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DEK's VectorGuard™ stencil system has been developed to lighten your load and keep things simple.

The high performance frameless foils are easier to manage than standard, permanently-mounted stencils. They are lighter, using finer materials. There are no sharp edges, making handling safe and changeovers quick. Tensioning and adjustment is done automatically, and mounting the foils in the VectorGuard frame couldn't be easier.

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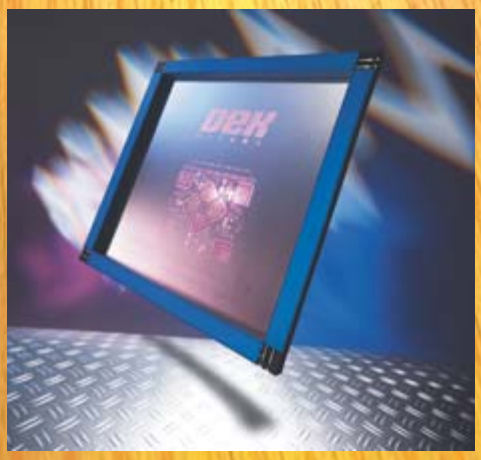

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UP Media Group

Service Excellence Award Winners, p. 36

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2 months

Countdown to July 1, 2006

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Avoiding the 'Oxide Envelope'

AXI for Pb-Free and SnPb

A First Look at China's RoHS Law

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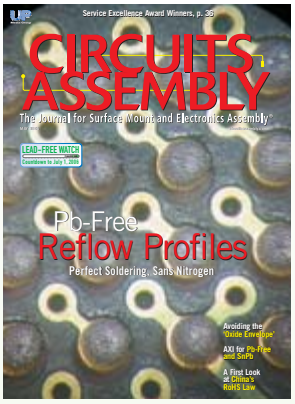
MAY 2006 – Vol. 17 No. 5



Courtesy Cobar Europe BV

ON THE COVER: Solder bumps are shown during reflow in air.

FIRST PERSON

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TECH TALK

FEATURES

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The Bottom Line

Customer experience over several years is that the TOTAL cost of running a standard wave soldering machine with SN100C when all factors are taken into account can be up to **one third the cost** of running the same machine with tin-silver-copper alloys. The actual savings in each case will depend on the number of factors that apply, but the cost of running a line with SN100C is ***always*** lower than the cost of running the same line with tin-silver-copper. Please contact AIM for additional information.

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Caveat Lector

8Telecom: Ringing Up Prosperity

How often does a company with no electronics contracting experience – heck, no electronics *manufacturing* experience – open a plant and within three months land as customers some of the largest telecom companies in the world?

I wouldn't be surprised if Zhejiang 8Telecom (8telecom.cn) was the first to hold those bragging rights. I visited the company's sparkling new factory in Hangzhou, China (about two hours outside of Shanghai) in early April. I came away with the remarkable story of a forward-looking company that went from nothing to an EMS player to watch in a relative heartbeat.

Its origins are anything but electronics. The company was launched in June 1997 as a designer and builder of telecom towers and synthetic pipe for running buried cables. Yet in roughly six months the company has opened an EMS division, outfitted a factory and hooked some of China's top names in telecom: Huawei Technologies, China Telecom, China United Telecommunications and China Mobile.

A veteran of Motorola and Pemstar, factory manager Wei (Johnny) Liu is one of six engineers and two managers at the company with an assembly background. Last fall, they were charged with procuring and installing three SMT lines. On deadline, they pulled it off. The factory was outfitted in December and pilot production began in January.

The three lines include Universal Instruments GSM pick-and-place machines, Speedline UltraPrint 2000 HiE printers, ERSA soldering equipment (HOTFLOW for reflow and EWS 500 for wave) and one YesTech YTX-3000 x-ray. They use Multicore solder for mobile phones and Alpha Metals for set-top boxes. AOI and ERP systems are still under evaluation. There is no Chinese-made automated equipment in the factory: According to Liu, it's not sufficiently stable to meet the 98% yields required by 8Telecom's customers.

Equipment evaluation centered on Cpk, reliability and throughput, using industry standard benchmarks. When choosing vendors, the emphasis was on flexibility and support, says Liu. The designs call for components ranging from 0102s to 55 mm^2, and low maintenance and downtime were musts.

Not surprisingly, 8Telecom relied heavily on its suppliers to pull everything together.

"We didn't know the type of equipment we would build," said Liu. "Today it's mobile phones. Later it might be base stations. We needed flexibility." Pointing to the lines, he says, "Universal was the best for this. The DPO software works very well; it balances the whole line." He added that Universal's lab and service center in nearby Suzhou was instrumental in establishing a high level of comfort.

The 8Telecom factory opened in January and is running two shifts, seven days a week. The EMS group employs 160 workers, and plan to grow to 250 (with 30 engineers) by year-end. It averaged eight inventory turns for the first quarter. The firm was undergoing an ISO audit during my visit.

8Telecom has hit the ground running, and in most respects seems like an old hand at building electronics. Customers, vice president Qiao Mu says, are interested in the equipment platform, process control, the management team's EMS experience, the capability to build custom product and – what else? – cost. The top defect is solder joint quality. And the major challenge they see is the strong management sported by other major EMS firms. "It's something a newcomer has to overcome," Liu adds.

8Telecom counters with its own "skilled management team, and a very low-cost solution." Says Mu: "I think MNCs are above the cost expectation that the customer requires."

None of this answers the big question: How does an EMS company go from nonexistent to winning programs from some of the largest and most demanding customers in the world? Answer: 8Telecom leveraged its relationships with several major OEMs by adding EMS work to other services already being provided.

The goals are ambitious: 200 RMB ($25 million) this year in EMS revenues and 1 billion RMB ($125 million) within three years. A new plant is already under construction, and the firm plans to add three lines in 2006 and four in 2007, giving it 10 in all. Given the customer list, the odds appear in their favor.

Finally, why "8Telecom?" Eight is a lucky number to the Chinese, meaning sudden fortune and prosperity. Sounds about right. ■

Mike Buetow

Mike Buetow, Editor-in-Chief
mbuetow@upmediagroup.com

Reliability

SMT

PROBLEM:

Voiding:

- Via-in-pad Voiding
- CSP Printing

SOLVED:

Indium5.1 Series No-Clean Pb-Free Solder Paste

- Low-voiding
- Print Deposit Repeatability
- Excellent Response-to-Pause

CSP

PROBLEM:

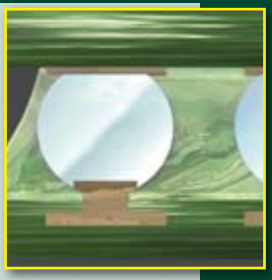
Cracking:

- Brittle Pb-Free Alloys
- Reduced Joint Size

SOLVED:

NF260 No-Flow Underfill:

- Air Reflow
- High-strength
- Low-voiding
- Reworkable

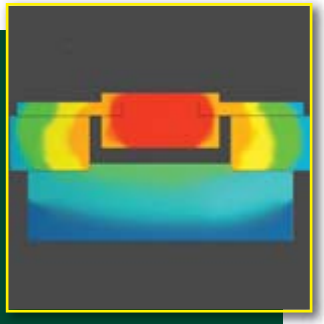


THERMAL

PROBLEM:

Overheating:

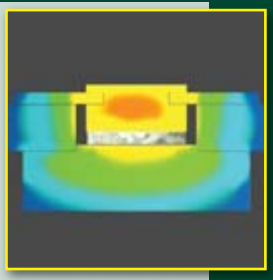
- Increased Power
- Decreased Package Size



SOLVED:

Solder TIM for heat dissipation:

- Flux-Coated SAC Preforms
- Compliant Alloys



PTH

PROBLEM:

Incomplete Barrel Fill:

- Reduced Wetting Ability Using Pb-Free Alloys
- Insufficient Solder Volume

SOLVED:

Wave Solder Products:

- WF7742 Wave Flux
- Pin-In-Paste+ with 0603 Preforms

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An Open Letter of Thanks

One year ago Speedline disclosed to the industry a new concept in printing a PCB called the Accela. That date also marked the end of a period that called for a substantial demonstration of integrity on behalf of a host of personnel in our industry. This letter describes that unusual statement, the timing of this note consistent with legal disclosures for patent rules.

Going back just over four years to the end of 2001, Speedline first met under non-disclosure agreement with a key competitor's customer to discuss a concept for a printer. They were interested because the machine promised to help them meet what was outlined in their roadmaps, and their interest was high enough to sustain 12 design review meetings between the two companies over the ensuing years, all held under NDA.

As the project grew to more than just baseline conversations, Speedline opened dialogue with customers at 47 locations around the globe, again all under NDA, to ensure that the requirements for the machine would meet the needs in the market. This took place throughout 2002 and into early 2003, and roughly 180 people knew enough about the printer to require NDA coverage that early. As suppliers were engaged and we progressed through development into beta-site testing, even more NDAs were executed, bringing the total to just over 1000 people who knew enough details to have critical information.

I started this letter with the word "integrity." Over the past year, since we made our first public disclosure of the new system, I have had the opportunity to discuss the surprise element of the launch of this system with customers, suppliers and even some competitors (especially with a couple we hired). Over 1000 people knew details about this product during its development for periods from six months to four years, and as far as I can tell there were absolutely no leaks, other than the project name itself.

Personal integrity is alive and well in our industry. This is a note of thanks to those who kept their word over such a long period of time. A couple have mentioned that it is to be expected when NDAs are executed, yet on such a grand scale as this it is heartwarming to know that the people we work with on a day-to-day basis hold themselves to such a high standard. To all who knew: thank you.

Bob Boyes
Speedline Technologies

Tomorrow Is Here

Interesting piece [Caveat Lector, March 2006]. In the last paragraph you mentioned "tomorrow it might be stricter environmental laws that will choke our business."

Tomorrow is here and you document it every issue on the cover. Lead-free is the most costly and useless thing I have ever seen (global warming notwithstanding). The potential for disaster from tin whiskers is more of a threat than any terrorist. We can only hope this boondoggle burns itself out before many people are killed.

Andy Pecota
San Jose

CEMS: It's All About Soldering

In response to Phil Zarrow's column on reflow profiling ["Reflow Profiling: Do it Right," February 2006], Amen! As a product engineer, I am the interface between design engineers and our contract manufacturers. I can't understand the reluctance of anyone who builds electronics to not have good, solid reflow profiles for each of their products.

I have had manufacturing engineers tell me, with smiles on their faces, that they have worked out a universal reflow (in this case, vapor phase) profile and it works for everything. Yet they can't explain the cold, grainy intermittent solder joints on my boards, except it's not due to their process.

And there are the folks who profile bare boards (thinking they are actually accomplishing something) but again, have no explanation for poor solder joints.

We manufacture outdoor-rated industrial computers ; our devices perform in an outdoor environment and are expected to operate for a minimum of 25 years. I have my hands full with CEMs and ensuring that the product is made to survive harsh environments for such a long time. Most of their focus and experience is in making products that do not have the life expectancies that we need, so I have to teach them the manufacturing and quality tricks and techniques that they need for our product requirements. The biggest problem area I encounter outside of product-specific requirements? Soldering. Profiling is near the top of the list, as it's a daunting challenge to convince manufacturing engineers that they can't just wing it by eyeballing an assembly, changing a few settings and hoping for the best. The better they solder, the better their bottom line: scrap and rework come out of their profits.

CEMs have one main operation: soldering. Everything they do hinges around their ability to solder. If they can't do it, it's time to turn out the lights and go home because it throws into question their ability to produce a product that will work in our application. My sentiment has been conveyed to CEMs on occasion to drive the point home that we are not pleased with their soldering quality.

Thank you for the column. It's nice to see that I'm not alone in this.

Name withheld by request

Send your thoughts to Editor, CIRCUITS ASSEMBLY, email: mbuetow@upmedia group.com. Letters must include the writer's name, address and company affiliation and may be edited for length and clarity.

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In Brief

Indium Corp. (indium.com) has begun manufacturing wave solder fluxes in its Milton Keynes, England, facility for European customers.

Sanmina-SCI Corp.'s Kunshan, China facility (sanmina.com) passed the registration audit for ISO/TS 16949, an automotive certification.

EMS provider **Fabrinet** (fabrinet.com) received TL 9000QMS certification for manufacturing electronics assemblies and optical devices for telecom equipment at its campuses near Bangkok.

EMS providers **SMC** (smcems.com) and **Note AB** (note.se) established a joint international procurement office in Shenzhen, where they source custom build-to-print products such as PCBs, cables, wiring harnesses, metals and plastics, and other devices.

Siemens Automation and **Drives** (automation.siemens.com) acquired the die bonder activities of F&K Delvotec Bondtechnik GmbH. **Siemens** will integrate the business with its Electronics Assembly Systems division.

Asymtek (asymtek.com) opened a customer applications lab in Guangzhou, China, and an office in Beijing.

