Graham Norman
Interview Inside
PLUS: Solder Assembly—a Steely-Eyed Look at “The Devil We Know”
• Four on Industry 4.0 • The Strength of the OSAT Companies
& more
“OSDA has always had the ultimate goal of obtaining real-time SPC data without sacrificing efficiency. We evaluated several AOI vendors and decided to partner with MIRTEC. Our AOI machines are in line, after reflow, enabling us to achieve our goal of real-time SPC as well as improved quality and efficiency.”

George Grom, V.P.- Technology and Engineering

ADVANCED TECHNOLOGY

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Download this issue to your mobile device:

If you don’t already have one, search for a QR code reader app in your smartphone’s app marketplace. Then use it to scan the code above & download this magazine issue right to your phone.
As we go to press with first issue in 2014, the signs are good for a robust year with many suppliers of equipment and materials reporting stronger business going forward. And the optimism is not solely related to the United States; Europe, India and China are all starting to emerge from their recent malaise.

But the heat I referred to in my opening title is not just related to market conditions. On-board assemblies’ geometries continue to decrease as designers try to pack in more functionality. This is particularly strong in most hand held devices, but can also be found in automotive applications where electronics are continuing to form a larger percentage of new vehicle build.

The obvious result from this added functionality is increased heat and thermal stress. This will drive the quest to find new and better thermally conductive materials. It is true to say that most scientific advances are limited by materials science, and they are the key to unlocking future technology advancements.

However, this also brings opportunity. The opportunity to make our devices work better and more reliably, the opportunity to offer OEMs and designers the greater functionality they are constantly striving for, and finally the opportunity to make increased margin from technically innovative materials.

So perhaps heat and thermal stress are not such a bad thing after all. They are the fuel that drive us forward to a more innovative, efficient and exciting future.

—Trevor Galbraith.
LOOKING TO REPLACE COSTLY SAC305 PASTE
WITHOUT SACRIFICING QUALITY OR RELIABILITY...
AIM HAS YOUR SOLUTION!

NC259 SN100C® Solder Paste
for when high performance and cost savings are your goal.

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March 25-27, 2014
See Us in Booth No.1217
So with 2013 now behind us, we can look back on the year of reshoring, dendrites, tin whiskers and improving industrial climate. We have seen the sale of DEK to ASM, the growth of bottom terminated components, and a resurgence of interest in exhibitions, with Productronica producing the goods and SMTAi also being successful. Both in terms of visitor numbers and quality, as well as enquiries and sales closed, these events were much better than anticipated. We have also seen the movement of high volume business from China to even lower cost countries. So no one could say it has been a year of stagnation and dullness or without challenge.

What do the ‘wise men’ say 2014 will bring? For sure, cleanliness, contamination and conformal coating will be the hot topics, at least for the start of the year. Reliability, after the change to lead free and with the onset of smaller component geometries, is an issue from aerospace to consumer markets. So the seminars, workshops and webinars on the subject will be well attended for some time to come, and consultants will earn a crust too.

The one thing that amazes me with this topic is that people still spend a lot of time, money and resources trying to remove soldering flux that is designed not to be removed: the clue is in the name “No Clean.” There are now many good flux chemistries that can be removed quite easily, but many companies insist on battling against the tide. A chemistry designed to stay on the board will become inert if it is cured correctly in the reflow oven. If the profile doesn’t allow this, then it is actually better to run the assembly through a “pizza oven” to cure it fully rather than try to remove it—cheaper, and better for the environment too probably. This cleaning battle is part of the reason for many issues with reliability failures.

Bottom terminated components have been around for a long time, as my good friend Bob Willis reminded me a few weeks ago; however they were in the small-volume high-tech area, small quantities and placed by very skilled engineers. Now they are permeating rapidly into the mainstream and are predicted by other ‘wise men’ to be over 40% of all components placed next year!

The trend is driven by mobile phone and tablet designers who like the small package size and the shorter and faster signal path. No one seems to care about how tough they are to place, but good engineers love challenges, so there is hope! This brings me to one of the bad things I noticed in 2013. There has been a change in the thinking at many large companies in relation to the people who have knowledge and experience of process and technology. These guys are the lifeblood of a company; the ones who can embrace new technologies and find ways to improve yield that others would miss. However many of us have been around for a while, and there is very little ‘new blood’ coming into the industry at this level. But the really bad thing is that companies no longer seem to value this type of person and have either got rid of them or not replaced those who have left. This has created a very dangerous skills gap. Many companies now rely on contracting in these skills when they have problems. This can be a solution in the short term, but there is no continuity in this approach.

A wish of mine for 2014 is that the true value of this group of engineers is recognised and their roles reinstated. This way the companies will benefit in the long term from having this high level of knowledge in house, but this knowledge also needs to find its way to the next generation of engineer, and this will be the tough thing. An engineer was a respected career person when I started out, but now, at least in Europe, it holds no importance to those
looking for an interesting and rewarding career. It was good to hear recently at the SMART Conference that major banks are supporting Graduate Initiatives for Engineering, but more needs to be done very quickly to bring talent into our industry, and the rest of general industry too.

I guess ‘short termism’ was the disease of 2013. I hope 2014 will see it die. Huge factories move around the globe almost continuously, each hunting for the next short-term low-cost manufacturing region, simply to give us consumers a new product for a few cents less and allow multinational companies to make a few dollars more, often with little thought for the environment or the low-cost labour force which sometimes seems to be exploited by these actions—or what happens to the cities that lose such a huge employer almost overnight.

I am as bad as most, buying the lowest priced technology without giving much thought to where it came from and how well the workers who built it are treated. But as a New Year Resolution I plan to pay a little extra for more ethically produced products. I often buy ethical or organic food from the supermarket but don’t think about doing it when I buy something with a circuit board inside! There is a strong and growing argument against ‘lowest cost at all costs,’ and I believe it will grow during this year and beyond. On-shoring has started this, but it needs to extend beyond final assembly to PCB manufacture, high-volume consumer goods and also components. I hope 2014 will see this extension and also an increase in end-user companies driving their CEMs to build product in the most sensible place and in a more sustainable and ethical way.

As this is a New Year message, I need to end on a positive note, so let’s talk about the recent shows. Their success was not so much about foot fall but quality of visitor and the fact that once more people are looking to buy capital equipment, with some placing orders at the shows. We are not back to the good old days, and in reality, like 2013 they have gone and will never be back. The world and our industry has moved on and has got much better in some ways, worse in others. My final wishes for 2014 are that the designers who dream up the big challenges give a thought to the engineers who have to cope with them. In this world of higher yield, higher reliability and lower costs that would be a great help.

And lastly, I hope that a healthy dose of realism returns, so that lowest cost becomes lowest realistic cost, and companies take a little more care of the world’s resources, including the skills base they have themselves!

HAPPY NEW YEAR!

Keith Bryant is a member of the Printed Circuit Association and Chairman of SMART UK. He has over 30 years experience of process and technology and has presented around the world on topics from DFM through lead-free to dendrites.
ASM PT to acquire DEK
ASM Pacific Technology (ASM PT) has entered into an agreement to acquire printing technology leader DEK. ASM PT is the world’s leading supplier of equipment for the electronics manufacturing industry and is traded on the Hong Kong Stock Exchange. If the transaction proceeds, DEK, with all its employees, locations and full management team, will be integrated into ASM Assembly Systems SMT business segment. ASM PT established this segment in 2011 following its acquisition of the SIPLACE SMT placement machine business. www.dek.com

Multitest handler selected to support Google Chromecast production
Multitest’s MT9928 gravity feed handler has been selected to support the Google Chromecast related production by a leading semiconductor company. Consumer products typically have a short life cycle and face intense competition. Therefore, time-to-market is critical for the entire supply chain. The MT9928 has an impressive worldwide installed base on test floors for volume production. All listed specifications are field proven and the system is technically mature without any infancy issues. Therefore, it is ideal for a fast ramping business. www.multitest.com/MT9928

EvolviSMT Ltd. launches
EvolviSMT Ltd. launched at the 20th International productronica Trade Fair in Munich, Germany. Staying competitive in today’s SMT assembly marketplace means managing costs and getting the best value for your equipment investment. EvolviSMT Ltd. offers quality used SMT equipment at affordable prices, delivered anywhere in the world. Evolvi provides various equipment solutions to customers based on their requirements. Whether footprint, budget or specific equipment manufacturer needs, Evolvi allows customers to choose the solution that best meets their requirements. www.evolvismt.com

Compurol invests in a third KISS 103 selective solder system
Compurol, Inc. has placed an order for its third KISS 103 Selective Solder System from ACE Production at its manufacturing facility in Meridian, Idaho. The new unit will be installed at the Orem, Utah plant. The fully configured automated selective soldering machine features the new high-speed Z-axis, resulting in a 20 percent increase in production speed. The KISS 103 comes standard with universal PCB location rails with motor-driven adjustment, a heated Nitrogen inerting system, manual fiducial alignment and the KFS-DJ Automated DROP JET Fluxing System. www.ace-protech.com, www.compurol.com

AIM Solder expands manufacturing into South America
AIM Solder has added Cobix Industry and Commerce of Metals as its local licensed blender and distributor for the complete AIM line of solder assembly materials in Brazil. With this arrangement, AIM will now offer locally made solder paste, bar solder, wire solder, and liquid flux in Brazil, thus expanding in its’ overall growing global footprint. Cobix will support AIM customers within all Brazilian regions with AIM’s products, service, and technical support assisting AIM customers in finding the best solution for their individual assembly process. www.aimsolder.com, www.cobix.com.br

Micron Technology appoints Rajan Rajgopal as Vice President of Quality
Micron Technology, Inc., recently named Rajan Rajgopal Vice President of Quality. Rajgopal will be responsible for overseeing all aspects of Micron’s quality systems including manufacturing, customer program management and product ramps. He brings more than 25 years of experience to Micron and most recently served as the vice president of Global Quality and Customer Enablement for GLOBALFOUNDRIES in Singapore. www.micron.com

Saline Lectronics to install factory-wide traceability from Cogiscan
Saline Lectronics, Inc., recently purchased Cogiscan’s Track, Trace and Control (TTC) system. The system will allow Saline to track, trace and control the components that are placed on every single assembly down to the reference designator on the board. The order was facilitated by Dave Trail, President of Horizon Sales, and installation is expected to be complete in early 2014. www.lectronics.net, www.cogiscan.com

Bill Astle joins JUKI
Juki Automation Systems Inc. is pleased to announce that Bill Astle has joined the Juki Team as Eastern Regional Sales Manager and Latin America Sales Manager, based at the company’s headquarters in North Carolina. Juki is the leading supplier of SMT Placement Systems and Complete Line Solutions in the Americas, and one of the top three suppliers worldwide. www.jukiamericas.com
Libra’s new VP of sales and business development to drive growth in 2014
Libra Industries appointed Thomas Dykeman to Vice President of Sales and Business Development. In his new role, Dykeman will report directly to the company’s president and will be responsible for the creative pursuit of opportunities that meet and grow the company’s core competencies while meeting profit targets. Libra Industries plans to double its business over the next five years with the VP of Sales and Business Development playing a large role in this accomplishment. www.libraind.com

Firstronic awarded $289,550 training grant
Firstronic LLC has been awarded a $289,550 Skilled Trades Training Funds grant by the State of Michigan’s Workforce Development Agency. This comes on the heels of a $300,000 state grant awarded in September to help Firstronic fund additional hiring driven by strong business growth. The majority of the funding will be used to ensure new employees are trained through Firstronic’s comprehensive internal training program, which includes training to J-STD-001, IPC-A-610 and IPC 7711/7722 standards. www.firstronic.com

Electrolube global sales rise 35%
Electrolube has announced its best ever sales performance, with global sales figures up by over 35% on 2012. Contributing to the company’s highest growth rate in 72 years, Electrolube’s facility in China reported an over 30% increase in sales across Asia from last year. The company’s long term strategy of developing specialist chemical solutions for emerging technologies and maintaining a presence for local customers in each country has proved highly successful in expanding the business and meeting the demands of its customers. www.electrolube.com

Paul Rachielles joins Dymax as global marketing manager
Dymax Corporation has appointed Paul Rachielles as Global Marketing Manager. In his new position, Paul will report to Jennifer Mann, Director of Sales and Marketing, and be responsible for developing and implementing strategic international marketing plans for the organization. Prior to joining Dymax, Paul was the Leader of Corporate and Product Development at PH2 Solutions in West Orange, NJ, where he developed the sales, marketing, operational, and overall business plans. www.dymax.com

