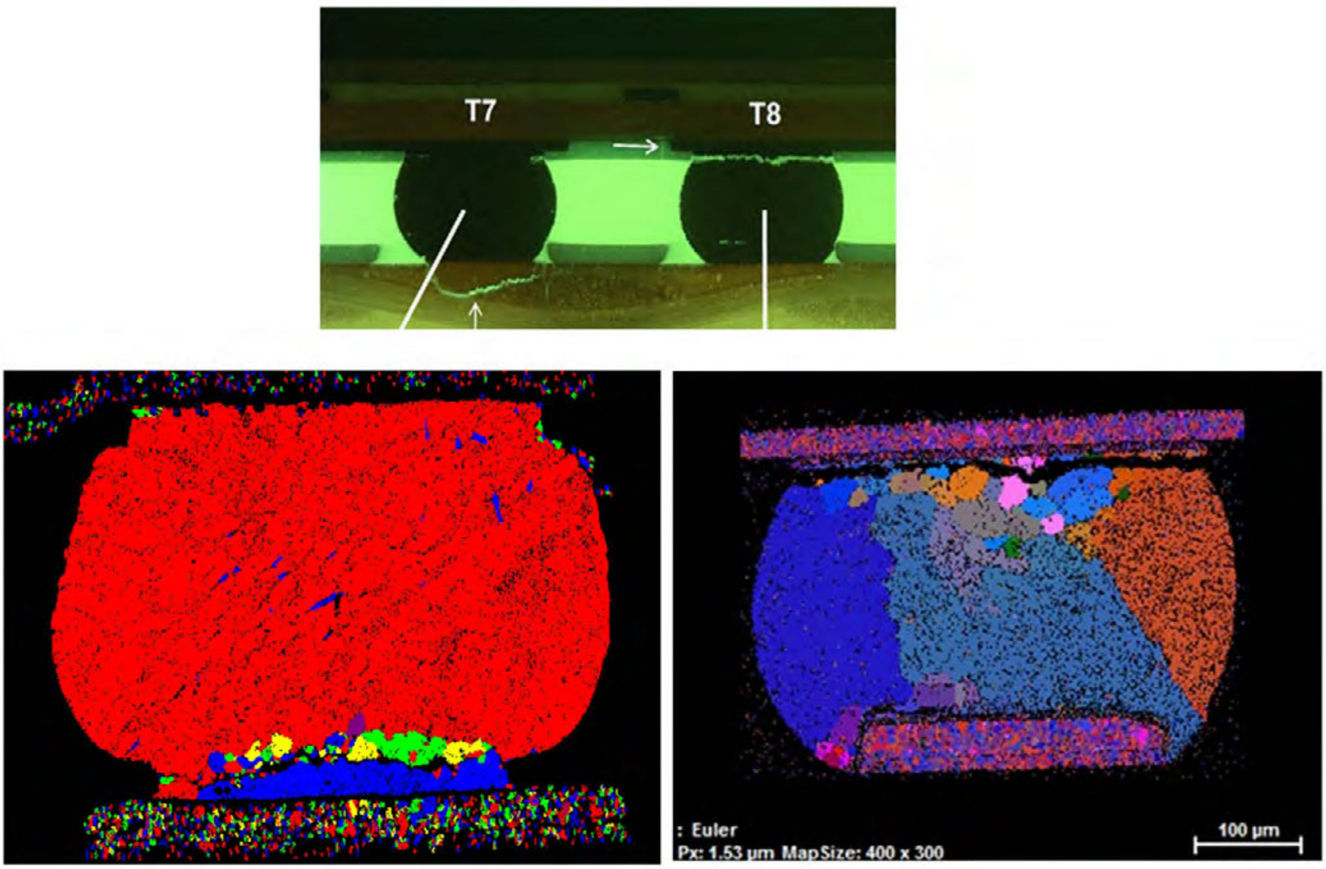


Figure 3: AGA ball joints made from SAC alloy but having various grain sizes, orientation and two distinct thermal-fatigue failure modes. Courtesy of SWERA-IVF.

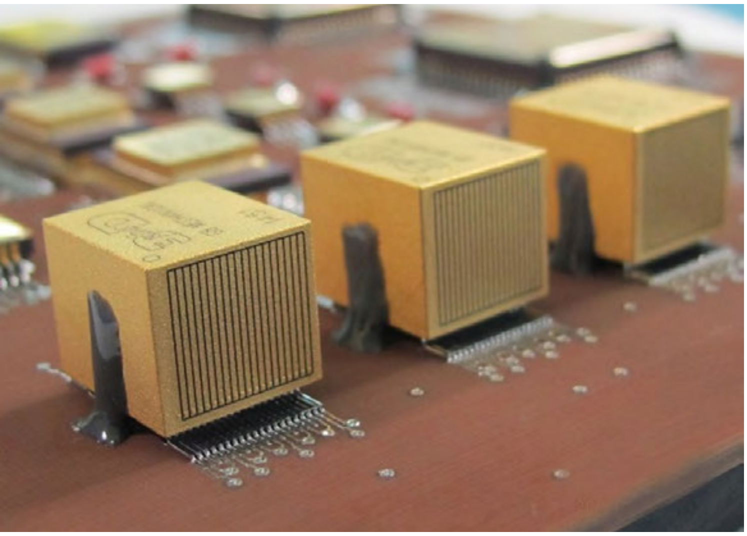


Figure 4: Populated PCB that included 3D-Plus EEPROMs for SMT Verification testing. (SENER)

and emphasized the importance of miniaturizing circuitry with high density interconnect technology. The roadmap also addresses spin-in opportunities and legislation threats posed by REACH and RoHS.

The REACH regulations and their impact on space hardware were also covered by Asensio Zapata of Airbus-Toulouse, their surface treatment and M&P expert. Of particular importance to the space industries will be the exclusion of hexavalent chromium whose sunset date is expected to be September 2017. This is of significant concern due to such chemicals being used extensively for the corrosion protection of spacecraft electronics and structures. The workhorse, Alodine 1200, employed throughout spacecraft hardware for surface corrosion protection, or as a primer for paints, also has a low contact resistance which is ideal for the grounding of spacecraft electronics constructed from aluminium based alloys. Zapata's laboratory research covered many coatings and indicated that alternative Cr+6 -free conversion coatings, such as SurTec R 650, may have suitable properties for passivating aluminium along with low contact resistance—this coating has a faintly visible blue coloration.

Engineers Ángel Bustos and Iñaki Hernanz, from SENER, Spain described an extensive verification program where a space-approved adhesive staking compound was used to provide more robustness to 3D-Plus EEPROMs solder-mounted onto PCBs (Figure 4). Without special component-lead bending design such adhesives can over-stress solder joints due to their high thermal expansion coefficients (during both assembly/curing and subjection to thermal cycling during verification tests). Of particular importance is the application point of the glue – by trial and error this location was optimized in order to satisfy both the vibration and the thermal cycling test environments stipulated by ECSS-Q-ST-70-38 (the European space standard: "High-reliability soldering for surface-mount and mixed Technology").

The development of a thermally conductive carbon fiber reinforced polymer (CFRP) manufactured electronic box for space applications was described by Luis Pina on behalf of teams from Portugal and Germany (led by INEGI, University of Porto), a study financed by ESA. The CFRP test structure represented a mass saving of 23% when compared to a similarly shaped aluminum housing. The electrical conductivity (Figure 5) and thermal conduction of the CFRP material was enhanced by adding carbon nanotubes to a special epoxy resin system developed by Huntsman for "low outgassing under vacu-