EMA Design Automation (ema-eda.com) and Ageus Solutions (ageussolutions.com) will provide environmental compliance solutions from design through manufacturing. EMA's Engineering Data Management solution will now supply the mechanical portion of RoHS/WEEE compliance.

Total Electronics (totalems.com) has opened a new facility in Reynosa, Mexico. The 20,000 sq. ft. expandable facility contains three SMT lines and several mixed technology lines, and receives warehousing/logistics support from McAllen, TX.

Digi-Key (digikey.com) will operate as Helicomm's (helicomm.com) distributor for its line of Zig-Bee compliant wireless products, including IP-link embedded modules, M2M terminals and EZ-Net development kits.

Collaborating with suppliers in China, **Dow Corning** (dowcorning.com) has developed environmentally friendly silicon-based materials for China's electronics manufacturers.

Practical Components (practicalcomponents.com) appointed **NPF DiPaul** (dipaul.ru) as its distributor throughout the Russian Federation.

Lucent in Hand, Is Thales Next for Alcatel?

MURRAY HILL, NJ – In April, Alcatel (alcatel.com) unveiled a planned merger with its smaller U.S. rival Lucent Technologies (lucent.com) for $13.4 billion. Together, the pair would have total revenue of $25 billion, roughly matching current industry leader Cisco Systems (cisco.com).

The two companies plan to cut about 10% of their combined workforce, or about 8,800 jobs. Patricia Russo, Lucent's current chief executive, will serve as CEO of the merged Paris-based company. Tchuruk will act as non-executive chairman.

In early 2001, the two companies nearly pulled off merger that at the time was valued at $23 billion, but the talks fell apart in a disagreement over how much control Alcatel would have.

Alcatel will also gain Bell Labs, Lucent's historic research arm, which is responsible for inventions ranging from transistors and lasers to cellular telephone technology, data networking and communications satellites.

The companies expect the deal to close in six to 12 months, barring any roadblocks from French or U.S. governments concerned with national defense contracts.

Meanwhile, reports from France suggested Alcatel could purchase a larger share of Thales (thalesgroup.com), Europe's largest manufacturer of defense electronics. Alcatel, which also makes top-secret military satellites, currently owns a little less than 10% of Thales. The company has long sought to raise its stake in Thales to 25 to 30%, a move analysts estimate would cost Alcatel some 2 billion euros.

Any move would require approval of Italy-based Finmeccanica, its space industry partner, and the French government, which owns a 31% stake in Thales.

Another player on the scene is The European Aeronautic Defence and Space Co. (EADS), which is reportedly offering its satellite production to Thales in exchange for a stake in the company. EADS (eads.net) is the parent of Airbus, the European aerospace consortium.

It is also possible that EADS would transfer its Astrium satellite production unit to Thales. EADS also tried to gain control of Thales in 2004. Doing so would consolidate the European satellite industry under Thales. – *Mike Buetow and Robin Norvell*

Nam Tai Shenzhen Expansion on Schedule

VANCOUVER – Nam Tai Electronics (namtai.com) has reaffirmed its timetable for construction of new manufacturing facilities in Shenzhen by the end of 2006.

The EMS company recently acquired approximately 1.3 million sq. ft. of property in the Guangming Hi-Tech Industrial Park in Shenzhen and will invest $150 million in the expansion, including real estate and equipment. The space is more than double the size of the land of the existing facilities.

Completion of the land transfer is expected to take place by this fall. The first phase of construction will be completed in the summer of 2008, with the second phase completed in the summer of 2010.

In the first quarter, Nam Tai invested $3.4 million in three surface-mount lines, raising its production capacity by about 17% based on passive chip placement.

Separately, the company has agreed to sell its unoccupied office space in Hong Kong for approximately $20 million. The deal was expected to close April 20, with an expected gain of $10 million.

Nexlogic Relocates to Larger Plant

SAN JOSE – Nexlogic Technologies (nexlogic.com) has relocated its PCB design, assembly, fabrication and procurement to a 30,000 sq. ft. facility in San Jose.

The new space is nearly three times larger than Nexlogic's former facilities.

The company also added an SMT line, its third overall. The new line has a dedicated Pb-free wave soldering bath, AOI and enhanced BGA x-ray capabilities.

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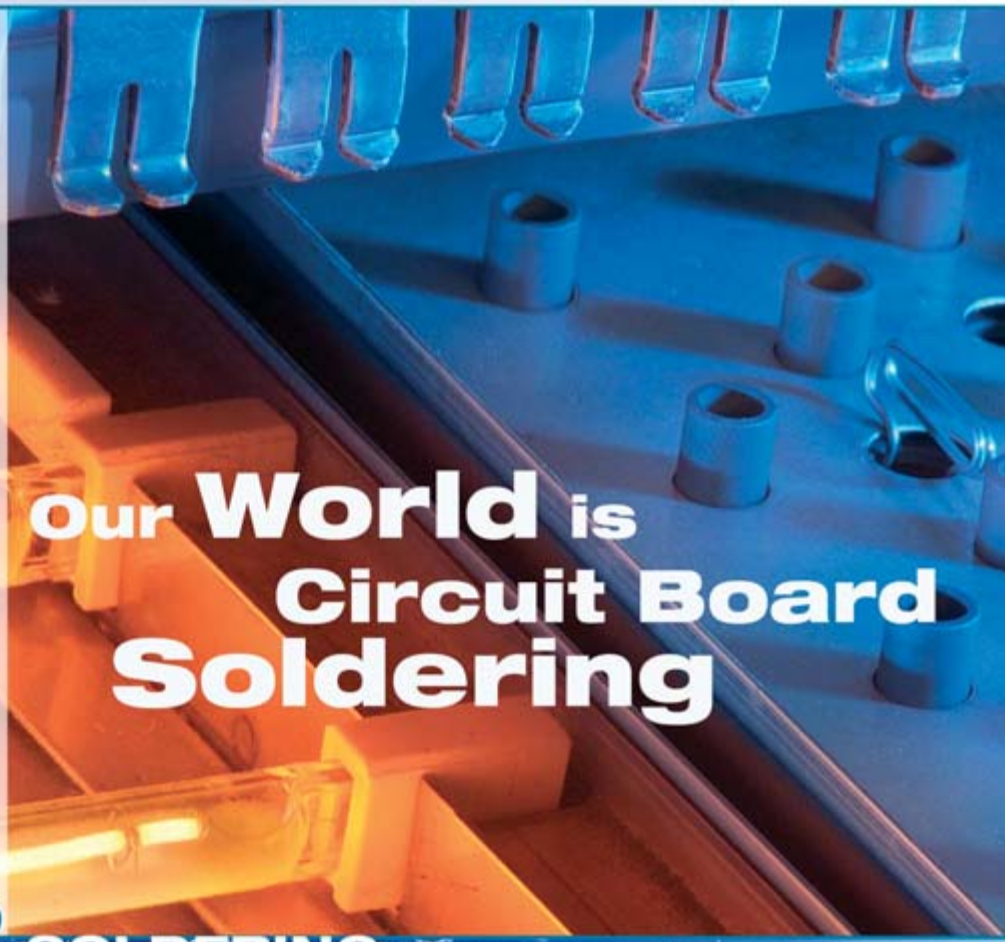

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In Brief

Finetech (finetechusa.com) named **Hattas and Assoc.** (hattasandassociates.com) and Technology Plus as partner representatives for Illinois and Wisconsin.

Blakell Europlacer International (europlacer.com) appointed PCI – Prime Group as its distributor for India. The company also named **RTS Engineering** as distributor for Russia and Ukraine.

Fuji Machine Mfg. Co. (fuji.co.jp) and **Cogiscan** (cogiscan.com) will jointly develop and market RFID Smart Feeder technology for Fuji XP-series machines.

The SMTA officially formed its first chapter in China. Executive committee members were inaugurated in April in a ceremony in Shanghai.

Hover-Davis (hoverdavis.com) named **Wilson Industries** as sales representative for eastern Pennsylvania, downstate New York, Long Island and Delaware.

Denso Corp. (globaldenso.com) established a new company in Tianjin, China, to aid production for automotive manufacturers there. **Tianjin Poong Sung Electronics Co., Ltd.** will produce instrument clusters, beginning production at the end of 2006.

EMS provider **EPIC Technologies** (epictech.com) completed a rapid deployment of **Camstar's** (camstar.com) Medical Device Suite to control production for the electronic top housing of a new transdermal drug delivery device. EPIC jointly developed the new processes with a major medical device manufacturer.

Router Solutions Inc. (rsi-inc.com) and **Sony TiMMS** (sonytimms.com) announced a cross-licensing and distribution agreement. **RSI** provides ECAD data translation and **Sony TiMMS** has over 15 years experience in PCB assembly solutions.

A.C.E Production Technologies (ace-protech.com) recently installed dual KISS-101 Pb-free compatible selective soldering systems at Governors America Corp. (governors-america.com), a supplier of electronic engine controls.

Speedprint Technology Ltd. (speedprint-tech.com), a division of **Blakell Europlacer Group**, appointed **A-Tek LLC** (atek-llc.com) as distributor for its printers in continental America.

Kato Denki (kato-denki.com) will increase its manufacturing capacity of non-lead IC packages by 50% to 15 million units per month this quarter.

Solectron Rebounds, But Analyst Warns of Trouble

SAN JOSE – Solectron Corp. (solectron.com) reported a second-quarter profit of $30.4 million, reversing a loss of $2.2 million last year. Revenue fell 10.8% to $2.46 billion from $2.76 billion a year ago.

For the quarter, the gross profit was $29.7 million, excluding charges and one-time items. Income from continuing operations was $17.1 million, up from a $3.1 million loss a year earlier. The company said $13.3 million of its net income came from discontinued operations.

Cisco (cisco.com) and Nortel (nortel.com) were Solectron's top two customers during the quarter, accounting for $452 million (18%) and $292 million (12%), respectively, of sales. Solectron is expected to lose much of the Nortel business as the telecom gear maker transfers its manufacturing to Flextronics (flextronics.com). Sales to Cisco grew 10% sequentially.

Inventory turns fell half a turn to 7, while inventory levels grew 9% sequentially due to cost-of-goods sold increases. Solectron cited poor inventory management in program ramps for the increase. However, Cisco plans to roll out its Lean initiative during the November quarter, which could mean higher inventories at Solectron.

However, the EMS company may be headed for a rough patch. In a research report, Deutsche Bank (db.com) analyst Carter Shoop said he expects Solectron to restructure its higher-cost manufacturing areas starting in the second half of the year.

Separately, Solectron's facility in Charlotte, NC, has gained certification to the IPC Restrictions on Hazardous Materials Lead-Free Electronics Assembly Process Capability. The site, which was the beta site for the IPC program, is the first of the tier one EMS firms to receive the certification.

The full rollout of the program was planned for early April.

In a press release, Solectron said it completed the audit program by demonstrating the processes necessary to be capable of producing Pb-free assemblies in complying with the RoHS directive.

Microsoft Ramps XBox Production, Delays Vista

SEATTLE – Microsoft has delayed – again – the launch of its Windows Vista operating system, pushing out the next generation software for PC consumers to January 2007. Business customers will get in the door a couple months earlier, in November.

Analysts are mixed on whether the delay will impact overall PC sales, but the consensus is that buyers will wait the extra few months for the new OS. Thus, fourth quarter shipments might not be as robust as previously forecast.

"A lot of people were pinning their hopes on Vista to drive a PC upgrade cycle this year," the Associated Press quoted Romeo Dator, co-manager of the All-American Equity Fund for U.S. Global Investors.

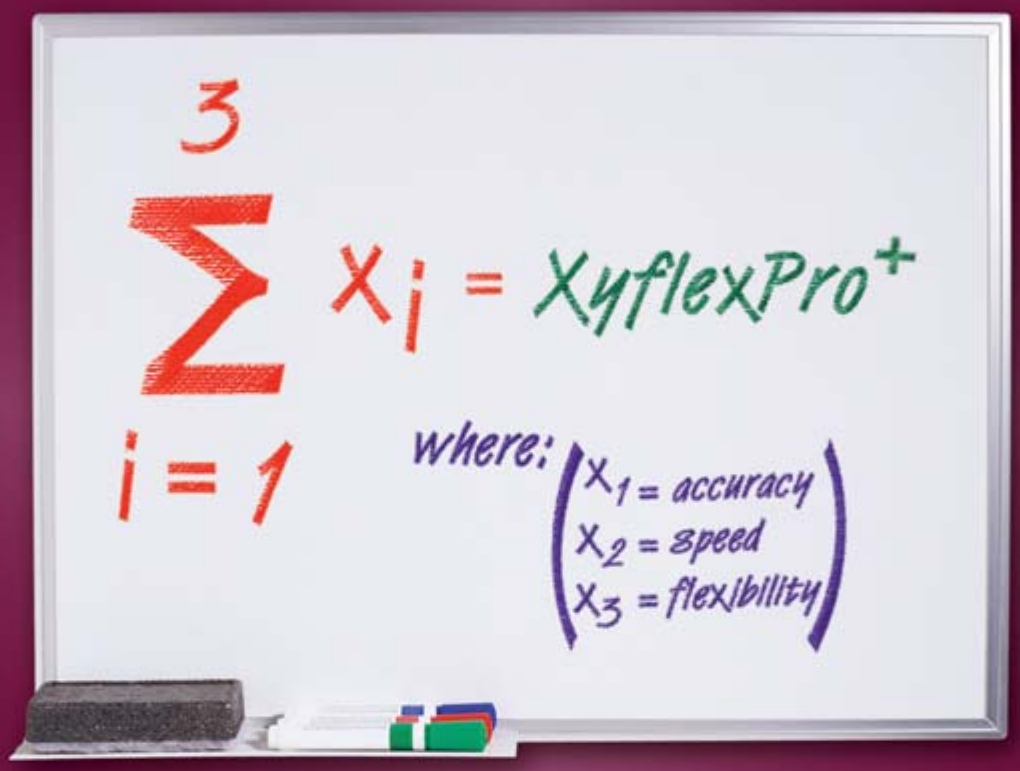
Most agree that the delay benefits Apple Computer (apple.com), as some consumers won't wait to buy machines from Dell, H-P and others that run the Microsoft OS.