Gorilla Circuits purchases ERSA POWERFLOW N2 Wave and VERSAFLOW 3/66 selective solder machine
Kurtz Ersa North America announces that Gorilla Circuits purchased a POWERFLOW N2 Full Nitrogen Tunnel Wave Solder Machine and VERSAFLOW 3/66 selective soldering machine. Long Pham, Gorilla’s Director of Assembly Operation, was tasked with the job of outfitting the company’s new factory in San Jose, CA. Pham chose to work with Ersa over the competition due to superior quality, design and relentless support. www.gorillacircuits.com, www.ersa.com

Ren Yang joins VJ Electronix
VJ Electronix, Inc., announces the addition of Ren Yang as Sales Manager for China. Ren Yang is responsible for sales and support throughout China for all VJ Electronix products and VJ Technologies industrial X-ray systems. Yang will be located in the VJ Electronix/VJ Technologies Suzhou China facility. www.vjelectronix.com

TeligentEMS installs Ersa’s ECOSELECT 1
Kurtz Ersa North America announces that TeligentEMS, based in Havana, FL, has purchased an ECOSELECT 1 Selective Soldering machine. The ECOSELECT 1 requires less than 3 m² of space, allowing it to fit optimally into cell production environments. In all process steps, the semiautomatic ECOSELECT 1 system uses the same successful and proven Ersa selective soldering technology as the large Ersa VERSAFLOW systems without compromising quality or accuracy. The high-precision servo gantry system and electromagnetic pumping system, together with top- and bottom-side preheating, provide the highest capability and best repeatability. www.teligentsms.com, www.ersa.com

Koh Young America appoints two new engineers to strengthen direct service capabilities
Koh Young America (KYA) announces the appointment of two new engineers, David Nemeth and Derek Barton, to its direct service staff. Headquartered out of the new Chandler office, they will be responsible for handling equipment service issues and process development assistance for Koh Young America’s growing customer base in the Americas, according to Harry Yun, KYA General Manager. www.kohyoung.com

Blackfox Training Institute expands into three additional locations nationally and internationally
Blackfox Training Institute reports that it officially expands its training and certification services to three additional locations with new facilities. In addition to the Blackfox headquarters located in Longmont, Colorado, Blackfox now has new facilities in Tempe, Arizona, Guadalajara, Mexico, and Penang, Malaysia. Each of these facilities offers the same IPC Certifications and Blackfox Skill-based Certifications as offered in Colorado. Additional locations are planned in the near future. www.blackfox.com
**Tools and techniques for material assessment in advanced technologies**

Martin Anselm, Ph.D., and Wayne Jones, Universal Instruments Corporation, Advanced Process Laboratory, Conklin, NY, USA

As complexity in advanced manufacturing increases, especially for consumer electronics, the need to characterize the materials and processes used in electronic assembly also increases. OEM and EMS companies look to perform characterizations as early as possible in the process to be able to limit quality related issues and improve both assembly yields and ultimate device reliability. Many analytical methods are available to us on the market that each has their own risks and benefits. This paper will help identify some of these key limitations in the methods used for characterizing and evaluating solders, circuit board materials and surface finishes available in the market today.

**BACKGROUND**

The real cost of failures in manufacturing is significant but is one that is not accounted for during up front calculations. Line-down situations, product recalls, engineering time spent on customer interactions and failure analysis can quickly add up to millions of dollars depending on the product. It is critical that all resources are optimized in order to effectively determine root cause in the shortest possible timeframe. Unfortunately the industry is moving away from a skilled labor force that can accurately assess failures and determine root cause. Often, too much time is spent tracing false positives and incorrect assumptions leading to ineffective corrective actions and “Band-Aid” solutions. In an industry that values “5S” practices, fishbone diagrams and “5 whys” we have lost our ability to employ intuition and experience. Lean manufacturing practices can be very beneficial for failure analysis since often Lean manufacturing practices are associated with tracking lot and date codes of materials used during production, which can be linked to failures. Having this data can be critical in determining root cause and assessing the extent of a failures effect on a population of fielded products.

To that end we must therefore assess failures using techniques that will be able to isolate material and process variations. Whether it be manufacturing process, material quality issues, product design, excessive stresses (in factory or in field), or an inherent weakness in a material selected for the product (e.g. lead-free solder alloy susceptibility to failure). Most companies do not have the resources to employ a staff of engineers and purchase software to conduct physics of failure (PoF) analysis techniques. Also product modeling techniques may only highlight an area of high stress in an idealized condition. An experienced failure analyst needs to take into account the outliers of a manufacturing process or design in order to properly determine and consequently implement a successful corrective action plan.

This paper will begin by isolating some key questions that can be asked of the supplier, manufacturing engineers, supplier quality engineers, and reliability engineering teams. Once these critical questions have been answered, only then can we assess what analytical techniques should be employed. From this high level perspective limitations and opportunities in low and high cost analytical techniques will be discussed.

**Introduction**

This paper is written in a logical format that follows the procedure that an engineer should take in performing a material (product or process) assessment. Initially one must understand the scope and nature of the defect or failure. This is followed by material inspection and finally root cause or corrective action strategies. In this paper, the focus is not only on a discussion of optical and scanning electron microscopy (SEM) procedures for material inspection. There are many more techniques available to the engineer. The optical techniques discussed in this paper can be performed with little resources that could be very helpful in determining root cause (if performed correctly). With that in mind, this paper includes some possible risks with performing these techniques that should be kept in mind. SEM has been included in this paper since it is a common first resource when selecting more sophisticated analytical techniques. This paper presents a common error in SEM analysis of solder joint cross-section inspection.

**Assessing damage**

It is critical that the extent of a failure is assessed, whether the product is a million unit cell phone or a $10,000 military
circuit board assembly where less than 10 are being manufactured. The difficulty in determining the extent of the failure is the same; the success of a product is typically defined by high yield and high reliability. The engineer responsible for determining root cause for a failure must segregate the failure into categories and determine how many opportunities there are for further failures. These categories will often determine if the failure is being caused in house or by a supplier, subcontractor, or user. Questions must be asked that will determine if the failure is die level (0th), die attach level (1st), component attach to PCB (2nd), or final assembly (3rd). Areas that can fall between these levels are often material specific such as circuit board failures or post component attach process defects (cleaning, coating, test). Often the failures can fall into the following categories:

Material quality
Material quality can fall into many categories however more often we consider paste, board, component, adhesives, coatings, cleaners, etc. Each of these materials has their limitations and complications. For example, circuit board manufacturing is a complex process utilizing mechanical (drill), thermo-mechanical (press/cure) and chemical (plating/etching/stripping) processes. Each process has its own unique limitations and characteristic failures.

- What are the date or lot codes of the failed devices/boards/paste?
- What solder alloy was used for the SMT process? (Sn/Pb paste with lead-free component?)
- What component broker was used? Are they on our Approved Vendor Lists?
- How thick is the solder mask?
- What plating is being used on the component?
- What surface finish is defined on the board drawing? What thickness requirements for the surface finish are outlined on the PCB drawing?

Assembly process
Assembly processes vary widely for electronic devices in our industry. Each process has operational windows that will produce high yield and reliable product. In order to assess the possibility of failure in each we must first understand the stresses that the product may face during assembly.

- What processes are being used for this product (print, placement, inspection, reflow, cleaning, dispense, final assembly, test, etc.)?
- How was profile development performed for this specific product?
- Were printing materials changed? New stencil?
- Is full I/O inspection being performed on placement machine?
- What torque specification is used for tooling whole locations when mounting product to chassis? What order are screws placed? How are boards supported?
- How are boards handled following assembly?
- How is the multi-up panel singulated?
- Is paste being under or over printed for a particular design? (1-2 mil reduction?)
Tools and techniques for material assessment in advanced technologies

Design
Design can affect many aspects of yield and reliability of a product. Simply following component manufacture recommendations for land patterns and stencil apertures may not be sufficient to overcome some unique product requirement. Proper design must be taken into account for managing reliability and determining root cause of failures.

- How close are fragile capacitors or associated passives to edge of PCB?
- What are the aspect ratios of the stencil?
- How close are critical components to tooling holes?
- Has the PCB manufacturer made modifications to PCB design from drawing?
- Is the failed part in a location of high stress? Has it been moved as compared to previous revision of the product?
- Is conformal coating being used on this product? What material has been selected?

Reliability
Functional testing, ICT, drop, vibration, ESS, HALT, HAST, are methods used to determine susceptibility of failure in manufacturing and in the field, however correlating them to true field reliability is difficult if not impossible for most reliability engineers. In order to interpret the failure modes identified by common failure analysis practices we must understand all the mechanical and thermo-mechanical stress conditions a product was subjected to, prior to the failure occurring. Often reliability issues are not associated with a single root cause. Therefore it is common in today’s research to see topics in assembly pre-stress. It has been shown that thermal or mechanical pre-stress can dramatically affect the reliability of components. Root causes for these accelerated failure conditions are not fully understood.

- What manufacturing and final assembly stresses is this product subjected to?
- What is the end use condition of this product?
- Is ICT fixturing designed properly (functioning as expected)?
- How were profiles developed and product fixtured in thermal and mechanical testing equipment?
- Were components removed immediately following failure or allowed to be tested far beyond their failure point in accelerated life testing?
- Can a particular I/O be identified as the failure location? A component? A circuit?
- Is the failure a short or an open?
- What environmental temperatures, corrosive media, or humidity was the product subjected to prior to failure?

Optical analytical techniques
Once a failure has been identified, prior to root cause determination, the first objective should be identifying failure mode. Failure mode must be established using techniques that do not subject the product to further stresses and risk of damage. Several non-destructive and destructive techniques are considered low cost and can be very effective in assessing root cause. However if handled or interpreted incorrectly can be costly.

The simplest example of low cost analysis is optical microscopy. The IPC-A-610, E-2010 standard section 1.9 recommends limiting magnification for inspection purposes to 1.5x-40x depending on the size of the land pattern. In cases of cleanliness or conformal coating inspection the maximum suggested magnification defined in IPC-A-610 is 4x. Often this is done to
Tools and techniques for material assessment in advanced technologies

limit the uneducated user of identifying anomalies that may not affect the overall performance of the product. Therefore it is best to have comparative samples from passing lots of product. These baseline samples often can segregate typical conditions from non-characteristic conditions. Having baselines of good products can also allow for higher magnification inspection of design and quality while reducing the risk of misinterpretation.

Optical microscopy is inherently non-destructive and can be used to identify failures in any of the categories listed in the previous section. Lighting techniques should be diversified in order to highlight defects. Low angle lighting, co-axial lighting, spot lighting and ring lighting can all be used at low magnification in order to illuminate surfaces. Lighting can have dramatic effects on illustrating contamination or fracture conditions that may normally be invisible. Often tin whiskering (Figure 1) and other surface conditions (Figures 2-4) will only be visible when adjusting lighting techniques.

Optical microscopy at higher magnification can be useful for assessing lead free solder joints. There is a lack of contrast in lead-free solder joints since they are 95% or more tin (Sn). In order to differentiate between alloys and precipitate structures in lead-free it is often useful to employ dark field or cross-polarized lighting techniques. A schematic of a polarizing microscope can be seen in Figure 5 along with examples of various lighting techniques in Figure 6.

It should be stated in order to get the contrast produced by images in Figure 6c cross-sectioning techniques must be optimized and perfected to eliminate not only scratches but the damage caused by the grinding and polishing steps to soft Sn-based solder. The details for preparing a sample for polarized light inspection are not covered in this report.

In addition to solder joint condition laminate failures may also be difficult to view using standard lighting techniques. Failures described as pad craters, where the top layer copper is separated from the circuit board due to thermal or mechanical stresses can be difficult to identify. Often the investigator optimizes lighting for inspection of the solder joint. This leaves the laminate material dark and underexposed. In order to properly image the laminate the solder joint requires over exposure as shown in Figure 7.

Poor cross-sectioning techniques can make evaluation of solder joint conditions difficult. Examples of poor sections can be seen in Figure 8. Improperly polished sections, where scratches and debris from the initial grinding operations occur, should be avoided. Improper visual interpretation of these “Laboratory artifacts” can produce false positives with respect to fractures or separations, conductive particulates or foreign materials, intermetallic anomalies, and laminate or dielectric defects.