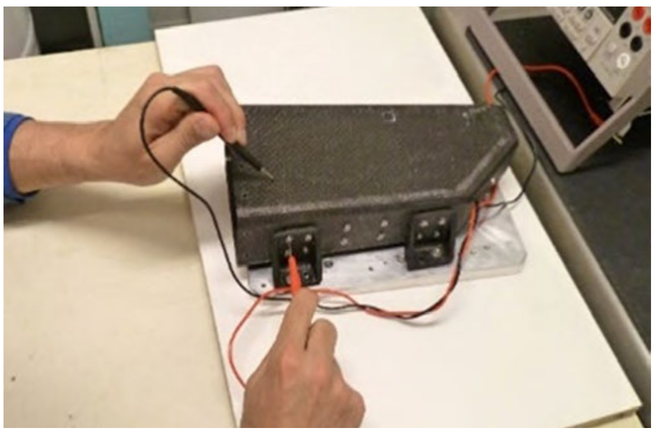
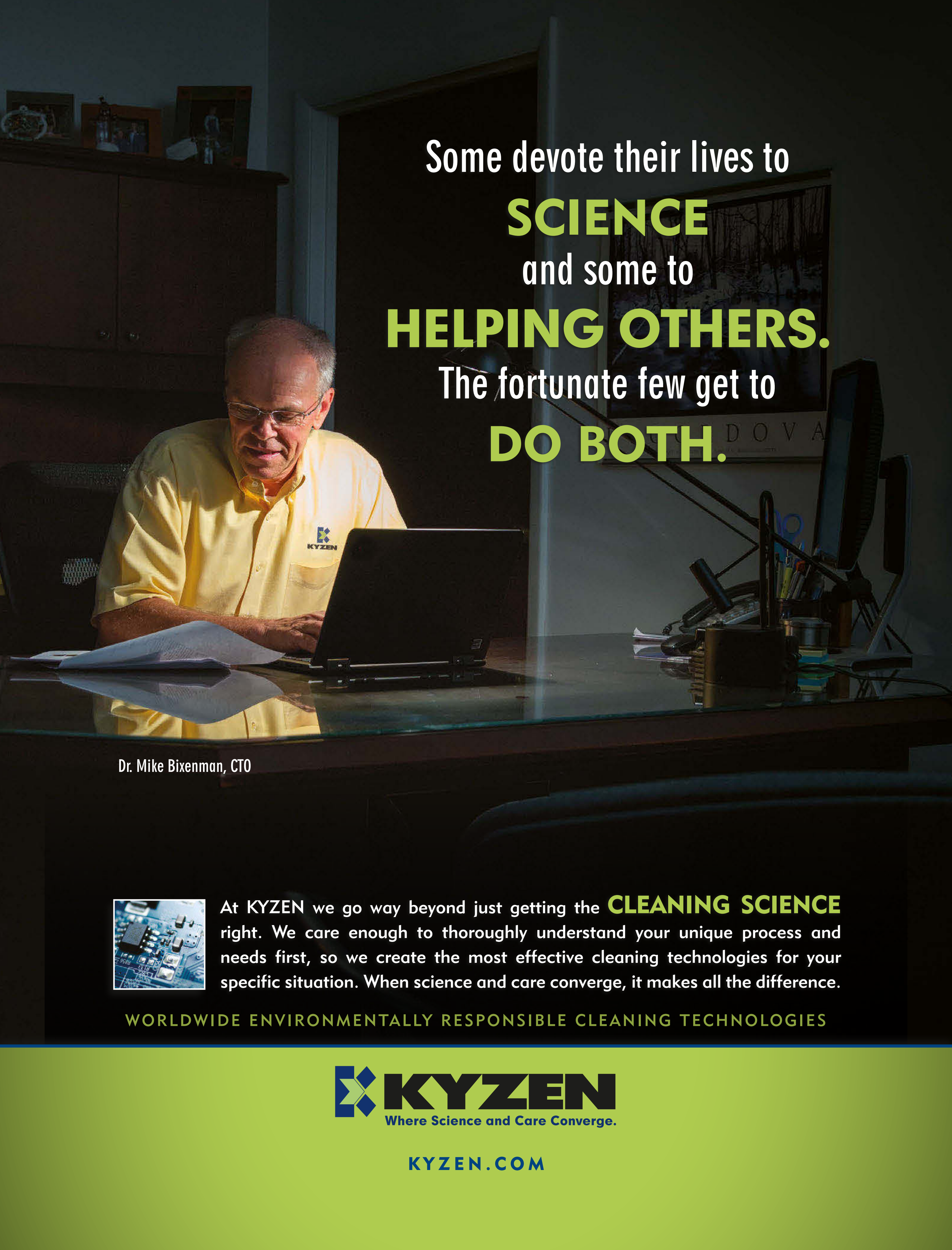


Figure 5: Electrical resistivity measurements being performed on a prototype CFRP electronic housing: Resistance between metallic base-plate and bonding studs < 0.1Ω. Resistance between housing surface and bonding stud (shown above) < 1 Ω. Maximum resistance between two arbitrary points on this housing <10 Ω. (INEGI).


Some devote their lives to
SCIENCE
and some to
HELPING OTHERS.
The fortunate few get to
DO BOTH.
Dr. Mike Bixenman, CTO
At KYZEN we go way beyond just getting the CLEANING SCIENCE right. We care enough to thoroughly understand your unique process and needs first, so we create the most effective cleaning technologies for your specific situation. When science and care converge, it makes all the difference.
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um" space systems. Although the mass reduction was deemed a significant success, the lower than expected thermal performance (92C compared with a predicted 85C) during thermal balance testing was thought to be due to the difficulty in mixing the nano-particles into the components of the Huntsman resin. Materials and molding/manufacturing times were costed. It was calculated that if more than seven housings were to be procured, CRFP housings would become cheaper than if manufactured from aluminum alloy.

David Pinsky described the results of an industry round-robin (including Raytheon-Boeing-Rockwell Collins and Raytheon Space) that investigated the risk of tin whisker growths on surface-mount components solder-assembled to PCBs. These components had been electroplated (leads and terminations) with pure tin containing less than 3% lead. Various well-defined soldering processes were selected by the participating companies in order to assemble a large variety of component types onto PCBs. Some soldering processes could achieve full dissolution of the pure tin into the resulting solder joints. These are termed "self-mitigation" processes as they prevent the risk of whisker growths and electrical shorting. The study included various PCB finishes and a very wide range of component package styles. The assembled sample boards were then inspected by XRF in several lead locations. It was found that the PCB finish and the PCB pad size had minor effects on whisker mitigation, but the actual soldering process applied was extremely significant. Pinsky's presentation highlights the component types nearly certain to self-mitigate under all process conditions (e.g., the smaller chip components). Usually it was the process which caused some components to self-mitigate, but one component (0612 chip) stood out as exhibiting a very low probability to self-mitigate. This round-robin study is continuing and will incorporate many new families of components/packages.

Tin whisker mitigation for lead-free surfaces was also described by Marko Pudas (Picosun Oy, Finland). Here, atomic layer deposition (ALD) conformal coatings were applied to finishes having a propensity to whisker. Scanning electron microscopy revealed that ALD coatings markedly reduce the occurrence and length of tin whiskers on so-treated PCBs. Mark Ashworth (Loughborough University) also characterized whisker mitigation processes that utilized the electrochemical oxidation of electroplated tin and tin-copper samples. The oxidation of parallel sets of samples was achieved either naturally in air, or by using both borate buffer solutions, and potassium carbonate/bicarbonate solutions. After almost 4 years of ambient storage the tin whisker density on samples naturally oxidized in air remained high (6000 whiskers cm-2), whereas the artificially oxidized coatings demonstrated far lower whisker densities (about two orders of magnitude below the untreated samples). Another coating was finally described; it was based on a molybdate conversion coating. Although this produced the thickest of all measured oxides on tin, remarkably, it was less able to mitigate whisker growth.

The session covering Space Design and Components commenced with Johan Leijtens (LENS R&D, Netherlands), and an overview of his designed and built BiSon series of sun sensors (Figure 6). These sun sensors have been used in commercial applications, in particular for the management of continually rotating/moving of solar arrays in the Sahara Desert in order to achieve optimal orientation to the Sun's rays. His latest design of sun sensor incorporates an integrated connector and PEEK inserts to a ceramic molded part. All build materials are selected so have low-outgassing-under-vacuum and matched coefficients of expan-

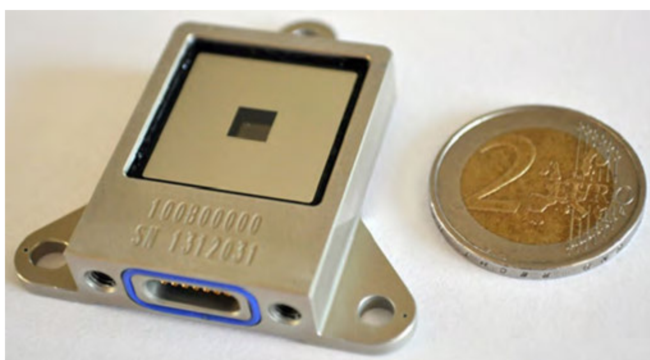


Figure 6: BiSon 64 type miniature sun sensor from LENS R&D.

sion; this provides for a simple design resulting in a high reliability with ultimately lower costs. The recent designs are very suitable for use onboard the many hundreds of solar powered small/cube satellites being built by universities and institutes.

Sarinova Simandjuntak, (University of Portsmouth), then reviewed the performance of sensors that have the potential to be used for the detection of corrosion or damage within electronic cables and connections. Spacecraft launch sites are frequently located in marine environments (e.g., the Kennedy Spaceflight Centre in Florida and the Kourou Spaceport in French Guiana). The proposed sensor designs are expected to detect degradation of both power cables and communication cables between launch complexes and on-site command centers. This technology is certainly of value to the wind power industry where turbines are located off-shore and where such saline environments have caused costly failures to power lines.