Deutsche Bank (db.com) analyst Chris Whitmore said the release of Vista "will support improving price and mix as customers migrate to richer configurations that support the higher requirements of the new OS." He said that in the wake of the delay PC estimates remain unchanged, but DB does expect many buyers will wait until 2007 to purchase new machines.

In late March, Microsoft increased supplies of its Xbox 360 games console to retailers by two to three times. The company (microsoft.com), which due to component shortages has struggled with production of the popular device, has lowered its target to 4.5 million to 5.5 million units to be shipped by June. The component situation has been resolved, the company said.

Microsoft outsources production of the consoles to Wistron (wistron.com), Flextronics (Flextronics.com) and Celestica (celestica.com).

Camalot XyflexPro+



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People

William (Bill) Scheu, president of Automated Production Equipment (A.P.E.), died in March of a heart attack. **Scheu** is survived by his wife, **Barbara**, sons **Casey** and **Ian**, and four grandchildren.

Ametek promoted **Alan Devenish** to vice president and general manager, Materials Analysis Division. **Devenish** was previously division VP of the EDAX Business Unit.

Landrex Technologies hired **Lyle Sherwood** as sales and marketing manager for North America and Europe. He has spent more than 20 years in the SMT industry, including 10 years developing and implementing machine vision technologies.

YESTech named **Giancarlo De La Garza** as Latin America sales manager. He joined the company in 2004 as sales applications engineer.

Jim Williams was appointed area general manager for DEK Northern Europe, based in the company's Weymouth headquarters. He was sales director for semiconductor processing equipment at Oxford Instruments.

Panasonic Factory Solutions Co. of America named **M. Faisal Pandit** director of solutions. His prior experience includes equity analysis with Morgan Stanley, project management with Unix and eight years at Panasonic as a group manager.

Essemtec USA hired **Jeff Stong** as technical manager. **Stong** has 22 years of microelectronics and SMT experience, and is an SMTA chapter officer.

Electronic Systems' Explains RoHS Strategy at Seminar

SIOUX FALLS, SD – Electronic Systems Inc. (electronicsi.com) recently shared lessons learned from its RoHS compliant processes at a workshop for executives and engineers.

About 70 persons from two dozen electronics companies attended the Bloomington, MN, seminar to hear the EMS company, which has RoHS-compliant products in production and pilot stages, describe everything from solder materials and profiles to supply-chain management.

Electronic Systems said the seminar was meant to be a jump-start for those who have not yet committed to a RoHS strategy. The first deadline for compliance is July 1, 2006.

According to company vice chairman Leo Reynolds, the seminar was not for "answer(ing) the unanswerable questions but rather to make our customers aware of the impending deadline and jog them into the realization that they need to be very aware of what may or may not have to do with their products and processes." Questions revolved around tin whiskering, preferred PWB finishes and soldering temperatures, he told Circuits Assembly. There were "a lot of questions on component availability and compliance [and] on verifying compliance, how can the EMS company ensure that every component is in fact lead-free compliant."

"Obviously, there are as many unanswerable questions as there are solid ones in this whole RoHS issue."

Speakers included Tony Hilvers, vice president of industry programs at IPC, who reviewed RoHS requirements and discussed issues related to managing the supply chain, processes and verification. Dave Paluck, Electronic Systems manufacturing engineering supervisor, gave an overview of the company's soldering and assembly processes, while director of program management Steve Hillesheim explained the logistics and planning needed for an OEM to move product into compliance.

Sparton to Buy Medical Products OEM

JACKSON, MI – Electronics manufacturing services provider Sparton Corp. (sparton.com) has signed a letter of intent to acquire Astro Instrumentation, a maker of medical test equipment. Astro is privately owned and had 2005 sales of $33.6 million. The deal is expected to close by June 30 and is subject to due diligence. No financial terms were announced.

Astro designs and manufactures a variety of specialized medical products, including laboratory test equipment. The company operates a 40,000 sq. ft. facility in Strongsville, Ohio.

Sparton will run the business as a wholly-owned subsidiary at its present location and retain current management and staff.

Nokia Exec Pushes Converged Devices

CUPERTINO, CA – Will cellphones make Apple's iPod obsolete? A Nokia exec says it's inevitable.

Anssi Vanjoki, head of Nokia's (nokia.com) multimedia unit, said in March that single-application media devices like the iPod will give way to so-called converged devices that can handle digital media and voice and data transmission. He pointed to Konica Minolta's (konica.com) decision to exit the camera and photo businesses as an omen of what is to come. "In the next six to 12 months, there will be more of these announcements," Vanjoki said. "The next to disappear will be the makers of music devices and then the manufacturers of video cameras."

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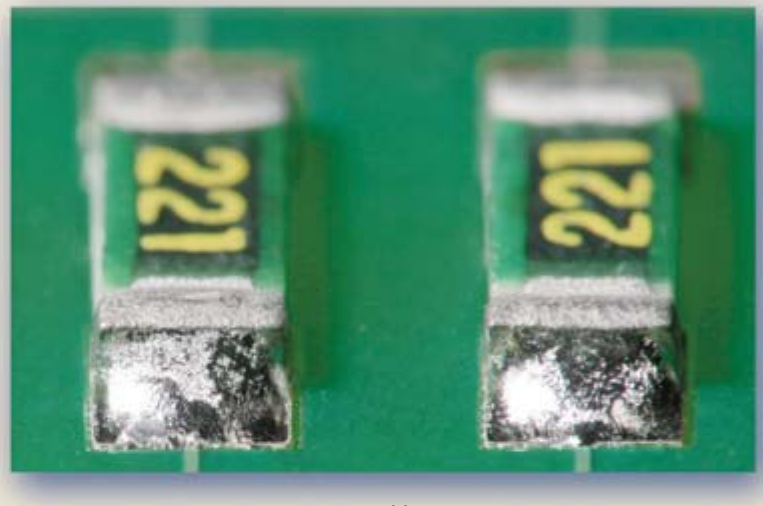
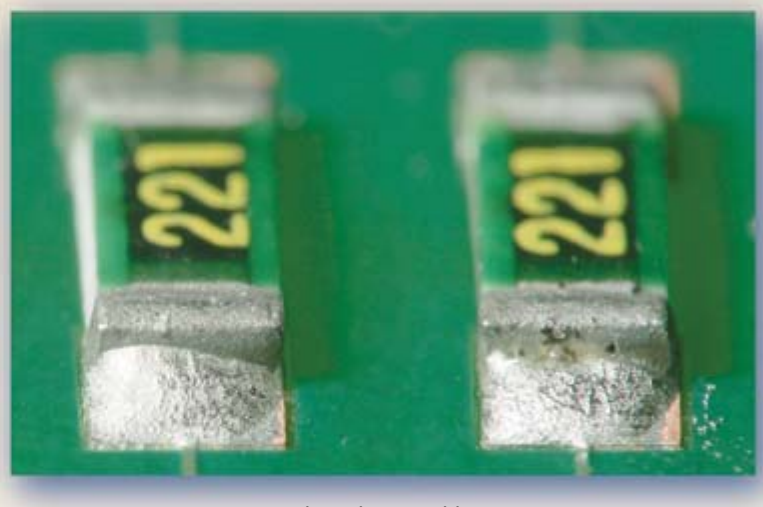


EM907 Solder Joint



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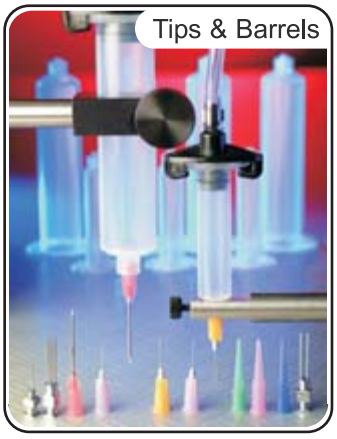

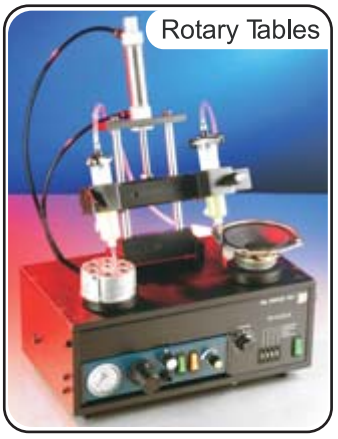

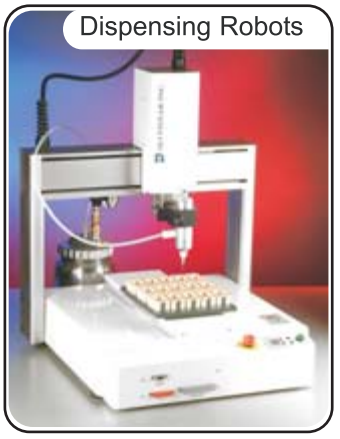

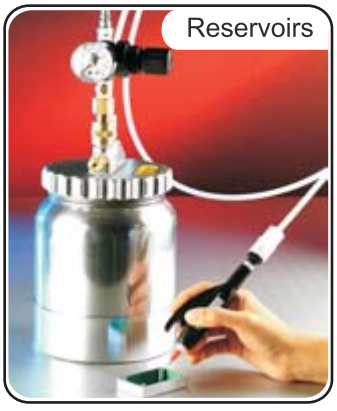

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Drive System/Stepping Motor	3-Phase
Motion Control	PTP & CP
Interpolation Linear/Circular	3 Axis
Teaching Method	Teach Pendant
I/O Signals	8 Inputs / 8 Outputs
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Power Supply	Auto-switching: AC95-132V 150W AC180-250V 150W
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On the Defense

Trends in the U.S. electronics equipment market (shipments only).

	% Change			
	Dec.	Jan[r]	Feb.*	YTD
Computers and electronics products	2.6	-1.9	4.4	5.9
Computers	0.2	-7.0	1.2	2.5
Storage devices	20.5	-3.0	-4.1	3.9
Other peripheral equipment	4.9	-0.3	-0.7	-7.7
Nondefense communications equipment	5.8	5.5	4.8	16.3
Defense communications equipment	8.0	39.4	-37.0	20.7
A/V equipment	8.5	-3.0	-4.5	1.2
Semiconductors	4.1	-9.6	23.1	8.2
Components[1]	1.5	0.3	0.8	7.4
Nondefense search and navigation equipment	-2.5	2.9	-1.6	0.3
Defense search and navigation equipment	-2.1	8.8	-1.7	8.9
Medical, measurement and control	0.0	-3.1	1.7	0.5

*[r]Revised. *Preliminary. [1]Includes semiconductors. Seasonally adjusted. Source: U.S. Department of Commerce Census Bureau, March 31, 2006*

March PMI Shows Continued Strength

TEMPE, AZ – The PMI index of U.S. manufacturing slipped in March but remained well above the benchmark for growth. Overall, the sector grew for the 34th straight month, according to the latest Institute for Supply Management (ism.ws) poll.

The March PMI was 55.2%, down 1.5 points from February. A score over 50% shows expansion.

"The manufacturing sector, led by continued strength in new orders and production, continued to grow in March," chairman Nobert Ore said. "The ISM data indicate that [the first quarter] was a good quarter for U.S. manufacturing. Prices are still a major concern, particularly in the energy and metals markets. In general, manufacturing continues to experience a significant level of growth."

For the month, new orders fell 3.5 points to 58.4%, while production upticked for the third month in a row. Backlogs grew sharply, up 5 points. Inventories dropped both at manufacturers and customers. Employment fell 2.5 points, to 52.5%.

The categories of electronic components and equipment, and industrial and commercial equipment and computers both reported growth during the month.