“Optical microscopy is inherently non-destructive and can be used to identify failures in material quality, assembly process, design and reliability.”
Dye penetration can also be an effective low cost analysis technique; in particular for failures where a specific target I/O has not been identified. Multiple devices can be tested and multiple failure modes can be identified. Graphic representations can be developed with locations of failures, percentages of fracturing and types of failure modes (e.g. component side pad crater, component side IMC, bulk solder, PCB pad IMC, PCB pad crater).

A short description of the method is listed below with the dye used for the test. At highest risk for processing error is the curing (step 6) of the dye. One must ensure that all the dye is dried prior to removal of the components. Otherwise liquid dye could migrate onto surfaces causing false interpretation. Figure 8 also shows the result of the test on pad cratering failure modes and IMC failure modes.

**SEM inspection techniques**

Most analytical techniques requiring outsourcing will range in cost from several thousand dollars to complete a root cause inspection, to several hundred dollars per hour for use of sophisticated analytical equipment. As an example current, Dual Beam FIB fees can exceed thousands of dollars to analyze a sample. Slightly lower cost techniques such as Scanning Electron Microscopy (SEM) analysis are a useful tool for identifying failure mode conditions, however the inspection can be poorly executed resulting in misinterpretation and confusion.

The most common error in SEM analysis is the use of secondary electron (SE) detectors for metallurgical cross-section inspection of intermetallic. Without getting into technical details, SE is used for

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**Dye penetration procedure**

1. Carefully cut the region of interest from the assembly by using a low stress technique. A water cooled diamond band saw is often an effective extraction method. Ensure at least ½ inch spacing exists between the edge of the coupon and the component being tested.
2. Clean the assembly with isopropyl alcohol (IPA) or an appropriate flux remover using an ultrasonic bath, and dry. This step should also clean most cutting debris from step 1.
3. The assembly is immersed in red dye (Dyken steel layout fluid #80496) to stain all exterior and fracture surfaces.
4. While submerged in the dye bath is placed in a vacuum of 9 in Hg for 1 minute to eliminate air from under the device. Ultrasonic baths are also useful during this step. When using an ultrasonic bath the circuit board should be placed vertically in the dye. The liquid is allowed to penetrate for 1 hour.
5. Excess dye is removed. Dye removal can be optimized by placing the coupon vertically and placing a paper towel at the bottom edge of the device to wick dye from under the component.
6. The component is dried 30-60 minutes at 100-125˚C.
7. The component is mechanically pried off the board using pliers to twist the board, or a thin screwdriver can be carefully placed between the component and the board to lift the component away from the board surface without damaging the solder joints.
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imaging topography. Cross-sections are by design flat, so atomic contrast between Ni, Cu, solder and intermetallic is not optimized. Back scatter electron (BSE) detectors provide excellent atomic number contrast and therefore should almost exclusively be used for imaging metallic cross-sections of electronic devices. Examples of BSE vs. SE images for a cross-section are shown in Figures 10 and 11.

As can be seen from the images in Figure 10 and 11, the ability to distinguish intermetallic regions is compromised using SE detectors, however SE can provide greater detail due to the inherent planarity variation in cross-sections due to the hardness differences in the materials. Harder materials like IMC grind and polish away more slowly than the softer Sn leaving a step between the materials. These steps are highlighted in SE due to edge effect charging.

**Determining root cause**

Once understandings of the product’s use condition, pedigree, and failure mode have been determined the responsible engineer must try to connect the failure mode to the environmental or process condition. This can be accomplished by either comparison to known good product or continued testing. Testing requires materials that may not be on hand and sufficient time to complete test. Both are often not available. Often the most concise conclusions are reached from identification of a clear defect or a dramatic reduction in fallout in the next manufacturing cycle following a corrective action.

**Conclusion**

This paper simply discusses a small fraction of the techniques available to engineers tasked with material assessment. The intent of this discussion was to illustrate the methodology, benefits, and limitations of critical techniques that an engineer may utilize in determining the root cause of a failure. Moreover, any technique used by an engineer has its limitations and requires consideration.

Cost of failure misinterpretation and delay is astronomical and is the cause of significant waste in time and money in an electronics manufacturing factory. With some simple analytical techniques, isolation of the failure and determination of the root cause may be possible. In order to accomplish “root cause” the data collected from analytical techniques discussed in this paper (and others) must be combined with knowledge and experience. Only then can production and field failures be effectively limited and controlled.

**Acknowledgements**

The authors of this paper would like to acknowledge Shantanu Joshi, a graduate student from Binghamton University’s System Science and Industrial Engineering department for providing the cross-section samples.

**References**

1. Singh, A., Meilunas, M., Borgesen, P., Anselm, M., Pitarresi, J., “EFFECT OF STRAIN RATE AND PRE-DAMAGE ON A PCB USING 4 POINT BEND

Figure 11. BSE and SE images of identical cross-section locations at 4000x.

Get the repeatability and performance you expect from the world leader. Dynamo’s simplified configuration delivers 24/7, with maximum uptime and low cost of ownership.
Winter chill followed by spring blooms

The “much hoped for” end-of-2013 recovery has indeed occurred, although its impact has varied regionally. A combination of real growth and normal seasonality pushed global electronic equipment sales to a record high in November (Chart 1). For November 2013 world electronic equipment revenues rose 4.8% compared to November 2012 and were up 8.6% sequentially from October 2013.

Pre-Christmas seasonal growth ended in November so December 2013 through early 2014 revenues will likely plunge compared to their November high. Semiconductor shipments (Chart 2) were already beginning to plateau in October and November world printed board sales (Chart 3) had already passed their seasonal high.

Looking forward, the SIA’s latest global semiconductor shipment forecast (Chart 4) predicts 4% world chip growth in 2014 vs. 2013. And the SEMI trade organization’s December forecast predicts a 23% increase in semiconductor equipment sales in 2014 (Chart 5).

Most prognosticators see 2014 as a better year than 2013. Chart 6 summarizes Henderson Ventures’ December 2013 forecast of electronic equipment production growth by year by region.

The 2014 outlook is currently quite promising—but remember that the forecasts a year ago for 2013 were also quite optimistic.

Most prognosticators see 2014 as a better year than 2013.

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Most prognosticators see 2014 as a better year than 2013. Chart 6 summarizes Henderson Ventures’ December 2013 forecast of electronic equipment production growth by year by region.

The 2014 outlook is currently quite promising—but remember that the forecasts a year ago for 2013 were also quite optimistic.

Keep watching the numbers! Expect a winter seasonal downturn followed by decent spring growth.

End markets

World

- Global electronics market is forecasted to grow at a 5% CAGR from US$1.36 trillion in 2012 to $1.74 trillion in 2017.—IC Insights
- Global consumer electronics market is forecasted to reach US$1.6 trillion by 2018 primarily supported by analog & digital TV, tablet, digital cameras & camcorder, personal computers and video/audio equipment.— ReportsnReports
- Telecommunication electronics application sector is expected to grow at a 12.8% CAGR to US$487.6 billion by 2018.
- Computing electronics application sector is expected to grow at a 10 % CAGR to US$436.7 billion by 2018.
- Medical electronics market is expected to reach US$372.4 billion by 2018 primarily supported by monitoring & surgical systems, imaging systems, diagnostics and medical therapeutics.
- Industrial electronics market is set to expand to US$321 billion by 2018 primarily supported by semiconductor capital equipment, test and measuring instruments, automation systems and process control instrumentation.
- Aerospace and defense market is expected to reach US$248.2 billion by 2018 primarily supported by engineering / aeronautics (body), in-flight entertainment, avionics and engine application sectors.
- China based white-box tablet shipments increased 40.4% y/y to 25 million units in 3Q13. Shipments increased 60-80% y/y to 80-90 million tablets in 2013 and are expected to increase 25% y/y to 100 million units in 2014.— Digitimes Research
- Chinese company smartphone sales declined 8.8% sequentially to 78.2 million units in 3Q13.—Digitimes Research
- India PC market grew 7.9% to nearly 3.2 million units in 3Q13.—Gartner
- India appliance market grew 24% in fiscal 2012 (which ended March 31) to

Source: Custer Consulting Group & Electronic Outlook Corp

Chart 1.
PC shipments fell 10.1% y/y to 314.2 million units in 2013.—NPD DisplaySearch

Personal computing systems (desktop systems) shipments are expected to increase 30% y/y to 1.24 billion in 2018.—ABI Research

Smartphone shipments are expected to grow 22% y/y from 221 million units in 2013 to 271 million units in 2014.—IDC

Smartphones sales rose nearly 46% y/y to 2.5 million units, while revenue decreased 2.1% to $12.6 billion in 3Q13.—Gartner

Tablet shipments are expected to grow 22% y/y from 221 million units in 2013 to 271 million units in 2014.—IDC

Consumer electronics

• Personal and entry-level storage market shipments grew 2.9% y/y to 18.6 million units in 3Q13.—IDC

• Disk storage systems market sales decreased 5.6% y/y to $7.4 billion in 3Q13; total disk storage systems capacity shipped expanded 16.1% y/y to nearly 8.4 exabytes.—IDC

• Hardcopy peripheral shipments grew 2.6% y/y to 28.1 million units in 3Q13.—IDC

Other

• Automobile driver monitoring systems are expected to reach 64.8 million units by 2020.—ABI Research

• Automobile shipments with factory-installed safety and security telematics to grow at a 34.5%. CAGR from 11.5 million in 2013 to 50.8 million in 2018.—ABI Research

Automobile electronics market will grow at a 7.3% CAGR between 2012 to 2020 from US$191.3 billion in 2013 to US$314.4 billion by 2020.—Research and Markets

Carrier router and switch market (IP edge and core routers and carrier Ethernet switches) grew 7% y/y to $3.6 billion in 3Q13.—Infonetics Research

Enterprise video conferencing equipment revenue declined 9.7% y/y to $576 million in 3Q13.—IDC

Ethernet switch market (Layer 2/3) increased 6.3% y/y to US$5.66 billion in 3Q13.—IDC

Microwave equipment market fell 7% y/y to $1.16 billion in 3Q13.—Infonetics Research

Smart connected device market (combined shipments of PCs, tablets, and smartphones) increased 12% y/y to almost 55 million units in 3Q13.—IDC

Smart household appliance market is projected to grow from $600 million in 2012 to $35 billion by 2020.—Pike Research

Mobile communications

• Smartphones sales rose nearly 46% y/y to 250.2 million systems in 3Q13, while overall mobile phone sales were up less than 6% to 455.6 million units.—Gartner

• Smartphones shipments grew 39.3% y/y to over 1.0 billion units in 2013, while ASPs declined more than 12%.—IC Insights

Computers & peripherals

• PC shipments fell 10.1% y/y to 314.2 million units in 2013.—IDC

• Notebook PC touch screen reached 11% penetration or nearly 19.8 million units in 2013.—NPD DisplaySearch

• Tablet shipments are expected to grow 22% y/y from 221 million units in 2013 to 271 million units in 2014.—IDC

• Server shipments expanded 1.9% y/y to 2.5 million units, while revenue decreased 2.1% to $12.6 billion in 3Q13.—Gartner

Winter chill followed by spring blooms
Winter chill followed by spring blooms

### Electronic Equipment Production Growth

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2012</th>
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</table>

Henderson Ventures 12/2013
www.hendersonventures.com

### EMS, ODM & related assembly activity

- Smart thermostat shipments to grow at 43% CAGR from 1.3 million units in 2013 to 8 million units in 2018.—ABI Research
- Large-sized LCD panel production used for televisions, monitors, notebooks, and tablets reached 34.1 million units in Q4Q13.—IHS
- Touch panel industry shipments are expected to grow at 12.5% CAGR from 1.52 billion units (US$31.4 billion in revenues) in 2013 to 2.52 billion (US$43.7 billion) in 2017.—IEK
- Wearable device (wireless and smartwatches, activity trackers, wearable GPS, heart rate monitors and smartglasses) market shipments are estimated to reach 191 million units valued at US$20.6 billion by 2018.—IEK

**Compal Electronics** merged with subsidiary Compal Communications.

**Computrol**
- promoted James Spencer to Engineering Manager.
- purchased third Kiss 103 selective solder system from ACE Production for its facility in Meridian, Idaho.

**Creation Technologies** obtained FDA registration at its electronics manufacturing facility in Milwaukee, Wisconsin.

**Deswell** appointed Edward So Kin Chung, CEO.

**Dethon EMS** added a DEK Horizon 03iX print platform.

**Ducommun** received multiyear PCBA contract from Parker Aerospace for Airbus A350 fuel management system.

**Fideltronik** is building a 9,600 M2 facility in Sucha Beskidzka, Poland.

**Flextronics**
- acquired Riwisa.
- introduced Lab IX accelerator program that provides support to early-stage, disruptive technology companies.
- Israel cut 50 workers.