Area Grid Arrays are usually terminated with solder balls or solder columns. Wilfried Akalmavo from HCM- Systel, France, described how such terminations can be removed and then replaced by far more robust columns of solder that are reinforced with very fine copper tape. Advanced electronic packages supporting the reinforced copper-SnPb columns have been evaluated to an "ESA-ECSS capability and verification test plan". The extensive program described in detail by Akalmavo, demonstrated that the refurbished AGAs have passed environmental testing (comprised of thermal shocks, 1,500 thermal cycles and vibration) with flying colors. Rajan Bedi (Spacechips Ltd) ended this session with a talk that described selected technical requirements for the next generation for spacecraft electronics.

The final workshop session, entitled Interconnection materials, was kicked off by Dong Junking of the Chinese Academy of Space Technology (CAST). She presented an overview of spacecraft assembly capabilities in China and described their visual inspection and x-ray requirements for column grid array packages. Typical defects were illustrated and an account given as to how they could be minimized during processing. Her second presentation was a review of the development and challenges associated with RF-MEMS packages for integration into spacecraft. Known good die (KGD) testing for best electrical properties is seen in Figure 7. RF-MEMS packages are considered more critical than IC packages, especially for space applications. This is due to effects of both radiation and RF loss – caused by miniaturized designs and exposure to thermal-mechanical stresses during operation.

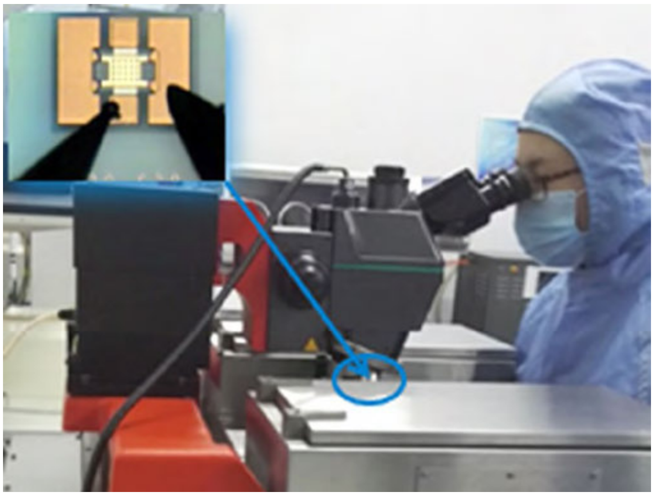


Figure 7: KGD testing during MEMS assembly for a satellite light phased array antenna (Courtesy of CAST).

An extensive overview of the work performed under ESA contract by Aerospace & Advanced Composites GmbH (Austria), was presented by Michael Scheerer. He discussed the results of testing the electrical resistance, microstructure and mechanical performance of a wide range of solder alloys. These included the SnPb, SAC and InPb solders prescribed by ECSS Q-ST-70-08 for specific applications. Properties were assessed from cryogenic, to room- and elevated-temperature environments. Microstructure features were equated to creep resistance, mechanical properties and modes of failure. The influence of grain boundaries on electrical resistance could be verified (smaller grains lead to higher electrical resistance).

The presence of voids in solder joints have been a focal point for electronic manufacturing engineers since the start of the Space Age. Until 1997, internal voids were not consid-

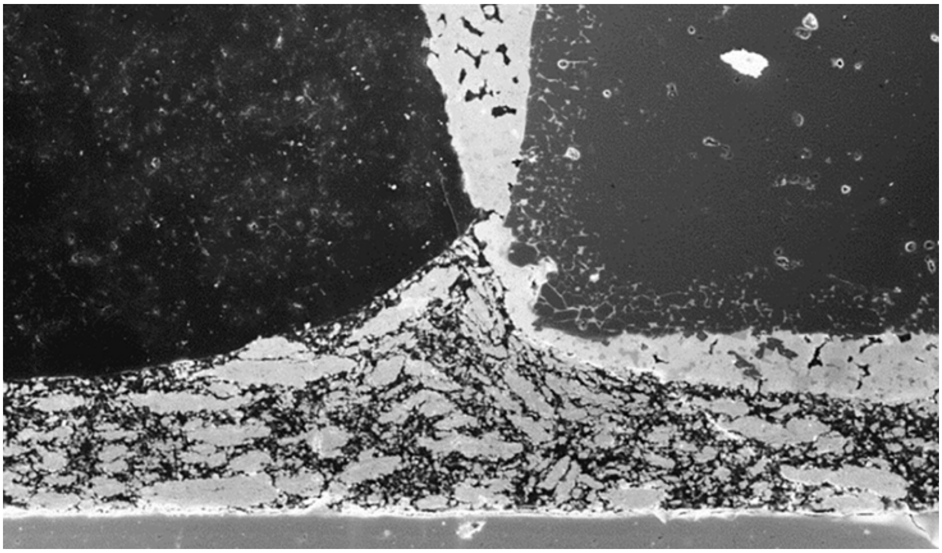


Figure 8: Micrograph of a high temperature adhesive under evaluation at the National Physics Laboratory, UK.

ered a real problem. However, today the same joints are considered a problem, but this might only be because we now have the ability to observe them under high resolution x-ray inspection! Poul Juul (manager of Hytek, Denmark) presented an interesting review relating various types of voids in solder joints to reliability concerns. He discussed the root causes of different kinds of voids and concluded that voids in solder fillets could be reduced by optimizing the quality of surface finishes on components and PCB pads. The selection of correct solder alloy and flux is also important, as is the optimization of soldering temperatures and profiles.

Luca Moliterni (IIS Progress, Italy) compared the impact of "automated paste in hole soldering" with "automated selective wave soldering" on the reliability of electronic assemblies. He described the characteristics of both soldering technologies. A chart compared "paste in hole" and "selective wave" against important parameters that included energy consumption, flux contamination, repeatability, defects (solder and short circuits), component availability and the prospect of successful industrialization of these processes.

The final presentation was made by Martin Wickham (National Physics Laboratory, UK). Martin assessed various sintered materials and conductive adhesives as alternatives to high temperature solder alloys. Such high temperature attachment processes are required for electronics incorporated within high performance power equipment, electrical vehicles and spacecraft such as the current ESA BepiColombo mission (to the planet Mercury) where electrical systems are expected to endure temperatures in access of 350°C. High lead-containing alloys are no longer permitted by RoHS legislation. Electrical connections between various ceramic component terminations and PCB finishes have been evaluated by NPL using conductive adhesive such as Elcosint. The properties of conductive adhesives were compared against samples made using conventional high melting point solder alloys. Preliminary test results, based on thermal ageing and thermal cycling, were presented and results demonstrated the Elcosint® materials (Figure 8) to have outperformed each solder alloy. Additional work is planned and will be supported by the sponsoring partners—persons interested in joining this partnership can contact Martin at NPL.

EMPS workshops are publicized on a University of Portsmouth website from which all past presentations (2010–2016) can be freely downloaded. For those wishing to present their work or attend the next Workshop, EMPS-8 will be hosted by ESA-Estec, in Noordwijk, the Netherlands on 10–12 April, 2017. Details will be announced here. SMT

Barrie Dunn is an EMPS (Electronic Materials and Processes for Space) co-founder, and professor at the University of Portsmouth. Previously, he was with the European Space Agency as head of materials and processes division.

Selecting a Selective Soldering System, Part 5

by Robert Voigt
DDM NOVASTAR

For the conclusion of our selective soldering discussion, I thought it would be useful to do a quick wrap-up to remind potential buyers about some important considerations that affect the purchase decisions they make. So, here goes:

Buy the Right Machine for the Intended Purpose

Selective soldering is often touted as being the "latest and greatest," but it's not the best technology for all boards. The fact is, selective is a much slower process than wave because it has to process each lead or closely spaced set of components one at a time. Selective is the only way to solder through-hole components in a production environment on a mixed technology board or if there are obstructions on the underside of the board. But wave soldering is by far the fastest way to preheat, flux and solder a board with only through-hole components.

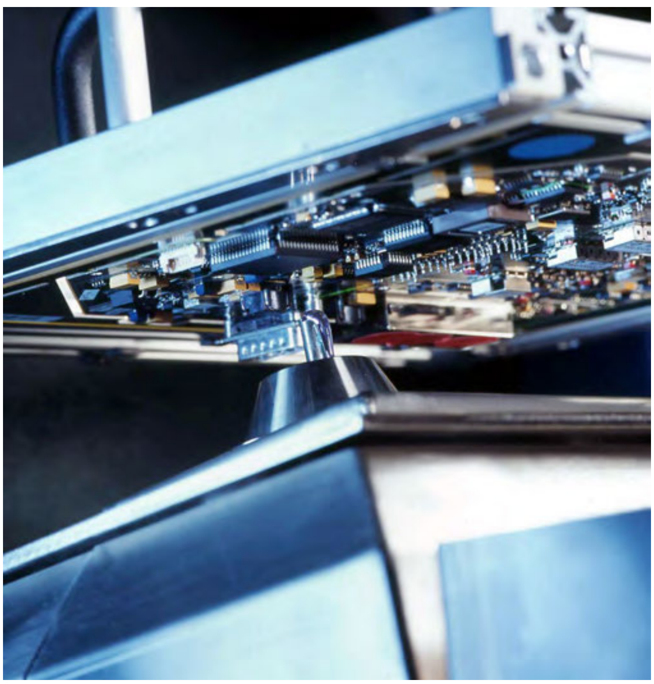


Figure 1: Selective soldering leads on a hybrid PCB both through-hole and surface mount components.