The March PMI corresponds to a 4.5% increase in real annualized GDP.

	Nov.	Dec.	Jan.	Feb.	March
PMI	58.1	55.6	54.8	56.7	55.2
New orders	59.1	55.5	58.0	61.9	58.4
Production	60.6	57.8	56.6	57.4	57.5
Inventories	49.3	47.2	46.5	49.5	48.7
Customer inventories	43.5	48.0	46.0	48.5	48.0
Backlogs	53.0	49.5	53.5	54.5	59.5

Source: Institute for Supply Management, April 3 2006

Industry Market Snapshot

Book-to-bills of various components/equipment.

	Oct.	Nov.	Dec.	Jan.	Feb.
Semiconductor equipment[1]	0.95	0.93	0.93	0.97	1.01
Semiconductors[2]	6.75%	7.2%	6.8%	7.0%	-2.2%
Rigid PCBs[3] (North America)	1.14	1.12	1.09	1.09	1.13
Flexible PCBs[3] (North America)	1.10	1.16	0.95	1.30	1.19

Sources: [1]SEMI, [2]SIA (3-month moving average growth), [3]IPC

2006 Promising for IC Sales

SARATOGA, CA – Revenues and unit sales of ICs worldwide in 2005 grew 7.8% and 10.6%, respectively, and 2006 is expected to be even more robust, said Advanced Forecasting, a semiconductor forecasting firm. "Our forecast showed an upward turning point to occur in the third quarter 2005 and another the first quarter of 2006," said Rosa Luis of AFI (adv-forecast.com). "We expect growth in 2006 for worldwide revenues to be in double digits."

Unit sales increased to 116 billion last year, while sales rose to $192.8 billion. Asia Pacific sales were up 18.6% to $89.4 billion. North American sales rose 4.3% to $37.2 billion, Japan fell 4.1% to $33.1 billion and Europe dropped 0.2% to $33.1 billion.

By segment, revenues of ICs for wired communications were up 38.2%, followed by computer and peripherals (up 36.5%) and consumer (up 21.1%).

In a separate forecast, Gartner Inc. (gartner.com) predicted worldwide semiconductor revenue to increase 9.5% to $257.7 billion in 2006, on a 10% hike in capital expenditures this year. The research firm expects a mild slowdown to 7% growth in 2007, then an upturn in 2008. Gartner said IC inventory levels across the supply chain fell during the fourth quarter.

Home is Where the Gear Is

NORWALK, CT – Sales of digital home entertainment gear will reach $411 billion by 2010, an AAGR of almost 20% over the $166 billion posted in 2005, said BCC Research (bccresearch.com).

Hubs and nodes (media PCs, digital audio and video players) are the largest device segment, accounting for 56% of total device sales in 2004 and 55% in 2010.

Output devices such as digital TVs accounted for 16% of total digital home entertainment devices in 2004, a percentage that is expected to rise to more than 27% by 2010. Gateway devices (digital TV receivers, cable and satellite boxes) are expected to increase share by 2010 by one point to 26%. Networking devices account for 2 to 3%.

India's EMS Sector on the Rise

BANGALORE – India's embryonic EMS sector is preparing for a breakout, based on recent forecasts from various market watchers. The Indian EMS industry will be worth $4 billion by 2010, growing over 30% annually, says the Electronics Component Industries Association (Elcina), a group of some 280 domestic electronics manufacturers.

Research firm iSuppli (isuppli.com) pegs the market as somewhat smaller, estimating contract assembly in India will increase 21% each year to $2.03 billion in 2009, from $935 million last year. Among the EMS firms growing in India are Jabil Circuit (jabil.com) and Celestica (celestica.com), which are acquiring Indian companies, and Hon Hai (foxconn.com), which recently committed $110 million in investments over the next five years. Driving investment are the telecom and computing sectors.

The number of telephone users is forecast to rise to rise to 2.2% from 0.9% by the end of 2007.

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'You Have to Be Prepared to Change'

In February, Electronic Systems Inc. (electronicsi.com) captured Service Excellence Awards for responsiveness and value for the price. The Sioux Falls, SD-based EMS company has a history of success in the SEAs, but vice chairman Leo Reynolds says it's the customer comments that feed growth and improvement. In late March he spoke on Lean manufacturing, procurement and RoHS warranty with editor-in-chief Mike Buetow. Excerpts (for the complete interview, visit circuitsassembly.com/cms/content/view/3155):

CA: How many employees does Electronic Systems have and how close to peak levels are you?

LR: Electronic Systems has about 250 employees; close to peak level, but we are at much higher revenue levels because we've become more productive. ESI has two SMT lines and an automated PTH line, and a good deal of box-build capability.


Electronic Systems' Leo Reynolds

CA: What does your Lean Enterprise initiative entail and what changes has it sparked in the plant?

LR: For over two years we've been in a formal Lean mode. We started by training all associates, which continues with new hires. We started with some high profile successes on higher impact programs, which gave everyone a taste for what is possible with the application of the basic tools of Lean. These tools include mapping a process, analyzing non value-added steps and redesigning the process. From these initial successes we went on to apply these principles in all areas of the operation, including administration and management where we had some of our biggest percentage improvements. Changes were made in how we pull and supply materials to the lines, how we process checks and even how we pay for MRO items.

CA: How did you initiate the Lean program?

LR: We looked at the challenges, particularly from offshore competitors. Our competitors are the some of the best and the brightest in industry. In fact, I was at one time a customer of this industry and was so impressed with the people we dealt with I wanted to be a part of it. But the waters are fast and deep. We knew we needed to make continuing and substantial improvements. Lean encompasses the best of all the programs that came before it: it's really about the elimination of waste. The decision to go Lean was a corporate decision, and we hired a manufacturing manager who had a lot of experience in Lean. You really need that: a Lean champion in a line position, where they are responsible for making things happen. We also hired an outside consultant to train Lean principles to all associates, and then later hired that consultant as an employee. We trained everybody and gave each team something bite-sized. Using off-the-shelf software, we also immediately did a value-chain map of the entire organization. The map rated projects by the amount of resources required and we attacked the low-hanging fruit first. We had one big project that was extremely successful. We think that was important because everyone needed to see that this could produce major results.

We've been careful to call our program Lean Enterprise, not Lean Manufacturing, because I think a lot of these programs get foisted on the back of the production people as if they are the only ones who add cost. In reality the management and touch labor adds as much or more.

We have continued with a Lean steering committee, implementing ad hoc teams based on individual challenges that appear to have the biggest benefit. In addition to specific program improvements, we have lowered our material burden, labor burden and SG&A percentages – those are improvements that affect our overall ability to compete on all programs.

CA: What problems, if any, have you encountered with parts that are mislabeled either leaded or Pb-free? Are you buying direct, or primarily from distributors?

LR: Electronic Systems took a proactive approach from the beginning, not necessarily agreeing that RoHS is a good idea, but that it would be inevitable in some form. We've had an RoHS steering committee for a year and a half guiding the company in every aspect of RoHS including component issues, process issues and formal compliance reporting procedures, none of which is entirely "settled law," as they say in judicial hearings.

We observed early on that most OEMs were not taking the deadlines seriously and we felt it was necessary that we be able to guide our customers through this when the time came. We have presented seminars to both individual customers and to industry colleagues in preparation for compliance. We are currently running several programs with full RoHS compliance and have several more in pilot stage.

As for specific components, several connectors that have been labeled to be RoHS have failed to withstand the elevated temperature in the reflow ovens.

CA: What approach to indemnity or warranty are you taking for RoHS compliant product?

LR: We have a formal policy statement that we've

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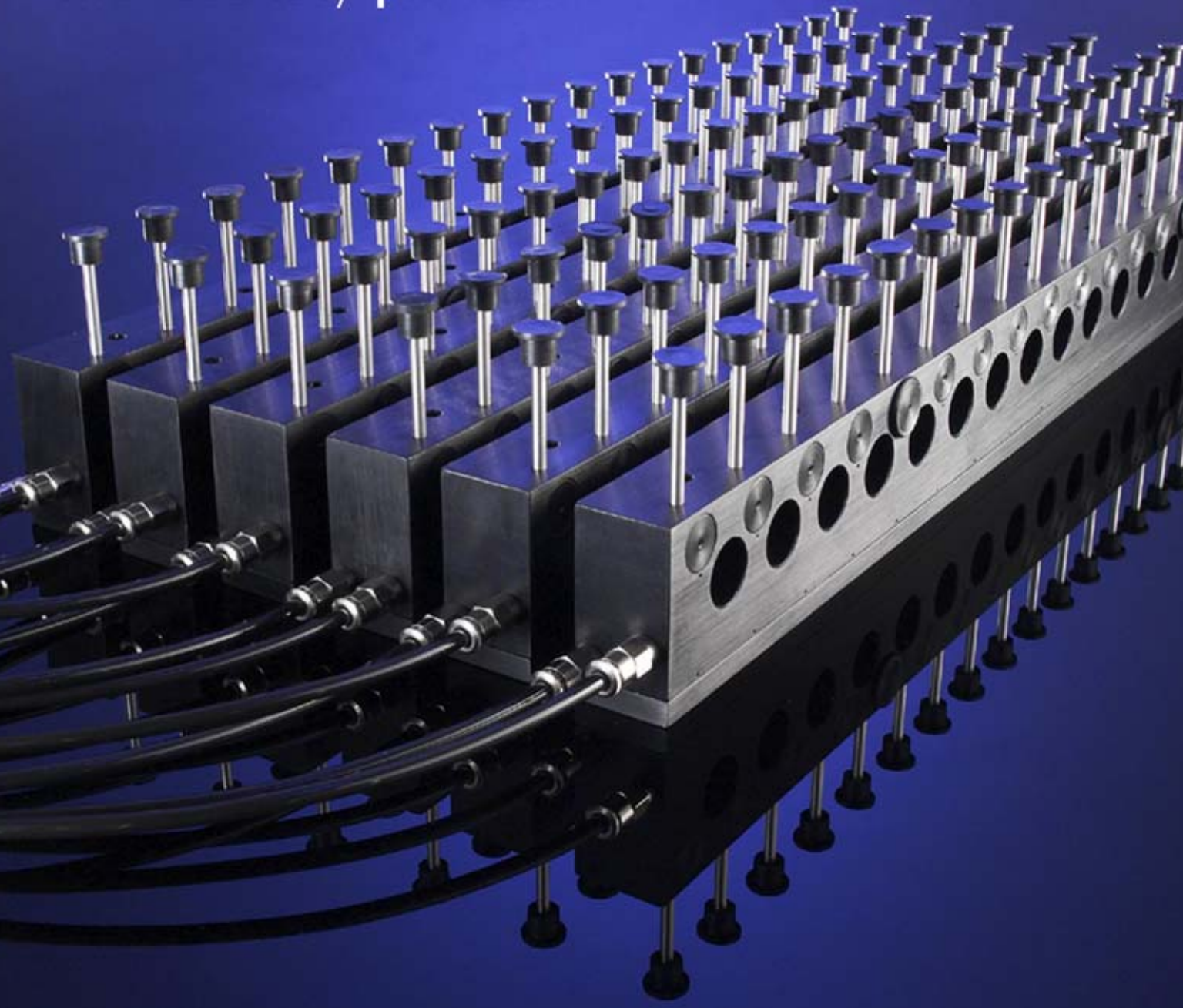

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discussed with each customer that lets them know that 1) they still have design control and must approve all changes, including each new RoHS compliant part and 2) that they must comply with certain specific time constraints to ensure availability of RoHS parts and the purging of existing leaded parts. We will go so far as to scrub the BoM, but the customer still has to approve it. Many parts have been converted to lead-free and are shipping under the same part number. When this happens we note that the part is now lead-free, even though it may be going into a leaded assembly. Compared to conventional product warranties, we treat RoHS product as conventional product.

CA: Electronic Systems has won several Service Excellence Awards, including two this year. What, in your opinion, is the net effect for the employees and the company of entering awards programs?

LR: First, the reason we enter CIRCUITS ASSEMBLY'S SEA program is to get an annual objective, third-party look at our customer's true perceptions of our organization. We also do a mid-year in-depth customer service survey. Both of these surveys are part of our overall customer service program, the results of which feed into our corporate measurement program. Therefore, the company receives a benefit whether we win or not. For the associates, it's a great feeling to know that your work is recognized as superior in some categories when compared to a national yardstick.

> "When it comes to warranties, we treat RoHS products as conventional ones."

Upon receiving the results, we have an all-plant meeting, and graph the results and post them. We show our latest scores against our overall score over the years. We also show our score in each category compared to this year. It's a main criterion of our corporate customer service program. Winning is great, but if someone scored you 5 out of 5 you have not learned anything. The value for growth and improvement are in the negative comments.

CA: As regional player, Electronic Systems is representative of many North American EMS companies. What do you see as the advantages of the niche market, and how do you keep up with changes in the broader marketplace?