**Foxconn**
- is considering shifting the company’s high-end manufacturing to the United States.—Chairman
- plans to invest in a machine-tool automation manufacturing plant and R&D facility for robotics in Pennsylvania.
- subsidiary Eson was listed on Taiwan Stock Exchange.

**Incap** streamlined operations to three factories: Tumkur in India, Kuressaare in Estonia, and Vaasa in Finland.

**iNEMI** named Grace O’Malley, VP of Operations.

**Jabil Circuit**
- Hungary terminated 673 jobs.
- received exclusive manufacturing services agreement for 390,000 micro-CHP flow boilers from Flowgroup.
- purchased SGI’s primary manufacturing facility in Chippewa Falls, Wisconsin.

**Kimball International** appointed Kimberly Ryan to its Board of Directors. Kontron closed its Kaufbeuren, Eching, Roding and Ulm locations.

**Libra Industries**
- added two Hanel Rotomat inventory carousels and upgraded its storage software.
- appointed Thomas Dykeman to VP of Sales and Business Development.

**Marsden Smith Limited** was sold out of administration.

**Michigan Manufacturing International** opened 39,000 SF HQ in Stevensville, Maryland.

**Micromax** plans to start assembling phones in India by 1Q14.

**Neways Electronics Production GmbH** in Kassel, Germany terminated production activities.

**OnCore Manufacturing** launched OnCore Interconnect business.

**Plexus** is spending $3 million to triple the size of its ISO 7, Class 10,000 compliant, cleanroom facility and upgrade specialized manufacturing equipment at its Boise Microelectronics Center of Excellence in Nampa, Idaho.

**Raytheon** plans to hire more than 150 new workers for its defense electronics manufacturing plant in Forest, Mississippi once it completes its 20,000 SF expansion.

**Saline Electronics** purchased Cogiscan’s Track, Trace and Control system.

**Samsung Electronics** entered JV with Venezuela’s government to assemble devices and home appliances in country.

**SMT Developments** acquired additional building for new clean room facility and pick and place equipment.

**Specialized Coating Services** appointed Plasma Systems’ co-founder, Ed Branco as its new CTO.

**Spectrum Assembly** added Hesse and Knipp’s Wire Bondjet 820 unit, Century Series Nordson Asymtek dispensing system for epoxy and a Metcal APR5000 soldering system.

**Steve Williams** started new consulting company: www.stevewilliamsconsulting.com.

**Tabemax** invested in an ERKA X3 screen printer, KOLOB PSB400 automatic cleaning system, reflow oven and an ERSA...
HOTFLOW 3/14e; plans to add new SMT line in 1Q14.

TelgentEMS purchased an Ersa ECOSELECT I selective soldering machine.

**PCB fabrication**

World PCB Market is forecast to grow from $59.8 billion in 2013 to $62.1 billion in 2014 and $64.2 billion in 2015. South Korea is expected to have surpassed Taiwan as second-largest manufacturing hub for PCBs in 2013.—Dr. Hayao Nakahara

Taiwan-based makers’ PCB production value (in Taiwan and China) increased 5.7% y/y to US$46.55 billion in 3Q13.—IEK

ACB acquired a Laser DI system, Leda 5 from Ucamco.

AT&S and Nanium developed method to embed eWLB packages on top of PCB substrates.

Brander purchased a Multistation EVO drilling machine at productronica.

Canadian Circuits added an Oxford CMI 900 X-Ray fluorescence coating thickness measurement system.

Chin-Poon Industrial expects its new automobile board plant to be completed by the end of 2014.

Endicott Interconnect Technologies emerged from bankruptcy and was renamed i3 Electronics Inc., led by president, Robert Nead.

EPFL made flexible electronic circuit board using elastomeric foams.

Gorilla Circuits added a POWERFLOW N2 full nitrogen tunnel wave solder machine and VERSAFLOW 3/66 selective soldering machine.

Ibiden spent $400 million to add equipment to plant # 2 in Penang.

Mitsubishi Materials developed direct bonded aluminum substrate with thick Cu for hybrid electric vehicle inverters.

National Technology

• added ATG Flying Probe testers, Hakuto MACH 630 UP laminators and an Excellon Century 2000 drill in Rolling Meadows, Illinois.

• Installed a Chemcut SES Etching equipment, TMP Vacuum Press, an IS Pumiflex pumice scrubber, OLEC 8kw Exposure unit and MacDermid Conv. Oxide line in Gandhinagar, India.

Panasonic will discontinue circuit board production in central Japan and north of Tokyo between March 2014 and March 2015 and end circuit board production at its plants in Vietnam by March 2015 and its ALIVH board production at both of its plants in Taiwan in early 2014.

SEMCO plans to build a new HDI plant in Vietnam.

**The 2014 outlook is currently quite promising—but remember that the forecasts a year ago for 2013 were also quite optimistic. Keep watching the numbers! Expect a winter seasonal downturn followed by decent spring growth.**

Unimicron is investing $500 million to build a new package substrate manufacturing plant in Taiwan.

Virtuoso Circuits acquired Marsden Smith for £50,000.

Würth Elektronik launched WEdirekt online shop for HDI microvia PCBs.

**Materials & process equipment**

Acryl film demand for LCDs is forecast to reach almost 200 million SM (18% market share of PVA protection film market) in 2017, or close to six times 2012 total.—IHS

Global tin market deficit is expected to deepen in 2014 to 12,400 tons from 7,400 tons in 2013 due to increased demand from a recovering electronics sector.—ITRI

Japan’s production of electronics materials declined 29% y/y to 11.86 billion yen in August.—JEITA

3M scientist, Dr. Andy Ouderkirk was named 2013 R&D Magazine Innovator of the Year.

ASM Materials factory workers in Shenzhen received 20% pay increase after 22-day strike.

ASM Pacific Technology acquired DEK.

Atotech developed Cupracid AC conformal plating process designed for vertical conveyorized line/ plating and sparger electrolyte agitation.

Introduced direct Palladium surface finish process, PallaBond.

Camtek is developing a commercial grade 3D printer for PCB market.

Cartesian raised more than $115,000 on Kickstarter to fund 3D silver circuit board printer capable of printing on any material.

CheckSum & Everett Charles Technologies unveiled its 12KN test system with integrated TILT® fixturing technology.

Daxin Materials developed copper-etching solution for ultra HD panels.

DKN Research commercialized ultra-thin microwave absorption film, Nikram.

Dow Chemical is contemplating dropping “Chemical” from its name as part of its migration away from low-margin commodity chemicals.

DuPont

• Microcircuit Materials expanded its suite of low silver, conductive ink materials specifically tailored for MTS, RFPD, and wearable electronic applications.

• Teijin Films developed ‘Clean-on-Demand’ PET polyester film for R2R production of flexible electronics.

ECD named Kimberly Solonka, Sales Manager; Wojtek Antoniak, European Business Manager and Craig Johnson, SensorWATCH™ Product Manager.

Enthone introduced comprehensive supplier quality engineering audit to enable immediate identification of PCBs coated with company’s patented ENTEK* organic solderability preservatives.

EvolviSMT launched a used SMT equipment business.

Intertronics introduced Dymax dual-cure 9482 conformal coating.

Juki Automation Systems appointed Bill Astle, Eastern Regional Sales Manager and Latin America Sales Manager.

LPKF moved its production facilities ten kilometers from Erlangen to Fürth, Germany.

LTX-Credence acquired Multitest and Everett Charles Technologies from Dover Corporation.

Oerlikon Balzers opened a coating center in the Philippines.


Picodeon developed ColdAb® ultra-short pulsed laser deposition technology for use in the application of gold and platinum thin films.

San Fu Chemical was listed on Taiwan Stock Exchange at an initial price of NT$29 (US$0.98) per share.

Teradyne named Mark Jagiela, CEO. VJ Electronix appointed Ren Yang, Sales Manager for China.

**Semiconductors & Other Components**

Semiconductor revenue grew 5.2% y/y to $315.4 billion in 2013.—Gartner

Continued on page 40
**Interview—**

**Graham Norman—**

**EVS International**

EVS International are the world leaders in solder recovery. EVS have been recognised as the world leader and propagator of recovering solder and has been honoured by 17 international awards for innovation, ROI, and efficiency. Trevor Galbraith had an opportunity to speak with EVS president Graham Norman at productronica in Munich about their latest solder recovery system, the EVS500.

Graham, EVS recently brought out a brand new dross recovery system that won a Global Technology Award at the productronica show in Munich.

We did. We were very fortunate and humble to receive that award because it says a lot about our small company, which is a family business, but we’re on the cutting edge of our industry.

Of course the nice thing about the award is that it was in the Environmentally Friendly Category, which is essentially what you’re doing with this dross reduction system.

Correct. We’re the green guys. We’re trying to reduce people’s costs and reduce the impact that industry has on the environment. So, green, green, and save some money.

You’ve been known for many years for your large systems, but this is the successor to that for smaller applications. Could you maybe tell us a little bit about the specification and how it works?

Sure can. What we wanted to do was make our technology available to all the guys with one or two waves or who are doing selective soldering. We wanted to make our technology available to the guys with one or two waves or who are doing selective soldering.”
What about the efficiency of the actual dross recovery?

Great question. It’s actually gone up with this technology by 15%, 20% more than we were getting before, so it’s stupidly efficient.

So you’re up to 75%...?

75%, 85%, yes.

Now you’re using a different technology than before. Before you were using a squeezing system. This is very different. Can you explain it?

The idea was my oldest son’s. He wanted to get more out of what we were putting in there. The new machine has a series of choppers. It’s all automatic; once you’ve filled it, you don’t have to touch it. Everything works automatically, which is essential for northern Europe and the U.S. So, it has a series of blades that chop the dross to make sure we get all the solder out that’s available. The solder goes to the bottom. It’s then drawn off at the bottom into a tray while the dross stays inside. Then the machine totally inverts the pot, goes all the way through 90 degrees, and dumps the waste, the fine grains of dross where the solder’s been taken out—it’s just like a dust, like a powder—into the other tray. So, two separate trays, and you get a fabulous clean ingot with no dross whatsoever anywhere near it.

So you have two separate trays. The good stuff comes out on this side, and then on the other side, you have the dross.

Great separation.

This unit, one of the ways you’re thinking it can be used is to mount it next to the wave soldering machine. Literally on a post.

On a platform next to the wave soldering machine that can be pushed in and pushed out. And the reason for that is a dedicated machine means that the operator will use it and not worry about where has this machine been parked, whether it’s been pushed away. They can use it anytime they want. They don’t have to have problems of availability. The cost is so low that the payback is tremendously fast. Have it next to the wave, dedicated; you’ll never then throw good solder away into your dross. That just makes the dross man rich.

So this platform. Basically you’d just—Swing it in, swing it out.

And then you’d scoop the dross from the wave solder machine.

Right. It’s no more work than what they’re doing now. Now they’re scooping it off, some of them are chopping and squeezing, spending twenty minutes doing it. Put it in here, three or four minutes, machine automatically recovers it. And then you just put it back in the wave.

That’s the way to do it. Make it easy.

Neat and simple.

Graham, thanks very much for giving us a run-through on the machine. What do you call it, by the way?

The EVS500.

The EVS500 compact dross recovery system from EVS International. Thank you again, Graham.

—Trevor Galbraith
2014 Milestone Anniversaries

Please join Global SMT & Packaging in celebrating the milestone successes of long-running, dedicated suppliers to the electronics manufacturing industry.