Wave soldering dates back to a time even before integrated semiconductors were used, so it's not a new technology. However, there have been many advances to the equipment as the industry has evolved, and it remains a very effective and cost-efficient manufacturing/assembly method to this day. No technology can match it for speed and no other method can improve on its joint strength.

Selective soldering is becoming much more common today, for very good reasons. It can process through-hole components on boards with mixed technologies, multiple shapes, patterns and devices; it is significantly faster and more reliable than hand soldering, so it's a natural step up from a prototype setting to a production routine; once programmed, recipes can be archived to perform the same operation in exactly the same way in the future, ensuring reliable repeatability.

Hybrid boards exist for a number of reasons. In spite of the proliferation of surface mount components, which are perfect for high density functions on smaller and smaller footprints, through-hole devices are still used for high-power applications and those with connectors which require a very strong, stable joint. And this is where selective soldering shines.

Understand the Process That's Best for Your Assembly

While selective soldering does not necessarily replace a wave machine, depending on the nozzle type used it can replicate the wave technique in a compact way. For instance, a fairly

Figure 2: A wide variety of nozzle types and shapes can be used for the most efficient process.

large row of connectors/leads not in close proximity to SMD components could use a wide nozzle to swipe (or wave) the entire row at once. On the other hand, a small area situated near an SMD would require a very small nozzle to avoid disturbing the surface mount device.

There are myriads of standard nozzle designs for performing dips and drags, and they are limited only by your imagination or the complexity of the board. Selective gives you many ways to tackle a soldering routine, so you want to think about the sequence, the nozzle configurations you use, and the best way to save processing time. It may make sense to buy a custom nozzle if you have a high volume board with a unique profile. After all, nozzles aren't very expensive and they last quite a long time.

Jet nozzles attack the board at about the same angle (7°) as a wave machine does and can deliver a high volume of solder using a tapered tip which guides solder roll-off in one direction, returning unused solder back to the pot from its trailing edge.

Wettable nozzles provide finer accuracy than jet type which makes them better suited to connections in close proximity to SMDs. It also produces less oxidation because there's less contact with air. For this reason, wettable nozzles are also best suited for lead-free solder, which tends to be more vulnerable to oxidation.

Contract manufacturers who assemble a wide variety of board configurations should make sure the machine they're investigating can accommodate both types of nozzles and/or custom/hybrid configurations if they think they are ever going to need them.

Think about the Future

Perhaps you're considering the acquisition of a selective solder machine for a specific new project, or you're a contract assembly shop expanding your offerings to handle custom configurations. Look beyond the immediate future and think about how your needs may grow. Some selective manufacturers can offer a base machine that allows for the addition of future modules to expand your capabilities. But some don't, so be sure to ask.

Additional modules can come in a number of formats, allowing you to double or triple your production throughput. You may be able to get them combined in pairs to perform two operations on the same lead, or get separate modules that only perform a single fluxing, preheat, or solder operation.

Beyond modules, some manufacturers offer automatic conveyors which allow the operator to stage boards and feed them automatically when a previous board is complete. This allows one operator to perform multiple functions rather than keeping his attention on a single machine.

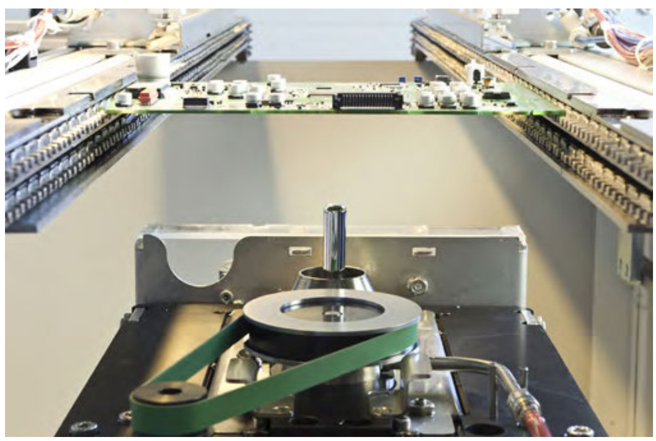


Figure 3: A wettable nozzle on an inline selective soldering machine.

Don't skimp by avoiding the small additional cost of a nitrogen inerting system. Nitrogen improves soldering performance by assisting thermal capability and improving surface tension of the solder. Leaded solder is considerably more forgiving than lead-free in terms of oxidation, degradation and connection quality, so nitrogen is not always needed in those cases. However, it is absolutely necessary for any application using lead-free solder. To ensure a good solder joint using lead-free, the nitrogen bubble protects the solder integrity during the process with no voids in the final connection.

Figure 4: Example of an easy-to-use Windows interface.

Programming Options

As described earlier in "Selective Soldering, Part 4," hybrid boards can be challenging to program because of the interface with SMT components and the nature and arrangement of addressable, through-hole points. Figuring out the best sequence to optimize production speed is usually a combination of common sense along with available software features.

The two best ways to "acquire" the board into the system are by scanning the board or importing CAD data from a Gerber file, although in a pinch, you can also take a digital photo.

With more advanced programming options come higher costs, but they often pay off in greater efficiency and throughput. A good software package will be intuitive and easy to use. And while many of these decisions can be made by a thoughtful and experienced board programmer, some sophisticated software packages offer optimization tools to achieve the best pattern for complex board geometries. Such software packages will, along with the judgment of the operator, be capable of deciding whether changing a nozzle would be advantageous or not.

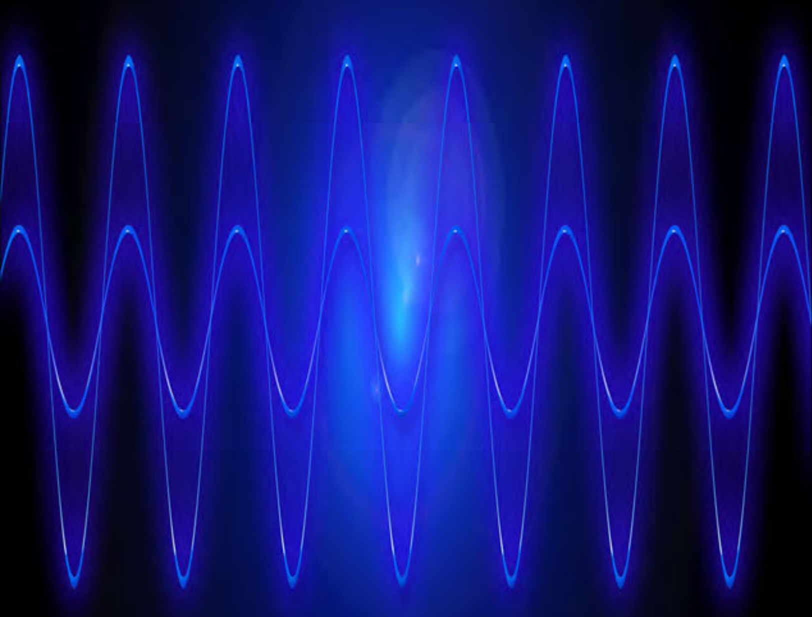
The selective soldering machine you buy will always offer its own software; however, if you like the machine but its software isn't exactly what you want, you can often purchase a third-party program which can export the formatted board back to the machine.

Be sure to ask for a free demo version of the company's software for you to evaluate before purchase. It will allow you to see how intuitively it handles graphic file imports, configures them, and programs special circumstances that may arise in your production routines.

Check References

Remember to consult a variety of machine providers. Talk to the manufacturers themselves if possible, and get references to contact before making a purchase. An important consideration for a complex machine such as a selective soldering system and associated options is factory support, specifically training, software, upgrades and spare parts. **SMT**

Robert Voigt is VP of global sales at DDM Novastar Inc. To reach Voigt, click here.



Nondestructive Inspection of Underfill Layers Stacked up in Ceramics-Organics-Ceramics Packages with SAT

By F. Sarrazin, et al.*
FLEXTRONICS INTERNATIONAL LTD

Abstract

Ceramics packages are being used in the electronics industry to operate the devices in harsh environments. In this paper we report a study on acoustic imaging technology for nondestructively inspecting underfill layers connecting organic interposers sandwiched between two ceramics substrates. First, we inspected the samples with transmission mode of scanning acoustic tomography (SAT) system, an inspection routine usually employed in assembly lines because of its simpler interpretation criteria: flawed region blocks the acoustic wave and appears darker. In this multilayer sample, this approach does not offer the crucial information at which layer of underfill has flaws. To resolve this issue, we use C-Mode Scanning in reflection mode to image layer by layer utilizing ultrasound frequencies from 15MHz to 120MHz. Although the sample is thick and contains at least five internal material interfaces, we are able to identify defective underfill layer interfaces.