LR: The obvious advantage of the niche market is that we can be more time-responsive than other players outside the region or outside the country. This is, to some extent, a temporary situation for a lot of EMS businesses as offshore competitors become more fleet of foot. Regional players will have to continue to improve quality, technology and productivity to keep market share.

We keep up with the industry through trade publications like CIRCUITS ASSEMBLY, IPC meetings and the SMTA.

CA: How do you find customers?

LR: We use sales reps in the Midwest and have a director of sales in the Minneapolis-St.Paul area. A lot comes from word of mouth. Electronic Systems has been in business for 26 years and has a solid reputation. The Midwest market is a large market but a relatively small community and word gets around.

CA: Do you ever get overload work from other EMS companies?

LR: We will pick up jobs from larger EMS companies when a customer isn't big enough for them. In one case where this happened, the customer was a Fortune 50 company but the program was too small for the larger EMS company to handle.

CA: Many EMS companies are launching repair depots.

LR: We have always had a fairly significant repair and refurbishment business. We don't work direct with the Dells or the Gateways, but typically work with their suppliers doing refurb, and it is an important business for our mainline customers too. Sometimes OEMs forget to settle on an out-of-warranty program, and we have helped some customers design a refurb program. We perform order fulfillment and ship a lot of finished goods ourselves.

CA: You have spent several years on the board of IPC. As associations try to keep up with members that are becoming increasingly global, how should they go about working with related organizations abroad?

LR: Each trade group has a primary responsibility to its membership. In the case of IPC, its membership was already global. I think it's in the best interest of everyone in our business, when it comes to global business, to engage, engage, engage. I wish I didn't have as many Chinese competitors, but what are the options? I can also buy things in that market and that helps me be a better supplier for some of my customers.

In a technology business you have to be prepared to change. I think the U.S.-based trade associations have to engage with the overseas trade groups, and it is way better to get our standards promulgated around the world than to let others take charge of writing them.

CA: Have you looked into offshore procurement?

LR: A few years ago I took a list of component materials to Shenzhen. I met with some suppliers, but they weren't able to get better pricing than I was at that point. We do have several suppliers there for PCBs. We have looked at having some China suppliers to do some higher volume assembly work, but so far haven't actually executed there. ■

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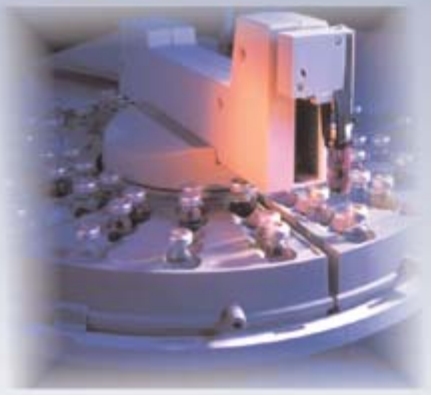

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What Backgrounds Build the Best Program Manager?

Six execs give their takes on the "face" of the EMS company.

One of the most difficult people to replace in an EMS company is a program manager. This month, we interviewed representatives at several EMS companies to learn what skills they consider important in program management. Because different EMS companies have different PM models, there is no one right answer. Even within the same company, factories in different regions may look for slightly different skills sets.

The interviewees:

- Henry Protzel, project support manager, WKK America (Holdings) Inc. (Sunnyvale, CA).
- Leo Reynolds, vice chairman, Electronics Systems Inc. (Sioux Falls, SD).
- Renee Rocca, program manager director, Hunter Technology (Santa Clara, CA).
- Lynn Cuperus, director operations, Goodrich Corp. (Albuquerque, NM).
- Tan Ka Huat, managing director, CEI Contract Manufacturing Ltd. (Singapore).
- Elliot L. Shev, Sr. VP sales and marketing, SMS Technologies Inc. (San Diego).

What is your vision of the PM's role in terms of customer support and project management within your company?

Protzel: The PM is usually the sole contact for the customer. A PM's expertise in handling a project often defines the way customers perceive the support they are receiving. Strong support leads to a happy customer. Resulting in more business.

PMs need to know the company inside and out. They need to understand available resources as well as limitations within their company. They should also know the same of the individuals within the departments. PMs should also know resources and limitations of the company's material suppliers.

A PM needs to be able to negotiate through the different departments to get the job done in their favor, and maintain those relationships. While they do not have to be an EE, they should have a strong technical background. A PM needs to have the ability to see the macro view of a project and a working knowledge of how it all falls into place. Finally, a PM should be able to act on a moment's notice and change channels just as fast.

Reynolds: PMs perform the single most defining role in an EMS company. The EMS business is all about understanding and managing customer expectations. The PM has to understand the technical, business and relationship issues to manage the expectations and then translate those expectations for the EMS company in a way that produces good outcomes. Ultimately, program management is a relationship-building endeavor.

Rocca: When the order comes in PMs will manage it from beginning to end. We do not have planners at Hunter so the PM must status material as it is purchased and have NPI meetings with engineers and production to go over how we plan to build the product. A key skill is maintaining good customer communication and monitoring daily schedules. When it is production ready, the PM must be sure assembly packages are complete and correct. After production the PM needs to feed to the customer any manufacturability issues for future builds.

Cuperus: We believe a PM needs to be a strong interface and a business development frontman (or woman). When new product development is involved, a PM must keep the design on track because design is the one thing that [can] derail programs quickly.

Tan: He or she is the business management person with arguably the most important function to implement: customer relationship management. This includes providing seamless customer care, encompassing the customer's demand and forecast management, materials and production activities coordination, quality/reliability and delivery fulfillment support, non-business/social interactions with the customers and anything else required. I see this position as most likely to be groomed into a general management function as the future leader of an EMS company.

Shev: The PM is the key customer interface and the lead for the product team which, in addition, consists of a quality engineer, mechanical engineer and production control.

Is there a corporate preference for either technical degrees or business degrees? Which degrees are preferred?

Protzel: Our background preference is experience. Our general manager is an industrial engineer. My team is all business majors with strong technical backgrounds. I would lean more toward BS or MBA. EE is nice, but too specialized and specific to deal with the variety of functions and departments a PM handles. A PM does not design the product. They manage it.

Reynolds: The PM position is challenging to fill because it requires a mix of skills and a high level of competence in each. The PM has to manage all the customer's business and technical expectations. At the

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same time, the PM needs to get the EMS organization to respond at all levels to satisfy the expectations as negotiated with the customer. We generally tend toward engineers or at least people with a technical background but then require a high set of people and business skills. A BS degree in electrical, mechanical or industrial engineering (in that order) and an MBA would be the ideal background but degrees are only the starting point for consideration. Many people with these credentials are not of the right temperament to manage the people side of the job. The best credential is prior success as a PM.

Rocca: We don't have a corporate preference for either degree. EMS experience is the most important to me. The last time we were hiring I asked that HR bring in only people that have done program management in an EMS environment. I have not had good luck with inexperienced people. I look for personality and intelligence, and computer skills are also a must.

Cuperus: Yes, we prefer a bachelor's or higher for anyone pursuing a PM career. Engineering degrees have traditionally been the preference, but this is changing to require an MBA to back up engineering degrees or experience. We are recognizing that a purely engineering driven résumé may not be adequate in the changing business environment. I don't have a preference in degrees, it is more about how it has been applied – or not applied, in some cases. The ability to survive college does not necessarily give the experience or skills to do PM work.

Tan: All other things being equal, a technical degree is preferred. An MBA is a feather in the cap, while a good engineering or technology degree is a basic requirement. Although a non-degreed person with EMS experiences will be equally welcome.

Shev: We normally look for a technical degree or equivalent. My preference is for a BSEE, but that is not the norm for PM applicants.

Can you describe an example where either a strong technical background or business background helped you or your PM better address customer issues?

Protzel: I was sent to a customer on a moment's notice regarding invoices. That is what I was prepared for. That meeting was underway 15 minutes when the QC department manager walked in. Next thing you know, I was out on their production line for three hours reviewing process improvement issues. By the time I returned home he had sent an email in recognition of my support in answering his questions, copying my team as well as his.

Reynolds: Recently, a newer customer asked us to take over a major program in the middle of a run from a competitor that turned hostile to both our customer and our people that were sent in to pull inventory and tooling. Our customer related that they appreciated our PM's (and his team's) professionalism in handling a very difficult situation. This exemplifies one of the major skills required by PMs: handling unexpected and difficult situations correctly, or in simpler terms the ability to think on your feet.

Rocca: I think knowing the business is the main

thing. I have had people that worked for me who were very bright but could not understand the technical side of our business. I want people who know what customers are talking about. They need to be able to come up with creative ideas to get difficult programs through the manufacturing process and keep good communication with customers.

> "A PM's expertise in handling a project defines the way customers perceive the support they receive." – *Henry Protzel, WKK*

Cuperus: On space hardware, the engineering background has frequently prevented us from agreeing to a scope change or technical requirement that would derail delivery of compliant hardware. Lack of business background, on the other hand, has cost us margin or profitability when scope changes become science experiments and the engineering nature would take over (the Jekyll/Hyde phenomenon).

Tan: I can think of several cases that involved the need to be physically present to help in diagnosis of technical issues that were either process or electrical test related. A PM with strong technical background traveled within 48 hours' notice without bringing a team of engineers or technicians. The PM could confidently relate to the customer technical staff to review and discuss the problems, and come to a decision stage. Where it involved phone calls or remote interactions, this technically strong staff member could discuss in a 24/7 fashion with much less need to adjourn the session for consultation with other staff. Staff members with technical backgrounds can pick up business skills much more readily than staff members with business backgrounds can pick up technical knowledge.

Shev: Most issues that PMs face are technical. They deal with issues that concern documentation, parts, production and test. Having a good understanding really helps to deal with the everyday issues that come up. From a business side, street smarts are the best skill to have. Preparing a quote is mostly by rote and predefined algorithms; knowing when to deviate is gut level, not something taught in school.

Common Ingredient

Throughout the responses a key theme was that PMs are often the "face" of the EMS provider and as such required people skills which included the ability to think on their feet, communicate clearly, negotiate well and maintain organization within the programs they managed. The degree to which a pure technical or business background is required is often driven by the breadth of support staff available and the PM's primary role in a given project. All respondents valued prior EMS experience over formal education, which reflects the specialized nature of program management within this industry. ■

Will Flip Chip Supply Crack Under Demand?

Limited capacity is driving longer delivery times and higher prices.

This past year saw unprecedented growth in shipments of flip chips. With stronger-than-expected sales of PCs, shipments of CPUs and chipsets with flip chip increased dramatically. The long-awaited shift of graphics chips from wire bond to flip chip began in the last two quarters of 2005. A larger number of ASIC designs moved to flip chip. All in all, the growth rate for solder-bumped flip-chip devices reached an unprecedented 48% in 2005. The strong demand outstripped substrate supply and caught some by surprise. As flip-chip-in-package shipments continue to grow this year, many remain concerned about the supply of substrates. Just look at recent headlines: "Xilinix Hit by Substrate Shortages"[1] and "TSMC May Build Flip Chip Substrate Plant in the Future."[2] Will the substrate shortage limit growth of flip chip this year?

Laminated substrates. Laminate substrates are the largest segment of the semiconductor packaging materials market, with a value of more than $4.2 billion in 2005 as reported in the *Global Semiconductor Packaging Materials Outlook*. The growth in laminate substrates has been driven by flip chip, which accounted for more than half of the revenue. Strong growth in demand for flip-chip substrates from chipsets and graphics applications coupled with the ASE fire that destroyed flip-chip capacity in Taiwan resulted in price increases and longer delivery times, pushing up the value of the market. This situation is expected to continue for much of this year, even though companies such as ASE are making laminate materials a major strategic focus.

The shortage quantified. Flip-chip substrate capacity in 2005 was calculated to be 1.16 million sq. meters with demand estimated to be 1.10 million sq. meters. Capacity calculations were based on direct input from such major suppliers as ASE, CMK, Dai Nippon Printing, Fujitsu, Hitachi Chemical, Ibiden, JCI, Kinsus, Kyocera, Mitsui Chemicals, Nanya PCB, NEC Toppan Circuit Solutions, NTK, Phoenix Precision Technology (PPT), Samsung Electro-Mechanics, Shinko Electric Industries, SMIED Globetronics Technology Industries (SGTI) (a subsidiary of Sumitomo Metals Industries Electronic Devices) and UniMicron. Operating capacity may actually be lower for some manufacturers and some capacity is allocated to key large customers, making it unavailable to the general market.

Design cycle times for laminate substrates are typically quoted as four to six weeks. With the current shortages, actual delivery times can be 15 weeks or longer. One company recently reported a quoted delivery time of more than 20 weeks. The situation is not expected to improve significantly this year.

While ASE, Ibiden, Kinsus, Kyocera, NTK, PPT and UniMicron are increasing capacity for flip-chip substrates, the market is expected to be tight through the end of 2006. Some new joint ventures, such as the one planned by Endicott Interconnect Technologies with Meadville Technologies Group to establish a production line in Shanghai, promise additional capacity in the future. However, it takes time to install and qualify a flip-chip line and for a new supplier the qualification process for a new substrate vendor takes 12 months or more.