**ACD—30 Years**
For the last 30 years, ACD has supported the printed circuit board industry in a variety of ways; from design to laser photoplotting, to supporting engineering software, to final test. ACD was founded by Chuck Michie and Darrell Vaughn in July 1984 and incorporated under the laws of the State of Texas. The company actually began operations in October 1984. Scott Fillebrown and Steve Schwaebler assumed complete ownership in October of 1999. Today, ACD is an AS9100 and ISO 13485 certified full service EMS company. The company’s services now comprise complete board layout, DFM/DFA capability, printed circuit fabrication, component procurement, thru-hole, SMT and part-on-part mixed technology assembly, box build, rework, flying probe, functional and JTAG test, and development. [www.acdusa.com](http://www.acdusa.com)

**Cogiscan—15 Years**
Cogiscan has grown to become a global leader in the industry for track, trace and control (TTC) solutions. Over the last 15 years, the company has developed innovative solutions to solve challenging industry problems. Among others, Cogiscan was the first company to automate tracking of moisture-sensitive components. The company also developed the unique and patented RFID Smart Feeder system that is used on hundreds of machines around the world. Cogiscan is now widely recognized as the expert provider of traceability solutions for electronics assembly. [www.cogiscan.com](http://www.cogiscan.com)
Anniversaries

Computrol—30 Years
Founded in 1984, Computrol has a long history of providing electronics contract manufacturing services and support to blue-chip customers ranging from military and medical electronics, to telecommunications and computer peripherals. The company continues to build on its core services and capabilities by investing in versatile, high-speed manufacturing equipment and technology, as well as continuing training programs for employees. Today, Computrol focuses on providing electronics manufacturing services throughout the lifecycle of high-mix products. Maintaining this focus enables the company to provide faster assembly operations than those in large factories. Computrol provides fast turnaround and high quality on small to medium lot size assembly.

www.computrol.com

CyberOptics—30 Years
The company was founded in 1984 by Late Dr. Steve Case with its first office located at 2331 University Ave and many of its first employees being graduated students from the University of Minnesota. Today, with a strong team of 140 employees worldwide and a 24/7 global network of channel partners in 87 locations in 39 countries, CyberOptics’ state-of-the-art inspection solutions are employed in hundreds of manufacturing plants around the world to measure solder paste and other components to eliminate defects and improve yield—providing the critical edge to their customers.

www.cyberoptics.com

Datast—30 Years
An ISO9001- and AS9100-certified provider, Datast is the first test services company in the United States to fully integrate the latest SPEA 4060 double-sided flying probe tester with the latest Goepel boundary scan tools. This integration provides crucial benefits, such as increased digital test and fault coverage as well as significant time savings using automatic diagnostics. Combining advanced test platforms (flying probe, X-ray, boundary scan and ICT) with 30 years’ experience, Datast delivers superior value-added services. Datast has been providing the CM/EMS as well as the OEM community with advanced, integrated PCBA testing and inspection services since 1984. The company offers in-circuit testing (ICT) and test development (hardware and software) for all major ICT platforms (Agilent 3070, GenRad, and Teradyne). Additionally, Datast augments ICT with SPEA Flying Probe testing, Agilent 5DX and Dage Ruby 2D X-ray with X-Plane Technology, benchtop boundary scan, and functional testing.

www.datast.com
The companies (and data transfer format) included in this year’s milestone celebration share 180 years of experience between them.

Mike Scimeca, President & CEO

FCT Assembly—10 Years
Shortly after FCT Assembly was established in 2004, Fine Line Stencil was acquired. Memphis, TN was a strong stencil manufacturing location due to the industrial area and proximity to the main FedEx hub and headquarters, allowing Fine Line Stencil to cut and ship stencils up to midnight same day. In 2005, A-Laser was acquired to serve the precision laser cutting and processing market. FCT’s vast experience with stencil lasers was a perfect fit for the addition of A-Laser. In 2006, FCT Assembly acquired the first license in North America for Nihon Superior’s SN100C lead-free solder. In April 2008, FCT Recovery was started to offer a responsible source for recycling solder dross and electronic scrap from the electronic assembly process.

Today, FCT Assembly has four divisions; FCT Solder, FineLine Stencil, A-Laser, FCT Recovery, and seven facilities across the country. The company that started with ten employees and 1.5 million annual sales ten years ago has grown to 70 employees and 15 million annual sales.

www.fctassembly.com

Brian D’Amico, President

MIRTEC Corp.—15 Years
Over the years, MIRTEC has adopted an aggressive expansion strategy resulting in a total of eight worldwide divisions or “Centers of Excellence.” The company’s corporate headquarters is located in Seoul, South Korea with its new state-of-the-art manufacturing facility located in nearby Anseong. MIRTEC now has three divisions in China that are strategically located in Tianjin, Suzhou and Shenzhen. The North American sales and service division is located in Oxford, CT. MIRTEC’s West European headquarters is located in Plymouth, England and the East European office is located in Slovakia. In addition to these direct sales and service divisions, MIRTEC has developed a strong network of more than 60 international representatives and distributors, providing its customers with a much required local presence.

www.mirtecusa.com

Koichi Koba, Executive Vice President

Seika Machinery—20 Years
Seika Machinery is the U.S. subsidiary of Seika Corporation, part of the Mitsubishi global group and an international trading company specializing in wholesale and distribution of industrial machinery, equipment and material. Headquartered in Torrance, CA, Seika Machinery is a supplier of SMT/ATE equipment and materials including solder, reflow ovens, PCB conveyors, PCB routers, in-circuit testers, solder paste inspection machines, low humidity storage cases, stencil cleaners, and more.

www.seikausa.com
Troubleshooting SMT Assembly

To learn how to apply advanced methods of SMT troubleshooting and implement IPC-9641, send an email to info@akrometrix.com

*(Measured per the new IPC-9641 Standard)*
2013 Global SMT Rep & Distributor Review

We have more responses! At the end of each year, Global SMT & Packaging interviews key distributors and manufacturers’ reps to take the pulse of the electronics manufacturing industry and get a forecast of the coming year. These are the people on the ground, talking with manufacturers across the tiers, all over the world, every day. We received a few responses after the deadline for last issue’s feature, and thought they were still worth sharing:

ARK’s Dave Murrin

Territory: AZ, NM, Southern NV, and the state of Sonora, Mexico

Top Lines: Aqueous Technologies, Assembléon, FCT Assembly/FINE LINE Stencil, Koh Young, Kyzen, On Site Gas, R&D Vaportech, RPS Automation, Sono-Tek, Speedline Technologies

What are the current technology trends in your region, and what emerging trends do you envisage for 2014?

A couple of trends that have been ongoing but seem to be accelerating over 2013 include migration to smaller component packages and the move to lead-free. These trends are nothing new, but now are impacting companies that previously have been resisting them. Also, there was increased interest, discussion and exploration into package on package this year. Based on this uptick, I anticipate some proliferation of this technology in 2014.

How has the market performed in your territory over the past 12 months, and what do you envisage for 2014?

2013 started strong, but fizzled during the summer. In the third quarter we saw purchasing start to pick up and this trend has continued into the 4th quarter for a fairly strong end to 2013. Many equipment acquisitions were put on hold during 2013 that we anticipate will reemerge in 2014. This, in conjunction with the strong end of year in 2013, gives encouragement that 2014 will be a year of increased revenues for our customers and accompanying equipment purchases.

—Dave Murrin
ARK Manufacturing Solutions
**American Tec**
www.americantec.com

**Territory:** Mainland China

**Top Lines:** Nutek, Ovation Products, Fuji, Parmi, MIRTEC, ATS, Seica, A.P.E., OK International, Getech

**What are the current technology trends in your region, and what emerging trends do you envisage for 2014?**

As most of the products goes with digital and smart devices, still touch pads and smartphones are the key technologies that encompass the market. There is a large volume of ODM, OEM and local makers who are now competing much in design, user interface and speed of access/processing. For 2014, many markets will invest in better screen resolution driven by retina display, LED lighting and LCD size, higher resolution camera from normal 5 megapixel, going to 8 to 10 megapixels in small packaging on a slim phone. Still the challenge is on compact design with better features and stable, reliable performance of those devices.

**How has the market performed in your territory over the past 12 months, and what do you envisage for 2014?**

The market came out very well, kicking up from December of last year 2012 and moving sharply until the third quarter, around is July–August. As most investment was set earlier for Christmas holiday shopping and the Chinese New Year market, the volume now shows a little bit of a slowdown but still better that compared to last year. The LED market may not be so promising in terms of volume, but surely a drop in selling price of digital devices with LEDs, like display panels, televisions, tablets, etc. will create more opportunities for consumers to buy, allowing a flow of business and manufacturing. Thus, pricing is a bit factor in making 2014 more productive.

—Vivian Li, American Tec

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**Evolvi**
www.evolvismt.com

**What are the current technology trends in your region, and what emerging trends do you envisage for 2014?**

EvolviSMT is inundated with second user opportunities for SMT and test/inspection systems. EvolviSMT also has had great success in selling pick-and-place feeders. The “hot” equipment at the moment seems to be AOI, SPI and X-ray.

**How has the market performed in your territory over the past 12 months, and what do you envisage for 2014?**

Business has been very good in the past 12 months. Europe is definitely out of the recession and manufacturing is coming back. Buying, selling and brokering of equipment is keeping the EvolviSMT team very busy. 2014 is looking very positive.

—Mike Nelson
Evolvi

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**Evolvi’s Mike Nelson**

**Territory:** Worldwide

**Top Lines:** Vitronics Soltec, VJ Electronix, Universal Instruments, MIRTEC, Jot Automation, Juki, PBT, ATF, Koh Young Technology, Speedline Technologies
Kasion Automation Ltd
www.kasion.com

Kasion’s Abby Tsoi

Territory: China

Top Lines: Assembléon, BTU, CyberOptics, ECD, Goepel, Hitachi, Pillarhouse, PVA, VJ Electronix

What are the current technology trends in your region, and what emerging trends do you envisage for 2014?

Flexibility becomes the current technology trend, flexible machines facilitate electronic assemblers in reducing the manufacturing costs through optimum utilization of installed capacity. Rising demand on miniaturization of electronic products which requiring a compact integrating of electronic modules in printed circuit board assemblies. Increasing demand from military and medical electronic products with flexible and reliable surface mount equipment for handling a higher efficient electronics package.

How has the market performed in your territory over the past 12 months, and what do you envisage for 2014?

Labor is no longer a major advantage to operate a high-end electronic assemble in China. Not only the shortage of labor and rapid increasing of wages level has become an issue, but also the technology trend made the electronic packages much smaller that require flexible and reliable equipment to operate. We supply high-end automatic and flexible equipment to our customers who can save more than 20% operating cost in reducing labor expenses over past 12 months. Automation will be a high demand also in low-end high through-put electronic assemblies, as the manufacturers will gain a high labor cost reduction.

— Abby Tsoi

Kaison

Torenko & Associates
www.torenko.com

Torenko’s Ron Torenko

Territory: TX, OK, LA, AK & interior Mexico

Top Lines: Nordson Asymtek, Cobar Solders, Ersa, Essemtec, Heraeus, KIC, Milara, MVP, Seica, Universal Instruments

What are the current technology trends in your region, and what emerging trends do you envisage for 2014?

Things continue to get smaller. We now are seeing a combination of die and SMD on PC boards. AOI now needs to be a combination of 2D and 3D measurement. Measurement of conductive and non-conductive adhesives come into play. Engineers are now doing something with the data from their AOI to improve their process, for example, finding out which feeder is misplacing the component and taking the corrective action. Vapor Phase is coming more into play. It has become for cost effective and solves a lot of the issues with lead-free and heat transfer.

How has the market performed in your territory over the past 12 months, and what do you envisage for 2014?

Texas and Mexico are expanding. High automated lines are coming back to Texas. The market has found out the Mexico is just as competitive as China. OEMs are investigating bringing their work back in-house with automating the process. We will see more demand for automation in 2014 and beyond.

— Abby Tsoi

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CONFERENCE & EXHIBITION • March 25-27, 2014
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LAS VEGAS, NEVADA

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Jorge Quijano
SMT Process Engineer
Viasystems
The Strength of the OSAT Companies

Sandra L. Winkler

OSAT, or outsourced assembly and test, companies are businesses which offer integrated circuit (IC) packaging services on the open market, rather than being captive to the manufacturer of the die. Thus they are a subset of the total worldwide IC packaging market, as much of the IC packaging assembly is still performed in-house at the fab which created the IC, the integrated semiconductor manufacturer (ISM).

Fabless and ISMs alike utilize the services of OSATs. Companies with their own packaging facilities use OSAT companies for work beyond the capacity of their own packaging plants and/or for specialty packaging. These OSAT companies are the “tail end of the whip”—it takes the brunt of swings in the semiconductor market. When the economy is down, semiconductor manufacturers will fill up their own packaging plants before contracting the work out to the OSAT companies, who can then be left with less work. Conversely, when the market is up, the OSAT firms’ plants are filled to overflowing. The result is that the OSATs can have an accentuated view of the swings in the semiconductor market.

The OSAT companies are in a position to invest in cutting edge packaging technologies, which the research and development dollars required for this effort being spread around many ISM and fabless companies. Over the last decade, numerous companies have tried to specialize in a few, specific types of packages. Many have failed. Although semiconductor companies want to use packaging foundries, they want to be able to go to just one or two companies for all of their packaging needs. This means that a packaging company must be prepared to assemble vast quantities of SOs—or even DIPs—at competitive prices.