Introduction

Since the introduction of scanning acoustic tomography (SAT) also known as C-Mode scanning acoustic microscopy (CSAM) technology to the semiconductor package manufacturing more than two decades ago, several thousand pieces of equipment have been serving the industry as essential quality assurance tools. Acoustic imaging offers inspection of imperfect material joints containing non-metal structures, such as delamination between silicon-metal joint glues, which in turn are difficult if not impossible to detect with X-ray imaging approach. Therefore, the device package failure analysis engineers routinely utilize both X-ray and acoustic imaging technologies as their complimentary non-destructive analysis tools.

The SAT technology does have its own limitations derived from the physical nature of acoustical wave: requirement of liquid medium to transfer ultrasound energy, requirement of flat and smooth package surface, difficulty in designing transducers, low resolution at lower ultrasound frequencies, less penetration at higher ultrasound frequencies, and slow acquisition speeds, etc.

To extend these limitations to their ends, development of new transducers or probes with applicable frequency range from 50MHz to 300MHz are very crucial, along with other signal handling advancements.

Recently, Kitami, et al., reported development of a specially designed signal processing unit and high resolution probes that can image 1µm features engraved in silicon material[1] and an echo gating technique that intelligently tracks the surface plane so that it drastically reduces invisible area due to rough exterior surfaces of the package[2].

Encouraged by these new developments, we conducted a case study of SAT and X-ray CT imaging for a multilayer package consisting of two ceramics with flip-chip packages on organics substrates in between. The SAT system available for this study is also equipped with high resolution unit that generates well compressed pulses with excellent signal to noise ratio in a wide range of probe frequencies. In this report, we describe how flaws around flip-chip substrates embedded in a thick stack of ceramics mounted with surface components can be nondestructively inspected layer by layer to pinpoint the manufacturing defects hidden in them.

Figure 1: Illustration of material structure of the sample and their thickness in micrometer. Outer layers are high-temperature, co-fired ceramics.

Experimental

On the manufacturing floor, we noticed that some of the multilayer devices electrically failed but they were also unable to find out the root cause using existing analytical equipment. Cross sectioning the sample is the only option which is not only destructive but also time consuming just to find out about the flaws along one line out of entire surface. Therefore, we selected to study the most acoustically complex device to investigate the capability with state of the art X-ray and ultrasound imaging technologies.

Sample Descriptions and Preview

The sample consists of high temperature co-fired ceramics (HTCC) substrates as top and bottom layers embedded with chip packages on polymer substrates in between as illustrated in Figure 1. The dimensions are 18 mm width, 35 mm length, and 3.3 mm height. The regions of interest for possible delamination or voids are the joints to each interfaces between deep layers. Of course, these HTCC layers themselves are multi-layered substrates as well.

So far we have accumulated some knowledge on computed tomography (CT) inspection of various complex structures[3-4], especially for solder joints with good and clear CT images. This ceramics package, however, was just quickly viewed with an X-ray CT system to find out any flaws in metal features and ceramics layers. 3D-CT inspection revealed that there are no apparent flaws in the material layers themselves; but no further attempts were made with CT inspection because it is difficult to observe delamination type of flaws between materials given the nature of X-ray beam that can easily penetrate such a flaw without significant intensity reduction. Comprehensive study with X-ray CT maybe needed elsewhere.

SAT Imaging

During manufacturing process at the beginning, the samples were inspected with available

CSAM system without much success, pointing at that complicated sample structure; eventually requiring destructive cross sectioning. For nondestructive inspection, it is challenging to construct acoustic image of multilayer structures, because the echoes usually involve multiple reflections as well as their interferences. The difficulty increases when the sample is thicker as it requires lower frequency acoustic beam with smallest possible beam spot at longer focal lengths to reach deep layers. To overcome these hurdles, we need to get optimized transducers[5] suitable to this particular sample.

All SAT results presented in this paper are from a new SAT system with high resolution unit option. This new SAT system has better capabilities covering transducer frequencies from 5MHz to 300MHz at prescribed frequencies, and especially with high resolution hardware option the user can virtually set any desired ultrasound frequencies that should fit to a particular sample conditions.

As preliminary inspection, we used lower frequency probes to image different layer interfaces and try to identify them with their pattern appearances. A 50MHz, 7 mm focal length probe was used to image the underfill layers UF1 and UF2 simultaneously with two echo gates. Figure 2 shows these images acquired by focusing upper underfill layer UF1.

After confirming solder balls of UF1, the focus target layer is shifted to lower level of second underfill layer UF2. The resultant images are shown in Figures 3 (a) and (b) in which we

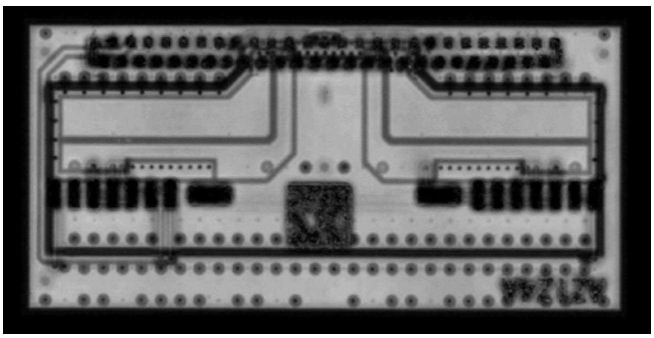


Figure 2(a): Image of underfill layer 1 focused with a 50MHz probe frequency. This layer includes solder ball connections between adjacent layers. The big square shadow is laser marking and smaller rectangular shadows are surface mounted components.

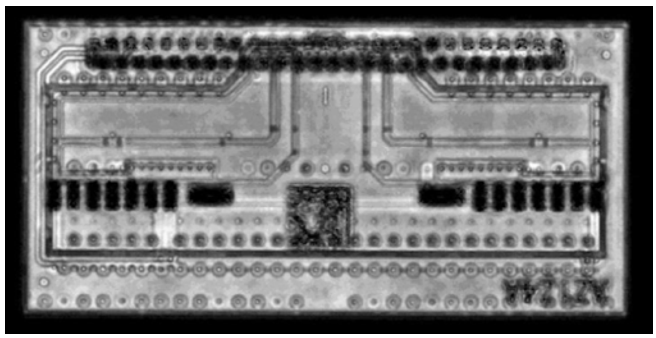


Figure 2(b): Image of underfill layer 2 acquired by focusing upper UF1 layer.

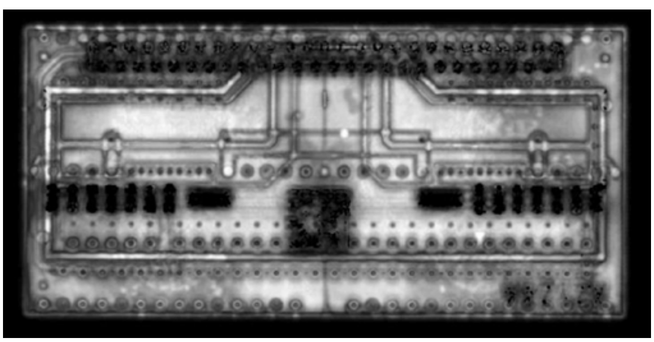


Figure 3(a): Image of underfill layer 1 with a 50MHz probe frequency. This layer is not in focus.

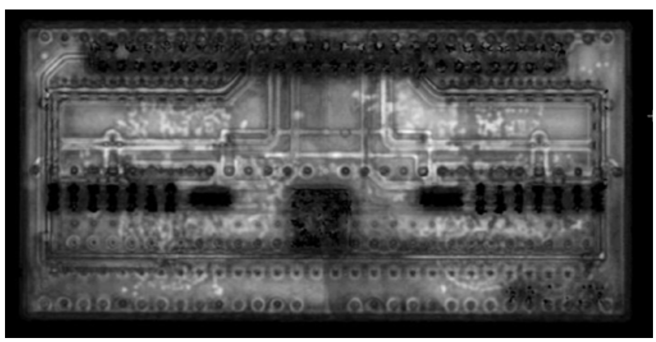


Figure 3(b): Image of underfill layer 2 with a 50MHz probe frequency focused right at this layer. Features of UF2 surface patterns can be seen more clearly at this focus condition.