In addition, some basic materials used to fabricated substrates are also in short supply. Bismaleimide triazine (BT) resin remains the dominant material for PBGA substrates and Mitsubishi Gas Chemical retains a monopoly position, even though substitute materials from Hitachi Chemical, Mitsui Chemicals (BN300) and others have been introduced. Sumitomo Bakelite is promoting a new epoxy resin multiplayer material and Nanya has capacity for a BT resin formulation in Taiwan. Companies in Japan report that the shortage of BT resin is driven by demand outpacing capacity. There are also concerns about other materials such as the Ajinomoto Build-up Film (ABF) material used in build-up substrates, but Ajinomoto is expanding its capacity in Japan.

Continuing growth. Drivers for flip chip continue to be performance, on-chip power distribution, pad-limited designs and form factor requirements. These trends are expected to continue and flip chip is expected to show a 31% CAGR through the end of the decade.

Continued shipments of CPU processors, DSPs, chipsets, graphics and field programmable gate arrays (FPGAs) will drive future growth. The expanding wireless communications market is expected to drive growth for a variety of flip-chip devices during 2006. Flip-chip substrates for wireless devices are not expected to be in short supply as there is plenty of capacity for less complex substrate structures. With sufficient added capacity in the future, there is hope for an improved situation in 2007. ■

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Upfront Evaluation Pays Big Dividends

Mom was right; it's easier to clean up as you go along.

No one wants to stop playing to clean up their toys, but we all remember our parents' sage advice: "If you just take the time to pick up as you go along, tidying up won't be such an overwhelming task." Mom was right.

The same holds true for electronics manufacturing. Periodic process assessments can help alleviate potentially monumental problems. The longer the problem persists, the more it will impact the bottom line and product quality. Conceptually and practically, process audits are not new. Establishing what is wrong and right about a process or a line is a good starting point. But by taking it a step further, putting a detailed plan of corrective action in place and illustrating what the plan's end-result will be, manufacturers can attain their goals: more good boards, and better results for the bottom line.

For pre-placement, a process audit methodology makes the report simple and easy to use, with each subject of the report graded on a beacon scenario (**Figure 1**). The goal, of course, is to minimize the total cost per printed board. In our assessment, several factors of pre-placement are evaluated:

- Solder paste.
- Stencils.
- Boards.
- Squeegee or print head.
- Tooling.
- Print parameters.
- Environment.
- Process.
- Inspection data.
- Operator training.

Within each of these elements many areas are observed and analyzed, therefore a full view of the process is established. We understand how demanding an engineer's role has become and, because of the enormous amount of tasks at hand it is often difficult for the engineer to see the forest for the trees. This is where an independent expert can provide value and bring to light underlying process issues.

Various parameters of each of the aforementioned areas are evaluated in depth and assigned a grade based on the beacon scenario. Then, improvement recommendations are made for every item that needs

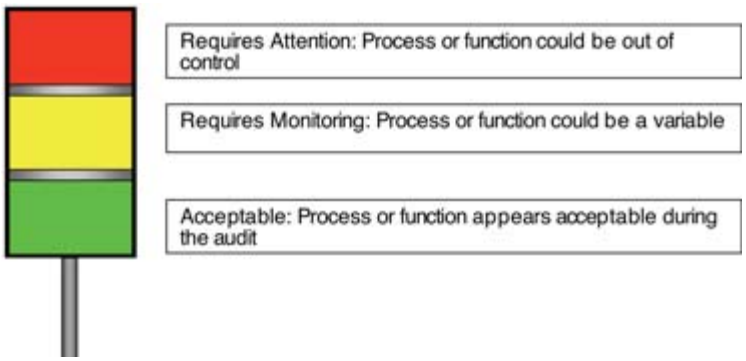

Figure 1: A simple beacon scenario makes interpreting data easy.

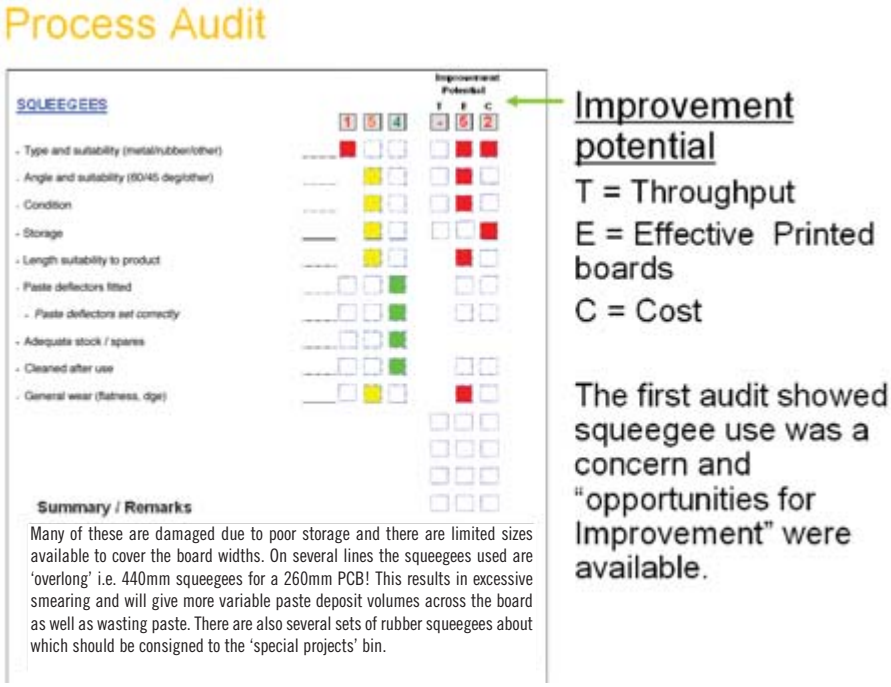

Figure 2: Summary report shows areas for improvement.

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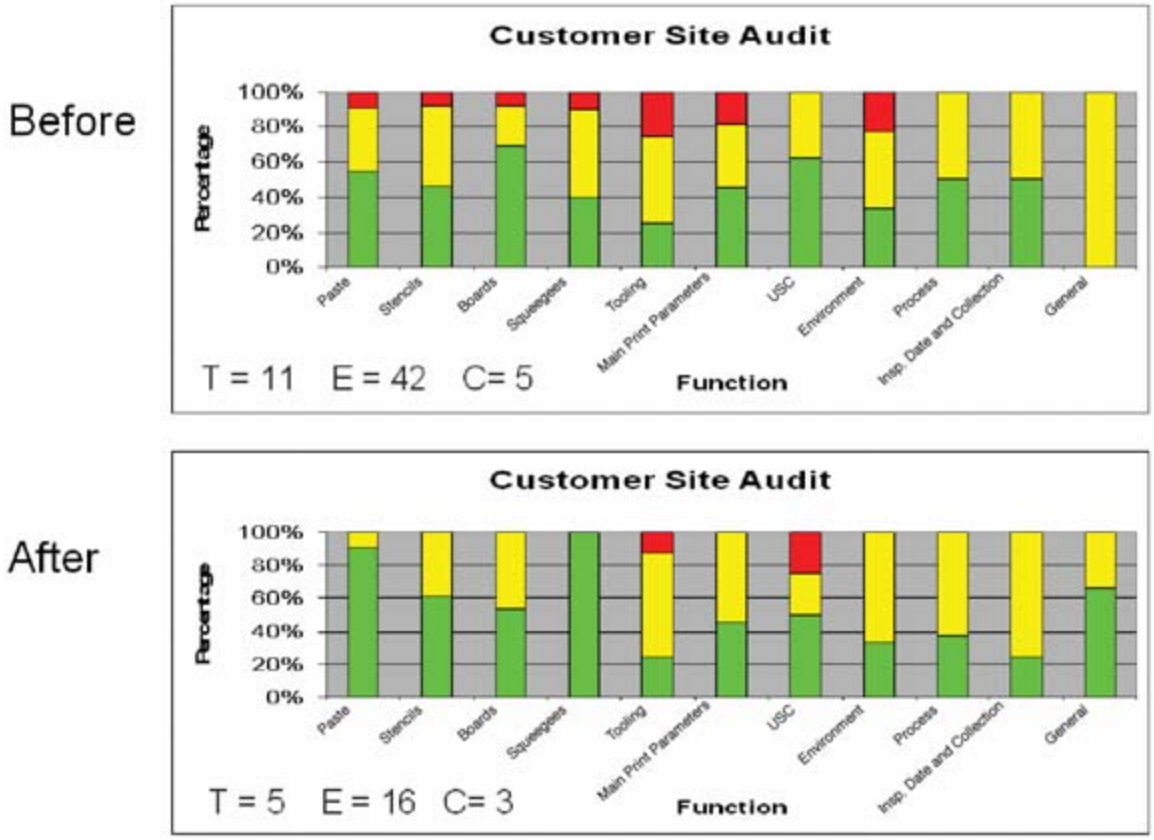

Figure 3: Baseline and post-implementation audit comparisons show improvement.

corrective action; this is where the value of dedicated expertise and a broad knowledge of the print process really become a true aid to the customer.

Finally, for each item, the improvement potential is illustrated as follows: T = throughput, E = effective printed boards and C = cost (**Figure 2**). In other words, if the manufacturer implements the recommended correction, there could be opportunities to improve throughput, effective printed boards or cost. The report contains the observations from the audit but the results are condensed into a one-page executive summary, permitting a quick view at which elements of the process require resources.

It is also important to establish a baseline for your audit so that improvements can be effectively measured and tracked as they are implemented (**Figures 3** and **4**). DEK's minimum recommendation is a quarterly pre-placement process evaluation. In fact, baselining a process before any major changes are implemented is a useful exercise because it means a data-driven decision on the success of the implementation can be made. Pb-free processing makes these audits more imperative.

But, the audits need not be all-encompassing. Our goal is to make this a simple, easy-to-understand, visual tool for manufacturers to quickly see where the process might be out of control, how they can correct problems and what results (throughput, effective printed boards or cost) can be realized by following the 10-point plan. Regular process audits are cost-effective, with most companies reporting a 100% return on investment within a month.

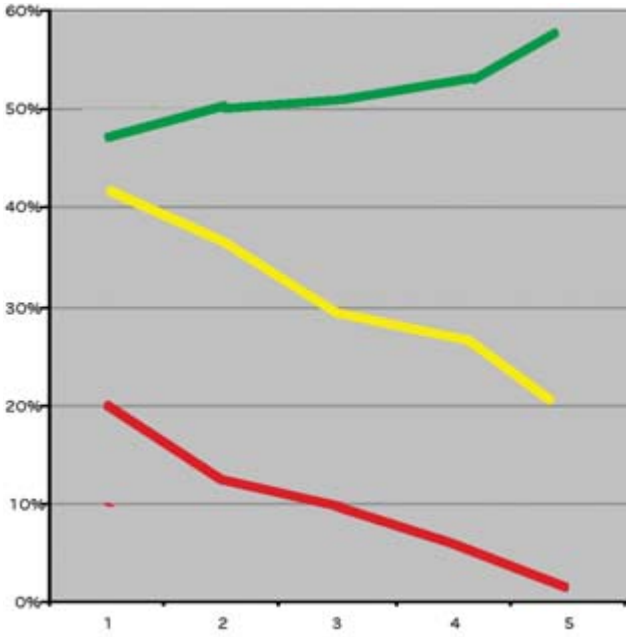

Figure 4: Continual improvements are tracked audit to audit.

So, remember the hard lessons you learned as a child, implement process audits and "clean up your toys as you go along." In our business, the payback can be huge. ■

Whither Analytical X-Ray

From RoHS to BGAs, the technology fills an inspection void.

Over the past few years, the use of x-ray to analyze solder joint structures has not only accelerated but has offered a wholly new view on joint inspection. (While the use of x-ray in electronics is a relatively recent phenomenon, the technology has been used for years in medical, metal casting and welding applications and for general metallurgical inspection.)

The impetus for using x-ray technology in electronics came when BGAs ventured into regular use. How could one determine if all the joints were formed correctly? The first systems were often adapted from medical x-ray systems and suffered from definition less acute than available today. It was difficult to interpret images and so the development of intelligent software routines accelerated. Early 2-D systems became 2.5-D systems that could tilt and twist the sample, or the x-ray tube, so that different perspectives of the same image could be determined and BGA joints could be seen with a high degree of confidence. For example, **Figure 1** shows a typical oblique view of a set of BGA joints, and it can be seen that the corner balls have not made good contact with their pads – possibly due to thermo-mechanical stresses within the BGA's structure.

X-ray parameters can now be fine-tuned to show a clear picture of the target image. Modern high power and microfocus tubes permit a more varied resolution and materials with differing densities can be more easily seen in detail. Hence it is possible to analyze voids in detail.