Approximately 42 percent of all packages assembled are DIPs, SOTs, SOs, and TSOPs! A broad portfolio of packages is a must.

Table 1. OSAT percentage of the total worldwide IC packaging market

<table>
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<tr>
<th>Year</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
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<td>32.8%</td>
<td>33.2%</td>
<td>33.9%</td>
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“The OSAT companies are in a position to invest in cutting edge packaging technologies, which the research and development dollars required for this effort being spread around many ISM and fabless companies.”

**Strategies of the top ten OSAT companies**

There are approximately 60 OSAT companies around the world competing for the outsourced package assembly dollars. Strategies vary, with some companies specializing in assembling multitudes of smaller packages, as is Carsem’s strategy, and others clamoring for the higher-value-added packages, such as 3-D solutions, FBGAs, BGAs, and the like. Amkor, ASE, SPIL, and STATS ChipPAC fall into this latter category.

How does each company position itself?

**ASE, Inc.**

ASE is the top OSAT company in terms of revenue. The company offers a broad spectrum of packages to fit a variety of needs, offering a one-stop shop for services. Though it assembles lower-end packages, ASE’s main focus and support is on the top-dollar value-added packages that bring more to the bottom line. Being vertically oriented to include package substrates in its product portfolio gives ASE a competitive edge in the array package business.

**Amkor Technology**

Founded in 1968, Amkor pioneered the outsourcing of IC assembly and test and is now a strategic manufacturing partner for more than 200 of the world’s leading semiconductor companies and electronics OEMs. A key Amkor strategy is to provide customers with innovative microelectronics assembly and test solutions to their challenging advanced packaging problems.

Amkor’s customers enjoy time-to-market benefits when they work with Amkor in an alpha customer engagement for the development of new package solutions to meet a device’s product requirements.

Amkor has built relationships with a number of system design companies to better understand long-term interconnect
and packaging performance requirements. In many cases, such as for package on package (PoP) design, Amkor has active co-development projects with system design companies to enable developing PoP solutions that address system and device integration requirements.

**Siliconware Precision Industries Co., Ltd. (SPIL)**

SPIL offers a variety of packages within its portfolio, but focuses mainly on those with high growth rates for handheld electronics: QFN and MCP solutions, which include stacked packages and SiPs. SPIL ramped up its package and service options approximately seven years ago, rapidly moving to higher revenue earnings. Wafer bumping, final test, and drop shipment became part of its service portfolio.

**STATS ChipPAC, Ltd.**

STATS ChipPAC is a merger of STATS, which had a focus on final test, and ChipPAC, a package assembly company. The merger, approximately six or seven years ago, enabled provision of complete back-end services. The company included wafer bumping as a service two or three years ago, thus completing its flip chip line. It offers a host of QFN, FBGA, and MCP solutions (stacked packages, SiPs) that cater to the handheld communications market, which constitutes a majority of its package assembly revenue.

**Powertech Technology, Inc.**

Powertech is a more recent entrant into the package assembly business, entering in 1997. The company assembles a large number of MCPs, and focuses on packaging memory devices. Package assembly is all performed in China. As with STATS ChipPAC, final test is a large part of its business.

**Signetics**

Signetics offers a number of array packages, in both wire bond and flip chip formats. The company also offers SO, QFN, QFP, and MCP solutions to round out its offerings. Its portfolio is not as broad as those of the top leaders, and is focused on the top competing packages rather than being a complete mix of all packages, which would include DIPs, TSOPs, CGs, DFNs, and WLPS. The company aims its products toward cell phones and consumer markets, flip chip products for networking, and graphics applications.

**Carsem**

Carsem’s specialty is meeting the tight tolerances of very small packages, and it offers numerous SOs within its package portfolio. Carsem also packages MEMS chips, which are coupled with ICs and have more complicated packaging issues in relation to ICs. The company produces a huge volume of assembly output, plus a full range of turnkey test services for RF, mixed signal, analog, digital, and power devices. It caters to the automotive, telecom, computer, and consumer electronics industries.

“Success lies in having a complete package portfolio, rather than just a narrow range of a few package solutions.”

**United Test and Assembly Center, Ltd. (UTAC)**

UTAC offers a wide mix of package solutions, covering nearly all major package categories. The company offers semiconductor assembly and testing services for a broad range of integrated circuits, including mixed signal, analog, and memory, areas for which units are in high volume.

**Unisem**

Unisem also offers a broad mix of package solutions. The company’s turnkey services include design, assembly, test, failure analysis, and electrical and thermal characterization. Wafer bumping is also offered for its flip chip packages. The company also packages some MEMS devices.

**Jiangsu Changjiang Electronic Technology Co., Ltd.**

Jiangsu Changjiang Electronics Technology Co., Ltd. (JCET) performs package assembly for both discrete semiconductor devices and ICs. Only its IC packaging figures were taken into account within this report.

The company packages analog, power, RF, MPU, baseband, and power amplifier modules for the smart phone and tablet markets.

**What makes an OSAT company successful?**

Success lies in having a complete package portfolio, rather than just a narrow range of a few package solutions. This broad spectrum grabs the higher revenue packages—SiPs, stacked packages, FBGAs, BGAs, etc.—as well as the multitudes of smaller packages such as QFN, SO, and the like. The smaller, lower I/O packages, in demand at high volumes in any economy, are used to package a multitude of analog and simple logic chips.

Right now handheld electronic gadgets are all the rage, so having a portfolio of packages aimed at these consumer electronics makes a lot of sense. These include stacked packages and SiPs. Flip chip and through-silicon vias (TSVs), found in the portfolios of the higher performing OSATs, offer advanced performance at a reduced size and also yield increased profits for the OSAT. The leading OSATs push the leading edge, and consider package development critical. They are aggressive at pursuing the top customers for volume production of higher revenue packages.

The leading OSATs offer test and turnkey services. The more complete the list of services that can be offered to meet all of a customer’s needs, the more successful the company. One-stop shopping helps both the customer and the OSAT company’s bottom line.

Sandra Winkler is the senior analyst for IC packaging at New Venture Research Corp (formerly Electronic Trend Publications). She began her analyst career as an independent consultant to the telecommunications industry nearly 20 years ago.

Since 1995, Ms. Winkler has authored all of ETP/NVR widely cited reports on IC packaging. She has spoken at numerous industry conferences and is a contributing editor for Chip Scale Review magazine.
HKPCA/IPC APEX builds on wisdom, shapes the industry

HKPCA/IPC APEX is now the biggest show in our industry in Asia. Five members of IPC Board of Directors attended, including next year’s chairman designate: Marc Peo, Bob Neves, Ray Sharpe, Tony Zhou, and John Mitchell (IPC President). The 150,000 square foot exhibit filled all of Hall 1 and most of Hall 2. Attendance was strong (not official numbers, but by observation) from the Wednesday opening into Friday afternoon. The IPC, which has six offices in China and will now open a seventh, grew about 40% this past year under the leadership of Phil Carmichael, now in his second year as President of the IPC’s greater China operations. We did not really see any new major products exhibited, but we DID discuss several innovations “offline.” Chinese equipment makers have improved and can now compete with almost anybody’s product. Many of the specialty chemicals and materials used in processing are now made in China.

Direct imaging is moving towards becoming “the standard” for primary imaging, with a shift from laser to LED in the works. More than 400 of these systems are reported to be in use. Direct imaging of solder mask will expand as photoimageable products requiring less energy to expose are brought to market in 2014. HDI continues to come on strong and should grow 15-18% in the region next year, even though the overall outlook is for a soft first half. The use of advanced high tech laminates continues to increase. Greater interest in the employment of robots for SMT manufacturing is developing to counter the continued annual wage increases mandated by the Chinese government. Automotive electronics remains strong. The Shenzhen police department has started to use all electric vehicles (from BYD) with roof-top video cameras and lighting.

We expect the purse strings for capital equipment acquisition to be loosened after April. All are awaiting to see what the required minimum wage increase will be next year. The “new” government is also reported to be signaling that it is increasing its battle against corruption and waste with a new guideline to prevent government officials from using 5-star hotels in 2014. We note that manufacturing companies in China are taxed even though they may have losses.

The island political situation continues to cause some disruption in electronic equipment businesses between Japan and China. Taiwan has now asserted its claim to the barren islands under territorial dispute between Japan and China. North Korea has followed China’s lead and expanded the sea area over which it claims protective rights. We believe that a new wave of emigration from Hong Kong to Vancouver is in the process of starting as young educated families have decided that it is a “better place to live.”

The Hong Kong government has apparently decided to “give” US$100 million to poor people (up to $10,000 each) sparking a series of protests (including a column in the HKPCA journal) stating how the money could be better spent on education, food, facilities, technology, job creation, etc.

Source: Weiner’s World at www.weiner-intl.com

Gene Weiner, president of Weiner International Associates, is an IPC Hall of Fame Inductee and has been voted one of the The 10 Most Influential Persons in the PCB Industry.
A Solder is an exceptionally practical technology with roots going back more than 2000 years. Somewhere in the distant past, one of our more clever ancestors created by chance an alloy of tin and lead, and they or someone who practiced their chance invention discovered that this unique combination of elements could be used to join pieces of metal together. This combination of chance observation and logic has had lasting effects and is a key development in the technological history of mankind. Those in the electronics industry of today are very familiar with this ancient technology, and today it is still the method of choice for making electronic assemblies of every sort. The only “fly in the ointment” is that the EU parliament, in a mad rush to try and look “green,” took the scientifically ill-advised position that lead needed to be banned from electronic solders. Sadly there was never presented a credible piece of scientific evidence that anyone had ever been harmed by tin-lead solder in electronic equipment. Nor could they prove their assertion that it would be a risk to ground water. Granted that greed and mismanagement of electronic waste resulted in physical and environmental harm coming to areas of the world where uncontrolled recycling was being carried out by uneducated individuals, but that hole in the system is being addressed. The impact of the EU’s decision has been significant and far reaching, and it has caused the industry to spend needlessly many tens of billions of dollars to make products that are, unfortunately, proving less reliable and arguably less environmentally friendly than those built with tin lead solders.

The devil we know (stripped naked)

While soldering (especially tin-lead soldering) holds many benefits in terms of offering a means of mass assembly of electronic components to printed circuit boards and is fundamentally simple, its application in the assembly and manufacture of electronic products of the present age is much more complex and fraught with opportunity for defects, but it is also the “devil we know,” and the old saying suggests that “better is the devil we know” because he is at least familiar, and most of us abhor change. But is dealing with the devil we know really worth the price we are paying? Following is a recitation of some of the many types of solder and solder related defects that test and inspection is tasked with finding before a product reaches market. Bear in mind as these defects are recounted and reviewed that the cost of defects rises as a product moves further from the manufacturing line.

Opens. Opens are discontinuities generated in the soldering process. They can be manifest in assembly in a number of ways. For example, a bent or lifted lead on a QFP component, a missing solder ball on a BGA, insufficient solder on an LGA, or the warp-age of the component during the reflow process can all result in an open circuit.

Shorts. Solder shorts are bridges of solder between one or more component leads on an assembly. As component lead pitch continues to drop, the incidence of short circuits increases. Presently the “threshold of pain” for most assembly is experienced when the lead pitch drops below 0.5 mm.

Insufficient Solder. Insufficient solder is a condition where the amount of solder in a solder joint is less than desired or specified contractually through industry specifications or customer requirements.

Excessive Solder. Excessive solder is fundamentally the opposite of the condition of insufficiently and is again measured against agreements.

Solder Cracking. Solder cracking is an obvious concern as it could result in a latent open circuit condition.

Tin Whiskers. Tin whiskers, small metal projections emanating from a solder joint. They can grow in length up to 15 mm, and given the fine pitch of today’s components, they are a significant concern. They are also challenging because they are typically a latent defect that shows up unpredictably. Past research indicated that the addition of lead to tin solder alloys would mitigate the formation of whiskers; however with the ban on lead in electronic solders, the incidence of whiskers is on the rise.

Poor Wetting/Dewetting. Good wetting is manifest by the presence of a uniform coat of solder on both the leads of the component and the terminations of the printed circuit to which they are joined. In areas of poor wetting or dewetting, the solder thins appreciably in areas, leaving only a thin silver sheen.