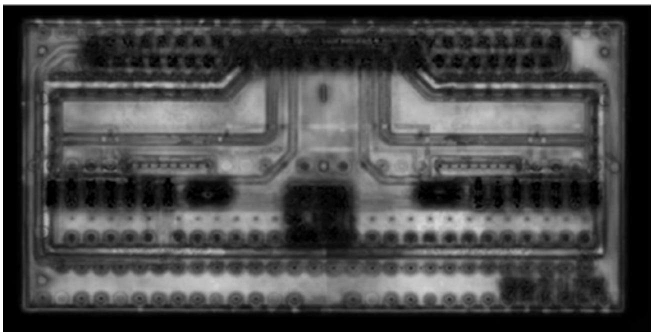


Figure 4(a): Image of underfill layer 1 with a 100MHz probe frequency. This layer is not in focus.

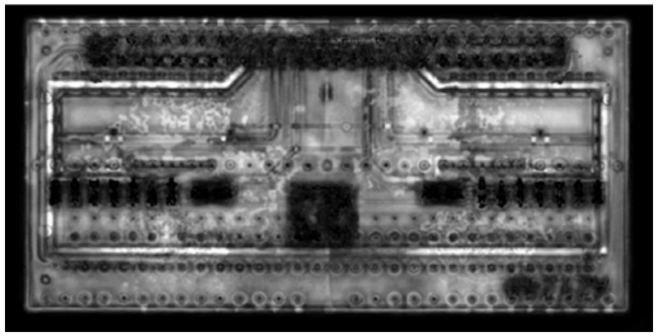


Figure 4(b): Image of underfill layer 2 with a 100MHz probe frequency focused right at this layer. Features of UF2 surface patterns can be seen more clearly in better contrast.

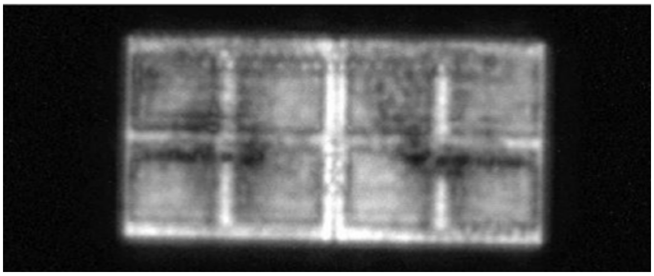


Figure 5(a): Through transmission scan with 15MHz.

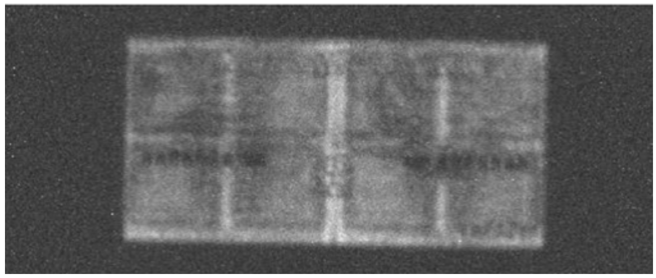


Figure 5(b): Through transmission scan with 25MHz.

can clearly observe circuit patterns of the interface. These initial results encouraged us to proceed with this focal length probe, we can attain images of desired levels to find their flaws.

When inspecting with SAT system, we prefer to use higher frequency probing for two reasons: improvements of image lateral resolution and better separation of layers or depth resolution. Therefore, we gradually increase the probe frequencies to 75MHz, 90MHz, and 120MHz above in 1MHz step until the penetration depth cannot reach to the surface of HTCC2 layer.

With similar focus conditions as in 50MHz imaging, 100MHz probe frequency is used to acquire the images as shown in Figure 4. With possible highest frequency, the SAT image quality improved in contrast as well as better resolutions in all x, y, and z directions. As we expect to gain clearer layer separation with higher frequency probing, we can now open up more echo gates for detail analysis which we will describe in the next session.

Image Inspection & Analysis

In acoustic image analysis routine, one popular method of finding flaws is to scan the sample in the transmission mode. In this mode, a transducer is placed at one side of the sample to transmit ultrasound signals and another transducer from opposite side listens the sound as it gets through all sample layers. If the lattices of the materials in the sample are mechanically connected and ultrasound energy is allowed to be transported, a portion of transmitted ultrasound gets through the sample, or otherwise the sound is blocked by the flaws such as voids and delamination. Therefore, the scanned image is quite straightforward to interpret: the sample under test is good when the pass–through sound intensity is high, or the image is bright, relative to flawed region that will appear dark. In Figures 5(a) and (b), transmission images of the sample inspected by using 15MHz and 25MHz transmission probes are shown.

As seen in the Figures 5, a through scan image quality is normally inferior to reflected echo image for several reasons. To penetrate a sample composed of organic compounds, lower frequency ultrasound must be used because more than 35MHz sound wave will be very difficult to penetrate most materials used in electronic packaging. A lower frequency (15MHz) unfocused probe will only offer low resolution images because their beam spot cannot be made small enough. Furthermore, through scan images do not offer layer specific layer information because transmitted sound wave have poor time resolution compared to the waveforms available in reflection mode. Therefore, this method is not appropriate for analyzing current sample that has several material layer interfaces, where we would like to find out about their flaws.

As we sweep probe frequencies from 50MHz to 120MHz for C-scan, best highest frequency for the sample is found to be around 100MHz at source. Therefore, we decided to employ this particular frequency in order to split layer interfaces and image them in a multi-gate setup. Figure 6 is the sample structure illustration and its associated actual echo waveform (A-scan) at

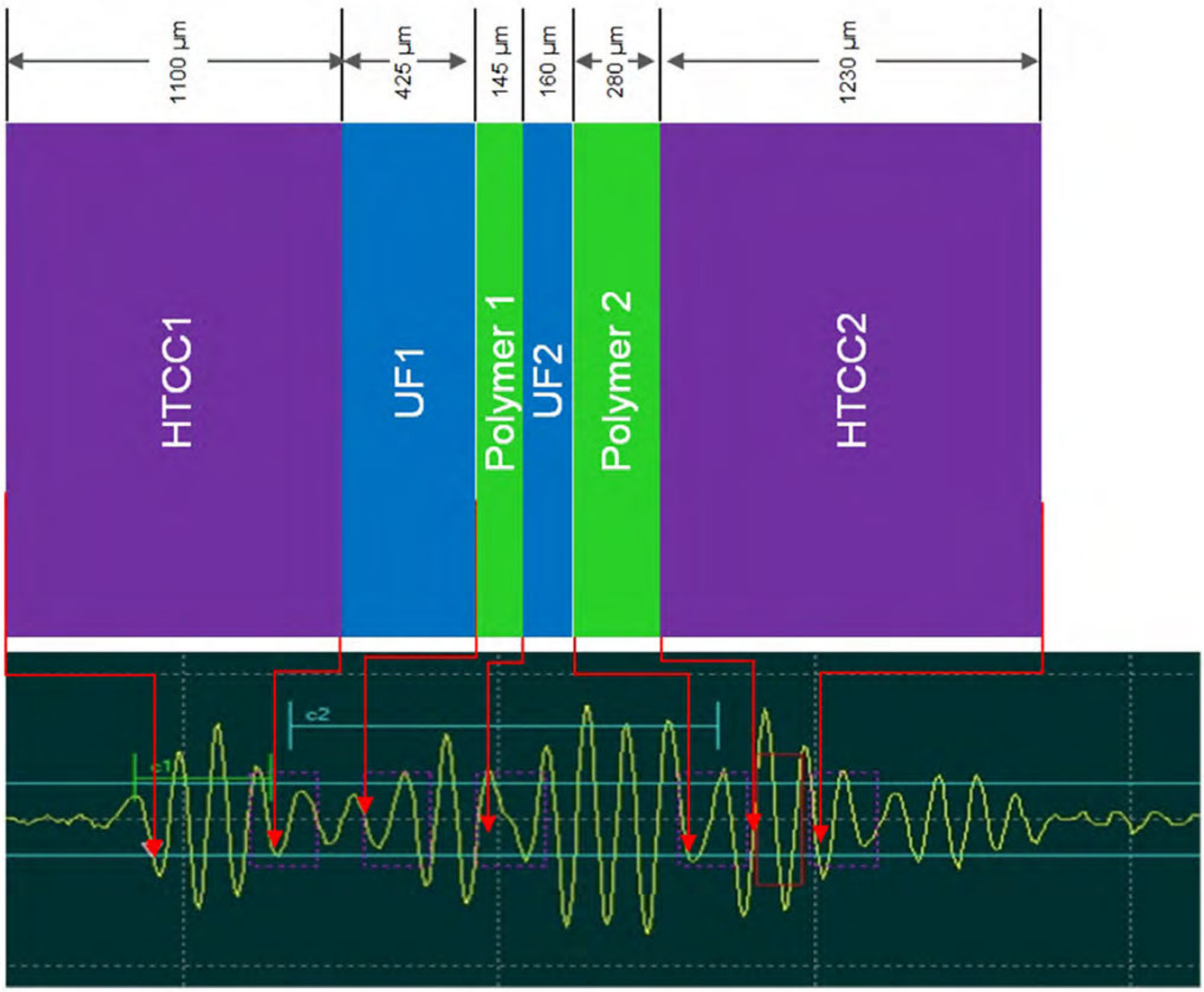


Figure 6: Echo pulse-train of the multilayer sample impinged with 100MHz acoustic wave packet. The arrows indicate the timed locations of each interface. Waveform sampling rate is 4GHz, and time resolution is 0.5 ns. Also note that HTCC and Polymers are multilayer stacked-ups.