Joints have always had voids, but they could be seen only under microsectioning. Microsectioning is a destructive exercise but we now have a nondestructive tool to identify voids.

Objects with strong contrasts, such as dense solder joints and copper traces within PCBs, appear cleanly at a good resolution and rapid interpretation of faults can be made.

But electronics assemblies almost always end up in some form of casing or rack system and the need is growing to see what may be in said casing or in a less dense material as well as what has happened to the PCB. We also need to see a true 3-D view of the assembly to hunt for defects that may pass all initial test criteria but threaten longer-term product life. For example, if the assembly is conformally coated or totally encapsulated, fault-finding a field return almost always results in destructive analysis; this destructive element can sometimes introduce faults or misleading information not present in the first place.

Materials used for coating or encapsulating are far less dense than the metallic elements found in assemblies and we now need x-ray systems to offer a range of abilities to suppress reflective images from dense materials while also permitting good views of dense materials.

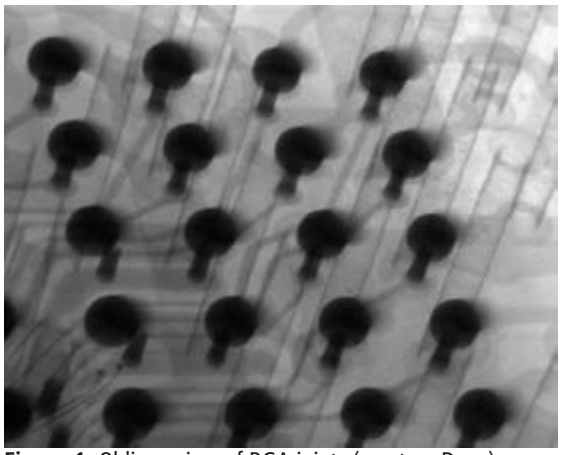

Figure 1: Oblique view of BGA joints (courtesy Dage).

Medical imaging has used CT (computer tomography) techniques for years to permit the varying densities of human tissues to be evaluated. In essence, the technique requires many x-ray images slices to be taken across the sample and the software then recombines all the slice images into a 3-D picture. The process is complex and the software is usually vast and requires huge amounts of computer memory.

A typical CT system used for electronics will probably take between 400 and 1600 slices. The tradeoff is the time required versus the ultimate resolution. Density variation across the slice will likely be large and so the focus spot size of the tube and its power rating are likely to be 130KV and 5 µm or so. But, we cannot talk just in terms of the spot size because the recompilation of the images is 3-D and the terminology used in this technology is VOXEL, or volume pixel. A 90KV tube power is likely to offer a 50 µm voxel or 50 µm cube element. Larger power ratings, different detectors and the sample size all factor in the ultimate result.

Confused? It's not surprising. It took the medical world years to work out the optimum parameters for analyzing a human body and we are only now finding sensible parameters for industrial use. **Figures 2** and **3** are individual slices from a CT scan of a seed and a Rotring drafting pen, respectively. Both have low but varying densities of material and they emphasize the level of the technology available by showing a good degree of contrast. One can clearly see what they are and the images are not "fuzzy" as they once were.

We cannot state here what is correct for all applica-

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Figure 2: Slice through a seed drafting pen (courtesy Procon X-Ray).

Figure 3: Slice through a Rotring (courtesy Procon X-Ray).

tions nor can we state the power or focus needs for everyone but it is clear that the analytical tools at our disposal are much improved.

Advances in CT technology are permitting looks beyond voids in joints to voids or other defects in the entire assembly. An encapsulated product may have tiny voids, or blow holes, anywhere in its plastic encapsulation, or it may not, depending on the process control of encapsulation. CT x-ray with high power and high resolution offers the chance to nondestructively check this at any stage during production or later during field return analysis.

As with any test equipment, x-ray is a non-value add tool and is less easy to justify than a production tool. But, considering our earlier example of the encapsulated product, the cost of destroying a product just to find a fault or introduce one that may not have been there in the first place is a burden on company finances. CT x-ray can be cost-effective.

The XRF answer. XRF (x-ray fluorescence) is now used to check the core substances of materials, often for compliance with RoHS laws. XRF is not the complete answer to finding banned substances as it has limitations in determining compounds. Individual elements can be found but brominated flame-retardants show up as bromine. However, as screening tools, XRF systems offer a good initial gauge on the likelihood of a substance causing trouble later.

The principle of XRF is as follows: High energy photons emitted by an x-ray tube interact with the sample target. The high energy photons are absorbed by an electron of the target atom. This electron is accelerated and forced to leave the atom. The "hole" thereby created in the structure of the electron shell is filled up by an electron of higher energy. The difference in energy between the ejected electrons and the newly arrived electrons may leave the atom as a photon of defined energy, or as an electron. If a photon, the process is called x-ray fluorescence and the energy of the ejected photon is characteristic for this atom and therefore for the element. This also happens in any x-ray system but the detectors are set to look for different parameters.

X-ray is playing an increasingly important role in electronics manufacturing and the pressures of traceability and product confidence mean that its use is unlikely to be transitory. The growth in the use of SiP and array packages will require a regular ability to check the construction of the package or the joints and CT x-ray is likely to play a large role in this. Even after the frenzy of RoHS activity has calmed, the need to check material content will remain, as exempt manufacturers are likely to want to check if lead is present. ■

参加IPC Apex贸易展销会的大部分公司期待在2006年再创坚实业绩，所展出的大部分产品已在其它展销会上推出。软件方面有所改进，特别是贴装设备的软件。还应注意到，旋转式芯片射出器正被更灵活的配置取代。作为主要发言者的Sanmina-SCI主席兼首席执行官Jure Sola说，印度与巴西的不同之处是，印度需要更好的基础设施，但（同中国相比）因民主的车轮转动缓慢而仍处于落后状态，但该国提供了“巨大商机”。而另一方面，巴西的市场具有吸引力，但没有达到公司的预期，而且缺乏印度那样的潜能。

Small Firms, Big Ideas

Mike Buetow and Robin Norvell

We are reminded that inspiration is not the domain of the biggest companies.

Another Apex has come and gone, and what have we learned?

That the industry is busier today than it was a year ago. That most – but not all – companies expect another solid year in 2006. That the buzz over Pb-free shows no sign of abating. That suppliers should be thinking now about what to do once that buzz does abate. That in ongoing Pb-free evaluations, the affect on component placement is being overlooked. That traceability is starting to take center stage, but there is no clear standard industry solution yet (and we need one). That materials suppliers big (Henkel, Cookson, etc.) and smaller (Indium, Electrolube) are looking to provide full solutions, not discrete products. That the decision by IPC to move the show to Los Angeles for the next three years has made exhibitors either really grumpy or downright mad.

Almost every company we spoke to at Apex said they expect to grow in 2006, in some cases well into the double-digits, and those who forecast a flat year noted that sales in 2005 blew the doors off. Most said that activity in Mexico and South America has been strong of late. The floor was livelier than past years, with attendance appearing to be up a bit. Another new element: A handful of Chinese and Taiwanese exhibitors.

In the opening day keynote, Sanmina-SCI chairman and CEO Jure Sola argued that customers need to wake up to the fact that electronics manufacturing is a huge cash generator but profit-poor industry. “The average operating margin over the past five years is 2%,” he said. “Customers need to realize this, that we can’t deliver the technology they want” without improved profitability. “The biggest mistake is that customers think they can do better by beating up their suppliers.”

Sola was upfront about Sanmina-SCI’s problems, saying that the company is “not as efficient in Asia” as it needs to be (for which he blames the tremendous migration there over the last two years). “Most of us are not good at ‘copy exact,’ ” he said, referring to the method of building identical product in any location. “When we transition to China we start over.”

And he sees distinct differences between the emerging markets of India and Brazil. The former, he says, needs a better infrastructure and is held back (relative to China) because the wheels of democracy move slowly, but the nation represents a “huge opportunity.” On the other hand, Brazil’s market is attractive but it is not meeting the company’s expectations and lacks the potential of India.

On to the products. Most of what we saw had been introduced in past years or at other shows. Attendees we spoke with pointed to improvements in software, particularly for placement machines. Also noted: Turret-style chipshooters are giving way to more flexible setups.

In this magazine’s humble opinion, the star was the MS2 surfactant from P. Kay Metal (pkaymetal.com). The dross-eating surfactant is

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like an elixir for electronics soldering. Several mega-OEMs are showing great results with it, the company said. (Read CIRCUITS ASSEMBLY'S interview with P. Kay Metal president Larry Kay at circuitsassembly.com/cms/cms/content/view/2854/95/.)

Speaking of dross reduction, Tamura (tamura-ha.com) showed its Flip (flat linear induction pump) solder bath, which is said to reduce oxidation and cut dross by up to 40%.

Vitronics Soltec's (vitronics-soltec.com) André Myny made two cogent points. First, he noted that although selective soldering is gaining momentum (and Vitronics expects to factor heavily in that market), industry is not yet designing boards to be selectively soldered. Also, he remarked that poor design and component choice are leading causes of defects.

ACE Production Technologies (ace-pro-tech.com) showed a selective soldering machine whose miniature (38 sq. in) footprint belied its 18 x 24" board capability. The machine, sans optional spray fluxer, priced at $39,000.

BTU International (btui.com) announced the asset purchase of Radiant Technology Corp. and hinted at other acquisitions as well, most likely in the energy sector.

Fineplacer CRS 10 comes with a reflow module for top and full-area bottom heating.

Heraeus (4cmd.com) launched its sixth generation of no-clean Pb-free solder pastes, the F640 series, for which it touts "near SnPB" voiding levels. The company recently merged its backend materials and circuit materials divisions.

Indium (indium.com) announced a comprehensive program that includes pastes, preforms, no-flow underfills and thermal interface materials (used between "hot" components and heatsinks) aimed at solving everything from barrel fill and joint cracking to CSP printing and thermal performance. The program, dubbed Reliability, offers applications help, an online interactive technology database and Pb-Free readiness assessment software.

ERSA (ersa.de) debuted six products, two of which are already patented. Of most interest was its innovative AOI+R machine (discussed in the February issue of CIRCUITS ASSEMBLY), but perhaps the biggest splash will be made by the iTool soldering iron, a 150W iron with exchangeable tips ($7) that reaches temperature within 2 sec., and is about the size of a pen. The iron has three patents pending. Also new: a full-tunnel N2 wave (president and COO Mark Cannon said ERSA has seen a "tremendous shift" to full tunnel machines).

Finetech's (finetechusa.com) Fineplacer CRS 10 rework system has added a top heater for more power for Pb-free applications. Their easy-to-use (we tried it) rework and bonding tool could perform individual ball removal (to 0.4 mm) without contacting other balls.

Juki Automation (jas-smt.com) is coming off a record January and says bookings are very strong. "The industry seems good," said president Bob Black. The company will soon roll out a low-cost flip chip bonder, retailing at about $200,000. He noted that while most companies have roughly one selective soldering machine per factory today, he expects the ratio could reach one per line.

We saw a new laser diode based system for selective soldering at ProMation (pro-mation-inc.com) aimed at the lower volume market. The single nozzle system has a bottom-side x-y gantry, an exchangeable pot, multiple cameras and automatic spray fluxing.

Thanks to an improved transport system, DEK's (dek.com) Europa printer has an improved (4 sec. cycle time) beat rate. It can now do 100% inspection, too. General manager Neil MacRaild said 35% of the orders for stencils are for its VectorGuard frameless version, and the company projects that will reach 60% by year-end.

Asymtek (asymtek.com) showed an innovative metal shield through which it could dispense a stream of underfill just 100 µm thick for components or stacked die. While vision is a limiter, the shield cuts one reflow operation and in case studies throughput rose as much as six times. The company forecasts flat sales in 2006, but only because it is coming off a year in which revenues rose 40%.

Known for its advanced placement machines, Samsung Techwin and its U.S. distributor, Dynatech Technology (dynatechsmt.com), were among the companies that showed end-to-end solutions (others included Sony and Essemtec). In addition to the placement gear, Samsung showed a 2-D vision screen printer (SP 450V) and a 10-zone, 110" (with two more optional) N_2-ready reflow oven (RF 30102). Dynatech president Isaac Robinson said the company has installed 700 to 800 of each worldwide and will continue to roll out new machines but will not get into the specialized printer or oven markets.

Essemtec (essemtec-usa.com) showed a variety of ultra-flexible placement machines capable handling of boards up to 23.5 x 31.5" and placement rates of 4200 cph per IPC standards. The company is working on better traceability, tracking part numbers, date codes and other aspects, and performing feeder setup, job planning, inventory control. The firm was readying a new demo lab, due to open last month, and has hired equipment veteran Jeff Stong, formerly of the American Competitiveness Institute and Quad Systems.