Voids. Voids are often difficult to detect without use of special equipment such as an x-ray apparatus. The challenge with voids is that they represent potential weakness in the solder joint, owing to their inconsistent nature. Voids can be found both in through hole and surface mount components. In the case of surface mount components, the voids are often extremely small and are sometimes referred to as champagne voids.

Blowholes. Blowhole is a term applied to a phenomenon where a small hole is observed in a solder joint. Typically the defect is found to be the result of discontinuities in the plated through hole wall that may absorb flux and then explosively out gas during the soldering process.

Cold Solder Joints. Cold solder joints are solder joints which did not form completely a good metallurgical bond. They are often the result of the joint receiving insufficient heat to cause complete melting and joining of the solder. Cold solder joints are often seen in cases where the component lead is connected to a large thermally conductive feature or element, and insufficient heat is retained near the lead to assure a good solder joint. With lead-free solders, the phenomenon provides a greater challenge, as the amount of heat that must be supplied is much greater than it might have been with a tin-lead solder.

Brittle Solder Joints. Brittle solder joints

Joe Fjelstad

www.globalsmt.net
Solder assembly—a steely-eyed look at “the devil we know”

The resulting alloy is less ductile than the grapes. Grapping is another lead-free-related defect wherein the small, often ball-like, particles of solder in a solder paste do not reflow completely, leaving a surface that looks like the surface of a bunch of grapes. Like head in pillow, it may not be easily detected.

**Graping.** Graping is another lead-free-related defect that was identified only with the introduction of lead-free soldering. It is an unsettling type of defect that was identified only with the introduction of lead-free soldering. It is a result of the high temperature of reflow causing rapid volatility station of the flex and spatter of the solder particles that are part of the flex. While a viable solder joint may be created even as solder balls are being formed, they represent a risk to the long-term reliability of the assembly as potential shorting elements.

**Misregistration.** Components with fine pitch leads, if jostled before or during the assembly, may be misregistered relative to the land pattern, resulting in a nonfunctional product.

**Insufficient Cleaning Under Devices.** As mentioned previously, insufficient cleaning under surface mount devices can result in latent failure through the formation of high resistance shorts or the growth of dendrites.

Clearly there is a great deal of nuance in the detection and identification of solder-related defects, and numerous books have been written over the last few decades to try to characterize and suggest methods for eliminating or mitigating them (the devil is also “in the details” as another aphorism attests). It is not within the scope of this brief commentary to provide detail on all of the various types of solder-related defects, which can extend from the macro to the micro, but for the benefit of the reader Figure 1 is offered, providing representative examples of a number of the defects described above.

**Solder’s impact on the printed circuit board**

The importance of managing the soldering process if clear but making a good solder joint is also just a part of the story, and there are a number of defects that can be generated within a printed circuit assembly because of the soldering process. These include:

**Corner Cracking.** A crack that forms at the interface between the whole and the land that surrounds it. It is normally the result of the z-axis expansion of the printed circuit board during thermal excursions such as soldering.

**Barrel Cracking.** Barrel cracking is another phenomenon associated with the soldering process. It is similar in some ways to a corner crack, except that it is manifest near the center of the hole.

**Solder Balling.** Solder balling happens during the reflow of a solder paste on a surface mount assembly. It is a result of the high temperature of reflow causing rapid volatility station of the flex and spatter of the solder particles that are part of the flex. While a viable solder joint may be created even as solder balls are being formed, they represent a risk to the long-term reliability of the assembly as potential shorting elements.

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which a component, normally a BGA, is assembled.

Decomposition. Decomposition of a printed circuit board is a relatively new phenomenon associated with higher temperatures used with lead-free soldering. In fact, a new term was added to the industry lexicon, $T_d$, which is the temperature of decomposition representing a loss of a specified percentage of the weight of the printed circuit.

Clearly printed circuit technology, like soldering technology, is fraught with its own vulnerabilities due to the complexities of processing. The demands on printed circuit board technology foisted upon the industry by the imposition of lead-free soldering requirements have placed a heavy burden on the printed circuit manufacturing industry. The need for higher glass transition temperatures to assure a measure of survival through the elevated temperatures of lead-free soldering has caused the printed circuit industry to have to qualify new materials. Simultaneously, a demand has been placed upon the industry to remove halogenated flame retardants from its materials. This double-barreled challenge is one that the industry had not faced before. Moreover, the industry has been challenged to provide circuits with even finer features that operate at ever increasing frequencies. To their credit, printed circuit industry technologists, engineers, and scientists have struggled admirably to address these challenges, including the challenge of finding solutions to defect modalities that were unknown to the industry just a few years ago. Unfortunately a number of the defects described are related to soldering and its effects. The earlier problems have been exacerbated by the increased temperature required for lead-free soldering. Figure 2 offers cross sections of representative printed circuit defects resulting from thermal excursions.

Solderless assembly—a simpler approach?

Given all the challenges and risks associated with soldering, it must be that every thoughtful and prudent manufacturing engineer is constantly seeking a way or ways to make assembly processing more robust. If one looks for inspiration on how they might end their dealing with the devil, they can find it in the Bible, where it is written: “If thine eye offend thee, pluck it out, and cast it from thee.” The passage continues to suggest that getting rid of one’s eye is a superior choice to ending up with the devil with two eyes, and that seems to be where the industry is today. Solder is arguably that offending “eye,” and thus we continue to deal with the devil as long as we persist in its use.

Presently, this and other journals on electronic manufacturing are filled with articles, papers and commentaries offering new materials, processes and equipment both for manufacture and inspection to try and beat “the devil we know” into submission but “Old Scratch” is a wily and crafty adversary who seems always to have a counter punch to every solution offered. This situation gives rise to the question: “Is there any alternative?” The answer in the opinion of this writer is “Yes.” The answer is to assemble electronics without solder.

The potential benefits of eliminating solder are significant in many areas of current concern or high interest, including cost, reliability, performance, environmental impact, design security, a means of addressing some elements of counterfeiting, sustainability, a means of sidestepping conflict metals concerns and others. So how can it be done? It is really quite simple: Build assemblies in reverse, and instead of placing and joining components on circuit boards with solder, build up circuits on “component boards” using copper plating, bypassing the soldering process completely, along with all of its many extra processing steps, ongoing challenges and problems. The next column will discuss the concept of solderless assembly in more detail.
Cognex Corporation releases In-Sight® Explorer 4.9, software that offers an expanded set of inspection tools and an enhanced Cognex Connect™ communications suite featuring the IQ Sensor Solution network (iQSS). This latest version of In-Sight Explorer software includes the surface flaw tool and the scene correction filter. The Cognex Connect suite of factory communication protocols ensures that In-Sight vision systems can easily communicate with a broad range of devices on the factory floor. www.cognex.com

HDI Microvia PCBs now available online at WEdirekt
The HDI specialist Würth Elektronik has added HDI microvia PCBs to the company’s online shop, WEdirekt. With just a few clicks, your HDI PCB is calculated and the price is shown immediately online. Ordering prototypes is considerably simplified and faster. Normally, the following statement applies: low quantity required plus a complicated production process results in high costs. This is not so at Würth Elektronik. Due to its mass of experience, the PCB manufacturer is a specialist in the field HDI and has now expanded its online shop with this technology. www.we-online.com

Laird releases a new Fingerstock product, the Edge Guide Clip-on Strip. Ideal for virtually every application where Printed Circuit Boards (PCBs) need to be grounded and/or shielded, this new product reduces installation and labor costs and is available in custom lengths. A customer installing a 10 cm, or 8 finger strip, could reduce installation time by up to 80% using the Edge Guide Clip-on Strip as opposed to performing a typical installation with 8 traditional single clips. www.lairdtech.com

VJ Electronix introduces the new X-Quik benchtop X-ray
VJ Electronix, Inc., debuts a new low-cost, easy-to-use X-ray inspection system—the X-Quik. The X-Quik is a small, general-purpose X-ray system for inspection of items such as electro-mechanical devices, sensors, molded parts, mail parcels and biological samples. With a size of just more than two feet cubed and a low, affordable price point, the X-Quik is well suited for engineering labs, machine shops and quality control departments for a wide variety of applications. www.vjelectronix.com

Handheld dispensing valve features low maintenance, internal diaphragm design
The new Dymax Model 300 dispensing system features a pneumatic, normally closed diaphragm valve that is designed for use with low- to medium-viscosity fluids. The valve’s diaphragm design prevents fluid from contacting the actuating components within the valve, reducing component damage and wear while extending
require the highest accuracy and precision as well as the full temperature scope of ambient-hot-cold. www.multitest.com

**Toughened two component epoxy is optically clear and resists thermal cycling**

Master Bond EP38CL was developed for bonding, sealing, coating and encapsulation applications that require toughness and durability. With a Shore D hardness exceeding 75, its toughness is a unique property that imparts resistance to rigorous thermal cycling, impact and mechanical shock. www.masterbond.com

**Power modules get their own upside-down C-SAM® system**

Sonoscan has shipped the first of its new D9600Z C-SAM® systems. This new model is designed expressly to facilitate the imaging of IGBT (Insulated Gate Bipolar Transistor) power modules. Power modules, such as IGBTs, are basically high-speed high-power switches used in railway engines, electric automobiles, and many other applications involving high power. Prior to packaging the transistors themselves are at the top of the module and are too susceptible to water contact to permit acoustic imaging from above. www.sonoscan.com

**Innovative sensors require advanced test equipment**

Multitest announces that its leading solution for 3-axis magnetometer plus 2-axis low g-test and calibration fully supports the technical features of today’s advanced 3D hall sensors. The modular concept for sensor test equipment ensures the most economic equipment utilization. The system has been designed for the industrial and automotive market segments. Both

**GOEPEL electronic improves flexibility of RAPIDO™ inline systems for programming and test**

GOEPEL electronic announces the availability of new features in the RAPIDO™ multi-site inline production system family for high-speed in-system programming and board test based on the latest Embedded System Access (ESA) technologies. One of the essential innovations is an option to utilize planar downholders in sandwich construction. Now ultra-thin, rigid-flexible boards with contact gaps of up to 50 mil can be safely handled in multiple-up production. Utilizing this technology, RAPIDO has become one of only a few systems that meet the challenges of safe inline contacting for such sensitive applications. www.goepel.com

**Advanced dual-cure conformal coating from Intertronics**

Intertronics announces the DYMAX Dual-Cure 9482, a UV light- and moisture-cure conformal coating specially formulated to flow underneath components on printed circuit boards and cure in these shadowed areas by using ambient moisture, which can result in faster throughput for through hole assemblies. DYMAX 9482 coating demonstrates excellent re-workability which is of particular importance to manufacturers of expensive PCBs or manufacturers looking to increase board yields. Typical applications include electronic assemblies for the general and consumer electronics, automotive, appliance, and military equipment manufacturing industries. www.intertronics.co.uk

**MT2168—successful evaluation proves superior performance**

Multitest announces that it received the official data from an evaluation of the MT2168 that confirms the superior performance of the MT2168 pick-and-place handler. During this evaluation on an HVM test floor in Asia, more than 2.3 million packages were handled. The MT2168 was directly compared to competitive products and demonstrated predominant results in major areas including jam rate, first-pass yield and downtime. www.multitest.com

Continued on page 39
Four on 4.0—four things I learnt about Industry 4.0

If there is one thing Productronica does better than any other trade show, it’s the setting of agendas, and this year top of the agenda in Munich was Industry 4.0. When I was asked to moderate a debate on the topic, I imagine I looked a little blank—it wasn’t a familiar topic, but with some online research and well placed questions, I learnt quickly and now realize it is a topic of many dimensions.

So, having had the debate, what have we learnt about Industry 4.0?

Evolution not revolution
It seems Industry 4.0 is more a journey than a destination, and the key to success is setting out on the path without fear. Frederik Andersson of Aros Electronics, one of the panelists on the session I chaired, was clear in telling our audience to be brave, to set out on the journey in any way you can and to develop the details as you go. If Industry 4.0 is about having all the equipment in your line communicating harmoniously, then getting the first two to communicate is a valid start.

In this way Industry 4.0 becomes not just a single goal but also a wrapper that brings together a number of industry trends and technologies currently at play. Trends like big data, the Internet of things, consumer behavior around manufacturing proximity and mass customization, greater supply chain design and visibility, traceability and an overriding and ever present desire to lower costs through efficiency.

Smart machine are one thing, smart lines another, but ultimately we need smart supply chains
These are the wise words of Dr. Ulrich Goddat from Porsche Consulting, another panelist at Productronica. Ulrich is right, value really comes when we start to think outside our own little area, be that a single machine or even an entire factory. We need to see Industry 4.0 as a way of looking at the entire product life cycle, from concept to end of life. Just as lean, which was initially applied to manufacturing only, has crept into all elements of business management, Industry 4.0 will need to do the same.