100MHz captured with 4GHz digital sampling rate.

At optimum transducer frequency and focus depth, the echo waveform composition can be understood by measuring arrival time provided that approximate sound speed and thickness of each material is known. In the SAT system we utilized in this study, the sound speed of most electronic materials are readily available, and the time of flight can be measured using cursors with a resolution of 0.5ns on time axis. Therefore, we focused the beam to the middle of the packages and opened 6 echo gates to image all layer interfaces simultaneously. Although the

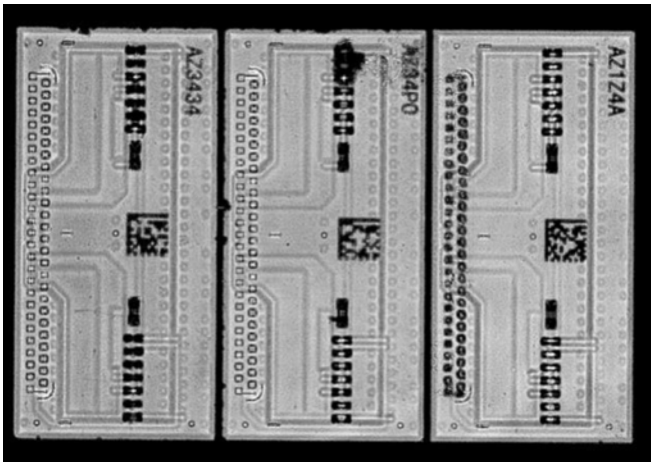


Figure 7(a): C-scan image from Gate #1 representing bottom layer of HTCC1 at 100MHz probe frequency. All three units show very similar images, except the shadow of misplaced surface mount condenser is seen different at the center unit.

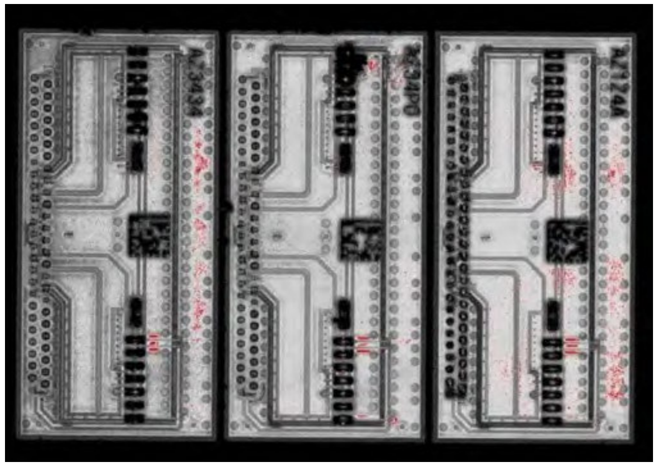


Figure 7(b): C-scan image from Gate #2, interface of HTCC1 top of UF1 at 100MHz probe frequency. All three units show very similar images. The inspection algorithm is set so that red color paint to highlight whenever a delamination of void is detected.

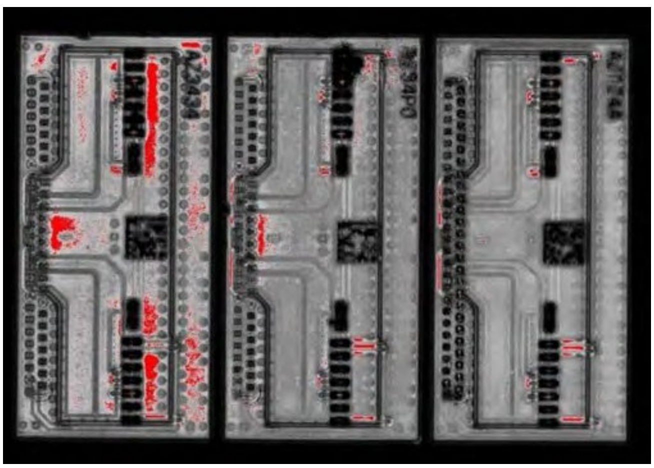


Figure 7(c): C-scan image from Gate #3, UF1 and polymer 1 Interface at 100MHz probe frequency. The inspection algorithm is set so that red color paint to highlight whenever a delamination or void is detected. Serious flaws can be seen in the left middle of the left-most unit possibly from UF1.

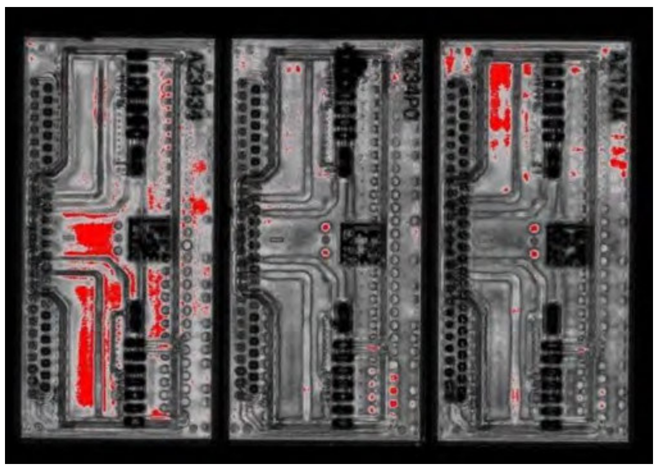


Figure 7(d): C-scan image from Gate #4, top of UF2 at 100MHz probe frequency. Both left and right units show significant delamination or less dense material regions as highlighted by red color. UF1 and some part of UF2 have flaws.

flaws can be detected by using one sample only, we present images of 3 samples together to make the discussion easier to visualize.

Figures 7(a), (b), (c), (d), (e), and (f) show 6 SAT images acquired by opening six different gates responsible for each layer interface to be inspected for three packages. The package at the middle is known to be an internally good unit while there is a misplaced surface mount device on it. The unit at left side has known electrical failure at left bottom area, and the unit at right side has electrical failure with no further information available.

While acquiring the images of every echo in a gate, the intensity level is simultaneously analyzed by an inspection algorithm to highlight red color over any area with abnormal increment of echo intensity caused by delamination or marginally low material density. As expected, the good part at the center exhibits very small red area for any layers imaged by the gates numbers 1 through 6. Inspecting the images of left part revealed that middle to bottom area at the lower level underfill UF2 has serious delamination, the finding generally agreed with the open pin area as indicated by independent electrical test report.

Recalling the images on Figures 2–5, the right side sample is the one we emphasize in this capability study with electrical fails at unknown area. The SAT inspection of this sample indicates that while upper underfill layer is free from flaws, top left corner of lower underfill layer (UF2) has delamination as shown in Figure 7(d). This flaw area is also appeared in Figure 7(e) at the attachment to the surface of HTCC2. All these flaw locations can also be confirmed by taking multiple synchronized A-scan waveforms of interested locations on the samples and by comparing their peak heights.

Cross Sectional Confirmation

We have selected the left most package of Figure 7 which showed delamination flaws from the top to the lower polymer layer to cross-section if we can confirm the flaws highlighted by red color. As expected the upper layer flaws at the center of the device are clearly observed under 150x optical microscope as shown in Figure 8.

The delamination at lower level are somewhat difficult to distinguish optically at 150x, and required higher magnification and image comparison. We carefully have inspected lower level joints at higher magnification up to 500x as well as by comparing with images of similar location of a different part. We noticed stronger contrasts at the boundary indicating a signature of thin delamination at the stack-up joint.

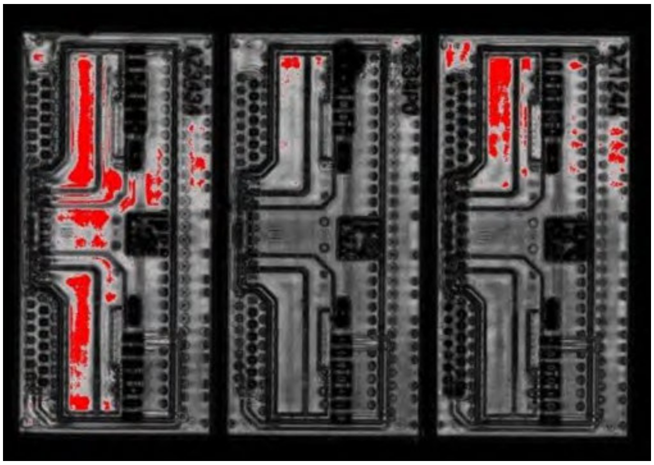


Figure 7(e): C-scan image from Gate #5, UF2, organics interfaces at 100MHz probe frequency. Both left and right units show significant delamination or less material regions.