If we do this, we can add real value in terms of traceability and understand the impact of each decision made in the development, manufacturing and eventual recycling or disposal of a product.

Not only do the machines need to be part of this smart line, and indeed this smart supply chain, they also need to be open in their communication. Openness is key to making data work well and work holistically. There is no shortage of data, but there is a shortage of open data protocols and an open approach that allows for a good bidirectional flow of data. Perhaps standards are key here, or perhaps fierce collaboration can produce the right results.

It’s all about the individual
Industry 4.0 is about the power of the single product and how that product, with its connection through the virtual world, controls the process and materials that occur during manufacturing and fulfillment. In a discussion I had with a distinguished journalist, I was told that Industry 4.0 was mass customization. I begged to differ. After some heated debate, and a couple of beers to keep everyone calm, we agreed it was only mass customization when that mass customization was controlled by the single deliverable part, in fact controlled by the details of the consumer’s order.

It seems that today’s consumer likes the idea of mass customization. The idea of every product being tailor made for us is certainly appealing, and with so many features to choose from it makes perfect sense. But as consumers we are also impatient: we may want a unique custom made product, but we don’t want to wait for it! This is where high velocity mass customization is needed, and for that to be economic and efficient it needs to be automated and driven by large amounts of accurate available data.

It’s a German initiative with global application
Many years ago, countries could and did operate in isolation, manufacturing in their own way with their own fully functioning supply chain. Now manufacturing is global, with global demands, global fulfillment and global supply chains. Industry 4.0 will only gain traction if it is taken as an international, not a German, initiative. Whether that means it needs to be championed by an international trade association, or perhaps an international manufacturer, remains to be seen, but it will only be a success if it gets high enough up the agenda in Silicon Valley, Shanghai and Taipei, as well as in Munich and Frankfurt.

The German government’s commitment has been supported by real investment.
This is because they see it as a competitive advantage, and perhaps it is. I suspect it isn't for German electronics manufacturers, be they OEM or EMS, as these kinds of technology trends travel the world very fast nowadays. But for those manufacturing equipment, writing software and providing services, it could offer real benefit. Germany is a dominant provider of equipment for manufacturing, and much of that will be 'Industry 4.0 ready' before the same equipment from elsewhere. This may win them some advantage in a very competitive market.

**In conclusion**
Industry 4.0 is on the agenda, but we should not see it as some kind of silver bullet for high cost regions or as a savoir for the German or European manufacturing industry. It is part of a drive to a smarter more integrated supply chain. It is a wrapper for a number of trends that are currently changing the way we view the product life cycle. And it is a reflection of the growing complexity of the consumer’s expectations and demands from the world's OEMs, which will in turn drive soldering. Any debate that increases the profile of the supply chain and encourages fierce collaboration is a good thing.

Philip Stoten has spent half his career in the electronics manufacturing industry and the other half as a journalist covering. You can find his work on YouTube and you can follow him on Twitter @philipstoten.

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**New products** — Continued from page 37

**Mek turns AOI on its head with in-line bottom side PCB inspection**
Mek Europe BV successfully launched the new SpectorBOX “Bottom-Up” Modular AOI system at last week’s Productronica exhibition in Munich. The system replaces traditional board flipping alternatives in less space and at lower cost. Optimized for the inspection of Wave & Selective soldering of THT & SMT components, SpectorBOX is designed to inspect PCB's inside solder frames directly from the conveyor system. [www.mek-europe.com](http://www.mek-europe.com)

**ACE announces revolutionary real-time temperature data logger**
ACE Production Technologies, Inc., announces its new revolutionary temperature data logger imbedded into the KISS selective soldering machines that provides significantly greater accuracy of thermal measurement and control for the selective soldering process. The new ACE real-time temperature data logger allows placement of up to 6 thermocouples at critical locations on a board to obtain topside printed circuit board temperature readings which inputs this critical process information into the machine control software. [www.ace-protech.com](http://www.ace-protech.com)
International Diary

12-14 February 2014
SEMICON Korea
Seoul, Korea
semiconkorea.org

18-20 March 2014
productronica China
Shanghai, China
e-p-china.com

25-27 March 2014
IPC APEX Expo
Las Vegas, Nevada, USA
ipcapexexpo.org

26-27 March 2014
Smart Systems Integration
Vienna, Austria
smartsystemsintegration.com

2-4 April 2014
NEPCON Korea
Seoul, Korea
www.smtpcb.org

8-10 April 2014
NEW (National Electronics Week)
Birmingham, UK
nationalelectronicsweek.co.uk

15-17 April 2014
Expo Electronica
Moscow, Russia
expoelectronica.primexpo.com

23-25 April 2014
NEPCON China
Shanghai, China
neponchina.com

6-8 May 2014
SMT/Hybrid/Packaging
Nuremberg, Germany
smt-exhibition.com

4-6 June 2014
JPCA Show
Tokyo, Japan
jpcashow.com

5-6 June 2014
Semicon Russia
Moscow, Russia
semiconrussia.org

10-12 June 2014
NEPCON Malaysia
Penang, Malaysia
nepon.com.my

Winter chill followed by spring blooms—Continued from page 19

Semiconductor sales are expected to expand 4.1% y/y from $304.3 billion in 2013 to $316.6 billion in 2014 and an additional 3.4% y/y to $327.3 billion in 2015.—WSTS

Processor shipments increased 24% y/y to 1.50 billion units in 2013.—IHS

World fab equipment (including new, used and in-house manufactured) spending declined 9% to 2.5 billion in 2013.—SEMI

World new semiconductor manufacturing equipment sales are expected to grow from $32.0 billion in 2013 to $39.5 billion in 2014.—SEMI

China MEMS increased 19% y/y to US$2.46 billion in 2013.—IHS

European semiconductor distribution market sales grew 1.8% y/y to 1.46 billion Euros in 3Q13.—DMASS

German component distribution market sales grew by 3.2% to €716m in 3Q13.—FBDi

North America-based semiconductor equipment manufacturers posted $1.12 billion in orders worldwide in October 2013 (3-month average basis) and a book-to-bill ratio of 1.05.—SEMI

OEMs in the Americas region accounted for 36.3% of global spending on industrial semiconductors in 2012.—IHS

Russia microelectronics component market reached $2.5 billion in 2012, representing 0.5% of global market.—Frost & Sullivan

Automotive sensor market worldwide is forecast to grow at 8.2% CAGR from US$16.2 billion in 2012 to US$17.4 billion in 2013, US$18.8 billion in 2014 and US$30.3 billion by 2020.—Research and Markets

Connector industry expanded 2.7% to $48,889 million in 2013.—Bishop & Associates

Home appliance semiconductor market growth expected to have doubled in 2013 (compared to 2012) to US$2.6 billion.—IHS

Smart device application processor market grew 43% y/y to 1.32 billion units in 2013.—Digitimes Research

LED lighting product shipments increased 68% y/y to 1.32 billion units in 2013.—TrendForce

Solid state lighting market is forecast to grow at 18.7% CAGR from 2013 to $56.79 Billion by 2018.—MarketsandMarkets

Worldwide DRAM market rose 9% q/q to US$9.3 billion in 3Q13.—TrendForce

Worldwide NAND flash output value is forecast to rise 13% y/y to US$28 billion in 2014.—DRAMeXchange

Walt Custer is an independent consultant who monitors and offers a daily news service and market reports on the PCB and assembly automation and semiconductor industries. He can be contacted at walt@custerconsulting.com or visit www.custerconsulting.com.

Jon Custer-Topai is vice president of Custer Consulting Group and responsible for the corporation’s market research and news analysis activities. Jon can be contacted at jon@custerconsulting.com.
SMTA International 2013 best papers announced

The SMTA is pleased to announce the Best Papers from SMTA International 2013. As speakers at SMTA International, individuals make contributions to the industry by sharing their research and findings. To reward exceptional achievement, $1,000 awards and plaques are given for the Best of Conference Presentation, Best of Proceedings Paper, and the Best International Paper.

The winner from SMTA International 2013 for the Rich Freiberger Best of Conference Award, as selected by the conference attendees, is Matt Kelly, P.Eng., IBM Corporation, for his presentation entitled “Plasma Stencil Treatments: A Statistical Evaluation.”

Babak Arfaei, Ph.D. from Universal Instruments Corporation, won the Best of Proceedings category for the paper “Effect of Sn Grain Morphology on Failure Mechanisms and Reliability of Lead-Free Solder Joints in Thermal Cycling Tests.”

You Chye How, Texas Instruments Malaysia Sdn. Bhd., won the Best International Paper category for the paper entitled “Reliability Improvement of Array QFN Package.” This award and the Best of Proceedings are selected by the SMTA International Technical Committee.

The authors will formally be presented their awards at the Opening Ceremony during SMTA International on September 30, 2014 in Rosemont, Illinois. For information on participating in the 2014 SMTA International Conference, visit the Call for Papers page at http://smta.org/smtai/call_for_papers.cfm, or contact SMTA administrator JoAnn Stromberg at 952-920-7682 or joann@smta.org. Abstracts can be uploaded directly on-line and will be accepted through February 28, 2014.

The papers are available in the conference proceedings available in the SMTA Bookstore at http://www.smta.org/store/book_store.cfm and will be available in the proceedings section of the SMTA Knowledge Base by February at http://www.smta.org/knowledge/knowledge.cfm.

IPC Hand Soldering Competition winner crowned at productronica 2013

Despite chilly temperatures in Munich, things got “heated” as 43 competitors went soldering iron to soldering iron at IPC’s Hand Soldering Competition at productronica 2013, November 12–15. Emerging victorious and taking first place, a cash prize of €500 and a new soldering station from JBC Tools, was Jacek Majchrzak, PartnerTech, Poland. In addition, Majchrzak earned a coveted spot at the IPC Hand Soldering World Championship at IPC APEX EXPO 2014 in Las Vegas.

Second place and a cash prize of €300 went to Baigyou Tamas, GÉMOSZ Elektronikai Kft, Hungary; Halil Ibrahim Demir, Tai Tusas Aerospace, Turkey, took third place and a cash prize of €100.

Participants in the hand soldering competition were tasked with building a functional electronics assembly within a 45-minute time limit. A panel of independent judges from Institut IFTEC and PIEK International Educational Centre evaluated each assembly based on workmanship, overall functionality, compliance with IPC-A-610E Class 3 criteria and speed of completion.

For information on upcoming IPC Hand Soldering Competitions, visit the website www.ipc.org/hsc.

North American PCB sales and order growth strengthening

IPC — Association Connecting Electronics Industries’”s October monthly North American Printed Circuit Board (PCB) Statistical Program found that sales and order growth strengthened in October, but the book-to-bill ratio declined to 0.94.

Performance over last year improves

Total North American PCB shipments increased 3.6 percent in October 2013 from October 2012. Year-to-date shipment growth is still negative compared to the same period in 2012, but is improving and reached -2.9 percent in October.

North American PCB bookings increased 7.0 percent year over year, an improvement that brought year-to-date growth into positive territory at 0.1 percent.

PCB shipments and bookings in October were both lower than in the prior month, reflecting normal seasonal patterns. Compared to September 2013, PCB shipments in October were down 6.6 percent and bookings were down 4.0 percent.

Interpreting the data

The book-to-bill ratios are calculated by dividing the value of orders booked over the past three months by the value of sales billed during the same period from companies in IPC’s survey sample. A ratio of more than 1.00 suggests that current demand is ahead of supply, which is a positive indicator for sales growth over the next three to six months. A ratio of less than 1.00 indicates the reverse.

Year-on-year and year-to-date growth rates provide the most meaningful view of industry growth. Month-to-month comparisons should be made with caution as they reflect seasonal effects and short-term volatility. Because bookings tend to be more volatile than shipments, changes in the book-to-bill ratios from month to month may not be significant unless a trend of more than three consecutive months is apparent. It is also important to consider changes in bookings and shipments to understand what is driving changes in the book-to-bill ratio.

IPC’s monthly PCB industry statistics are based on data provided by a representative sample of both rigid PCB and flexible circuit manufacturers selling in the USA and Canada. IPC publishes the PCB book-to-bill ratio at the end of each month. Statistics for the current month are not available until the last week of the following month. This report is available free to current participants in IPC’s PCB Statistical Program and by subscription to others. More information at www.ipc.org/market-research-reports.
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