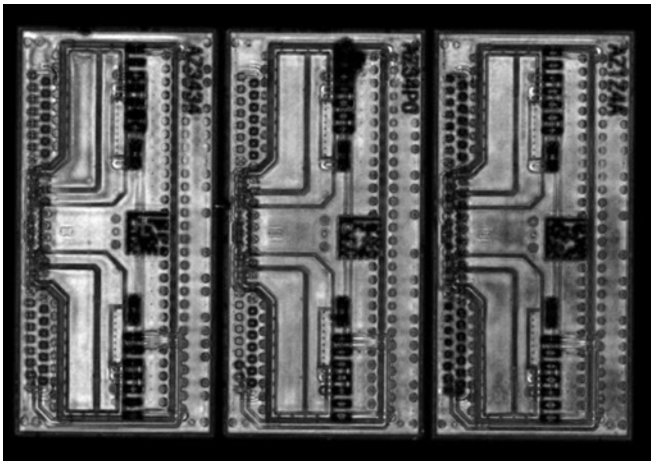


Figure 7(f): C-scan image from Gate #6, top of HTCC2 at 100MHz probe frequency.

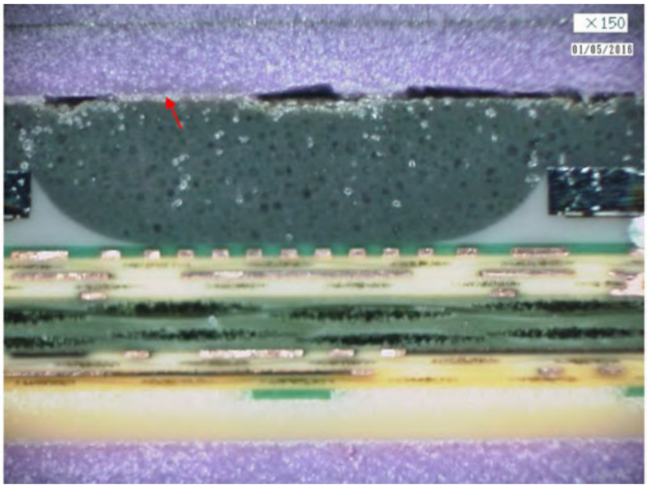


Figure 8: Cross section image of center region with 150x optical microscope.

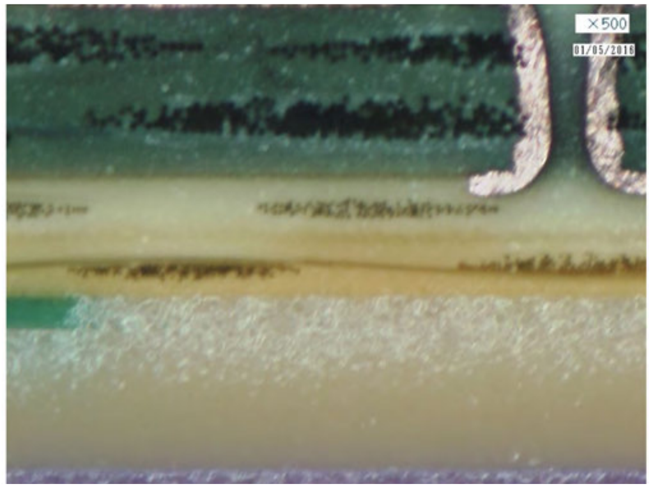


Figure 9: Cross section image of center region with 500x optical microscope, the lower level delaminations are somewhat difficult to distinguish by optical cross sections.

Conclusions

We have demonstrated that SAT images from a multilayer stack of ceramics-organics-ceramics structure with embedded devices can be separated to individual layers to characterize if flaws are included in the acoustically deep layers. The SAT findings are confirmed by cross sectioning a selected sample. To successfully image such samples, the transducer frequencies should be able to vary at will in certain range and the acoustic beam spot small while focal length of the probe long enough for a given sample.

Acknowledgements

The authors would like to thank the members of Flex China and Failure Analysis Lab in the USA, as well as the experts of SAT demo lab at Hitachi Power Solutions, Japan, who all relentlessly supported this project to conclude a success. **SMT**

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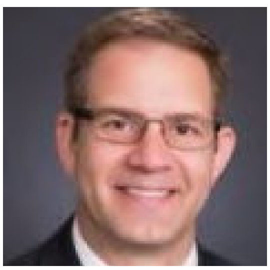
TOP TEN

Recent Highlights from SMT007

1 IPC President John Mitchell Discusses IPC's Footprint in China

At the Capital Club in Beijing, IPC's president John Mitchell met with I-Connect007's Edy Yu to discuss the current activities of IPC China.

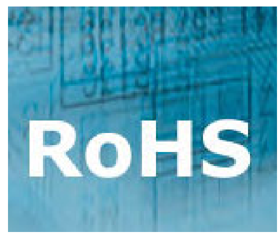


2 IPC Standards Committee Reports, Part 4 — Packaged Electronic Components, Rigid Printed Boards, Embedded Devices, Printed Electronics, IP

These standards committee reports from IPC APEX EXPO 2016 have been compiled to help keep you up to date on IPC standards committee activities. This is the fourth and final in the series of reports.

3 Consultants to EU Publish Recommendations on RoHS Exemptions

The Oeko-Institut e.V., Institute for Applied Ecology and Fraunhofer-Institut IZM for Environmental and Reliability Engineering, consultants to the European Union (EU) Commission (Commission), recently published their recommendations on 29 requested renewals of RoHS exemptions.



4 Celestica Honors Partners at 2015 TCOO Supplier Awards

Celestica Inc. has announced the winners of its 2015 Total Cost of Ownership (TCOO) Supplier Awards.

5 Power Design Services Completes Major Expansion in San Jose Facility

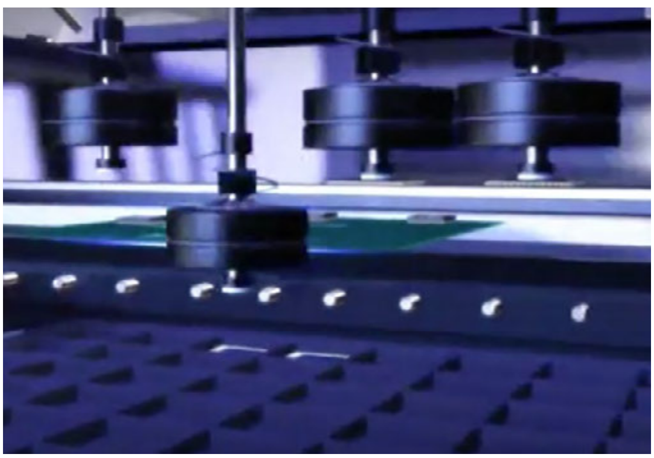
After six months of planning and construction, Power Design Services has completed its expansion in its San Jose, California PCB assembly manufacturing facility.

6 Scanfil Strengthens Operations in Poland

Scanfil has decided to expand its operations in Sieradz, Poland by doubling the size of the plant.

7 Invensas and Jabil Collaborate to Qualify BVA Interconnect Technology

Invensas Corp. and Jabil Circuit Inc. have completed the first phase of qualification of Invensas Bond-Via-Array (BVA) interconnect technology.



8 SMTA International Keynote Presenters Unveiled

The Surface Mount Technology Association (SMTA) has unveiled the keynote presenters for the upcoming SMTA International 2016 conference, which will be held from September 25–29, 2016 at the Donald E. Stephens Convention Center in Rosemont, Illinois.

9 Lincoln International 2Q 2016 EMS Index Down 1.9%

Lincoln International's EMS stock index underperforms the S&P in the second quarter of 2016.

10 ITL Celebrates Double Win at KEiBA 2016

Integrated Technologies has received the Manufacturing Business of the Year and Large Business of the Year awards at Kent's most prestigious accolade, the Kent Excellence in Business Awards (KEiBA).

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August 30, 2016
Laurel, Maryland, USA

Medical Electronics Symposium 2016
September 14–15, 2016
Portland, Oregon, USA

IPC India 2016
September 21–23, 2016
Bengaluru, India

SMTA International 2016
September 27–29, 2016
Rosemont, Illinois, USA

electronicAsia
October 13–16, 2016
Hong Kong

IPC-SMTA Cleaning and Conformal Coating Conference
October 25–27, 2016
Chicago, Illinois, USA

IMPACT Europe 2016
November 1, 2016
Brussels, Belgium

PCB Carolina: Regional Trade Show
November 2, 2016
Raleigh, North Carolina, USA

electronica 2016
November 8–11, 2016
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International Printed Circuit & Apex South China Fair (HKPCA)
December 7–9, 2016
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