As is becoming its norm, Tyco Electronics (tycoelectronics.com) rolled out several machines. Most impressive was a laser depaneler, which uses a 200W CO_2 laser to saw boards up to 0.093" thick. It currently handles FR-4 boards, and the company is looking at modifications that could accommodate flex and ceramic. The first sale was to Siemens, Tyco said. Tyco also displayed the Champion 8300 for dispensing underfill or adhesive for RFIDs on paper, polyester or polyimide. The machine handles materials up to 20" wide, while the die can come in all media (wafflepacks, trays, etc.)

Service Excellence

MACK Technologies is a provider of integrated product delivery solutions. We focus on responsiveness, flexibility and total quality. Our clients attest to this; they voted us winners in *Circuits Assembly*'s Service Excellence Awards for medium-size EMS providers in three categories: **Dependability/Timely Delivery**, **Responsiveness** and **Value for the Price**.

CIRCUITS ASSEMBLY'S SERVICE EXCELLENCE AWARDS 2006

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Each of our locations can provide **cost-effective solutions** covering a wide range of volume and complexity, as we service the needs of product creation companies around the world. Our engineering, manufacturing and materials staffs develop and deploy the best possible solutions to satisfy the **unique needs** of our customers.

MACK Technologies is armed with a comprehensive arsenal of the **most sophisticated tools and technology available** in the industry with the rare ability to actually deploy them for our customers at the appropriate time. Planning and executing with the tools and resources we've invested in is what sets MACK Technologies apart from its peers both large and small.

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BP Micro (bpmicro.com) is now producing a programmer that can handle devices from MSOP8 to PLCC44. Over 100 of the machines have been sold in Japan already.

It's getting hard to move on the show floor without running into an AOI or x-ray tester of some kind. Hepco (hepcoblue.com) had a benchtop XRF tester called LeadHound that in demos was very quick. The machine retails for about $45,000.

DigitalTest (digitaltest.de) noted that business is looking up in Europe. The company has installed 1200 machines in the avionics and military sectors, and showcased its Condor flying probe tester, a second-generation system that debuted at Productronica.

ViTechnology (vitechnology.com) was among those who introduced improved software to ease programming and data sharing. The company is still building its machines in Europe, but is looking to move some operations to Asia soon. The company emphasized the benefits of closed-loop AOM (automated optical measurement), its attempt to go beyond defect inspection and incorporate process control.

FocalSpot (focalspot.com) is targeting small companies looking to perform BGA rework. The Den-on RD-500 Series II and SD-3000M rework stations include new software for controlling preheat temperature setpoints and auto-profile settings. The firm also showed an x-ray (Verifier FSX-080/090) with 5 µm resolution that sells for $45,000.

When it comes to automation software, electronics manufacturing is "the most underserviced segment imaginable," claims Valor Inc. (valor.com), adding that the time has come for more than just "point solutions" for MES and ERP systems.

You can still count on most of the industry leaders showing up at Apex. For instance, Henkel Electronics Group (henkel.com/electronics) president Pat Trippel said the materials maker is reaching the point where it can offer a full product line for IC and board assembly, and claims to be the only company that can offer all the materials needed for SiP on a global basis. Another differentiator: Henkel has invested heavily in field support, and is hiring technical process personnel in the Americas and Europe. (Read the full interview with Trippel at circuitsassembly.com/cms/content/view/2836/95/.)

Jim McElroy, executive director of iNEMI, said the consortium (inemi.org) will seek more international participation for its latest roadmap. The 2007 edition will for the first time include a chapter on organics for ICs. Also launched: working groups for heat transfer, medical electronics (Guidant and Medtronic are now iNEMI members), and system-in-package (SiP). McElroy also predicted a more proactive stance on environmental issues. "We now have several members who are saying, Maybe we need to be more forward thinking, so if new regulations come at us we will be ready." To that end, a project on brominated flame retardants is planned.

IPC inducted a pair of respected veterans into its Hall of Fame. "Don't just be a taker," inductee Vern Solberg advised. "Take part in the planning, the reviews, the tests, the discussions. You'll get your rewards." Likewise, fellow inductee Gene Weiner, who has been an IPC member for almost 48 years, said, "Become an agent for change, not a victim." (Read Circuits Assembly's interviews with Solberg and Weiner at circuitsassembly.com/cms/content/view/2855/95/ and circuitsassembly.com/cms/content/view/2857/95/, respectively.)

This year's Apex was the last for a pair of familiar faces, at least in their current jobs. DEK president Rich Heimsch has left the company, and Valor Inc. president Chuck Feingold has moved to the company's board.

This was also the last time the show will be in Anaheim. Its home for the next three years will be the Los Angeles Convention Center, a move that was met with frowns by most asked because of the site's location (near the intersection of two densely trafficked roads) and lack of nearby hotels. ■

Mike Buetow is editor in chief of Circuits Assembly. Robin Norvell is associate editor.

Life After Pb-Free

There have been changes at the top at Alpha Metals, as the company is already looking ahead to the day when Pb-free soldering is no longer the hottest thing going.

In an interview with Circuits Assembly, the chief executive of Alpha's parent company predicted smaller components would become mainstream and that he sees a need to prepare the solder materials giant for that time. "The lead-free music is going to stop," said Steve Corbett, CEO of Cookson Electronics (cooksonelectronics.com). "So how do we avoid the post-game price war?"

One need only look to Japan, Corbett said, to realize that smaller components are becoming commonplace. To meet customer needs that may come in as soon as 12 months, he said Alpha needs to "go back to the basics of powder," adding that the company must be able to make leading-edge Type 4, 5 and 6 powders to sustain its margins.

In some cases, avoiding the price war means Cookson will attempt to leverage its expertise in other areas, including surface finishes through its Enthone (enthone.com) division, to present customers will a complete materials solution. "OEM selling is a huge global strategy for us," Corbett said.

The company is also pouring resources into R&D, with about 10% of its total research spend going to the so-called high-end science projects. Much of that research is taking place at Cookson's labs in Bangalore.

Meanwhile, Alpha's longtime president, David Zerfoss, left the company in January. For the time being Corbett has assumed the role.

Finally, the sale of Cookson's Polyclad Laminates unit is expected to close early this month. From a CEO standpoint, the divestitures are done, Corbett said, while not ruling out potential acquisitions down the road. – *Mike Buetow*

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Service Winners Go the Extra Mile

A number of companies that go the extra mile were honored at CIRCUITS ASSEMBLY'S Service Excellence Awards ceremony during Apex. In the EMS category, the overall winners were Elcoteq (for companies with revenues over $500 million); Reptron Manufacturing Services (revenues between $100 and $500 million); and Key Electronics (revenues less than $100 million).

Also receiving awards were EMS companies with the highest scores in each of five individual service categories. (The overall winners were excluded from winning individual categories.) In the small-company category, ACC Electronix tied in the dependability/timely delivery category with APSCO Inc. APSCO also won the technology award. Masstech EMS won for manufacturing quality, and Electronic Systems Inc. received awards for responsiveness and value. In the medium-company category, EPIC Technologies, Integrated Microelectronics Inc. (IMI) and MACK Technologies tied in the dependability category, with IMI also winning for manufacturing quality. EPIC and MACK also tied for the responsiveness award. MACK won in the value category, with EPIC taking home the award for technology.

Electronics assembly equipment award winners were Asymtek for dispensing; Assembléon for pick-and-place (with a perfect 5.0 score); DEK for screen printing; VJ Electronix for rework/repair; KIC for soldering; and YESTech for test and inspection.

EFD Inc. won the electronics assembly materials suppliers award in the solder paste category. Aegis Industrial Software Corp. received top honors in the manufacturing/supply chain management software category.

Winners of the EMS categories display their awards. A record number of companies entered this year's SEAs.

Equipment, materials and software winners were also recognized at the SEA ceremony in Anaheim.

Customers of the SEA participants rated each company on a scale of 1 (poor) to 5 (superior) in five service categories.

In presenting the awards, editor in chief Mike Buetow issued a challenge to companies that claim great customer service but avoid participating in the SEAs to put their reputations on the line in the 2007 program."Many companies claim great service," he said. "These are the ones who put their reputations on the line."

A donation of $5,000 was made on the participants' behalf to the Surface Mount Technology Association's Charles Hutchins Educational Grant. Part of each participant's entry fee was included in the donation.

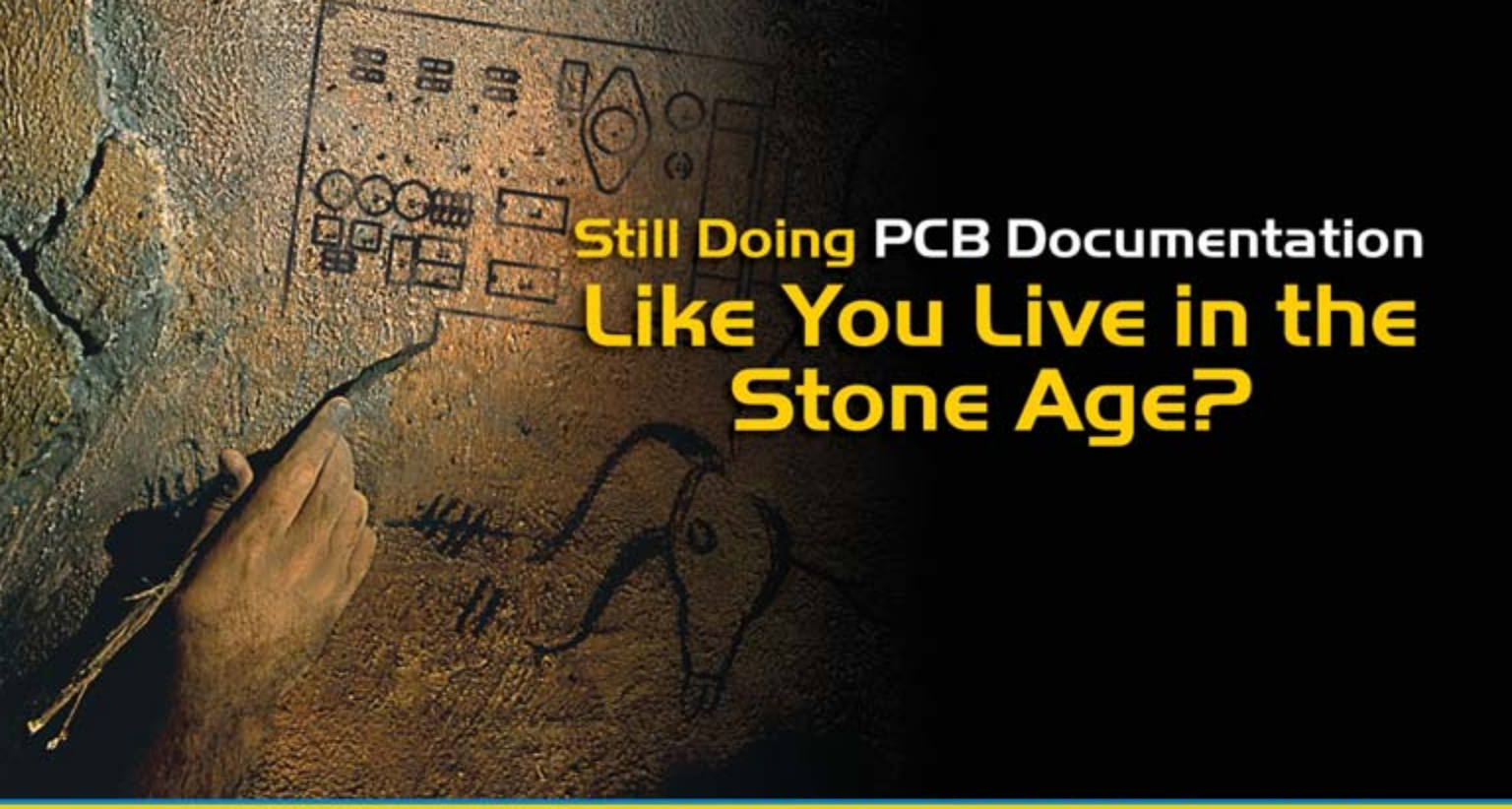
This is the 14th year CIRCUITS ASSEMBLY has sponsored the awards program. ■

2006 SEA EMS Provider Winners

	Company		
	Large	Medium	Small
Category	Over $500 million	$100 million to $500 million	Less than $100 million
EMS: Overall	Elcoteq	Reptron Mfg. Services	Key Electronics
Dependability/timely delivery		Epic Technologies	ACC Electronix
		Integrated Microelectronics Inc.	APSCO Inc.
		Mack Technologies	
Manufacturing quality		Integrated Microelectronics Inc.	MassTech EMS
Responsiveness		Mack Technologies	Electronic Systems
		Epic Technologies	
Technology		Epic Technologies	APSCO Inc.
Value		Mack Technologies	Electronic Systems

Each company was rated using the following scale: 5 (excellent), 4 (good), 3 (average), 2 (fair), 1 (poor).

Robin Norvell is associate editor of CIRCUITS ASSEMBLY; rnorvell@upmedia group.com.



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为了确定无铅焊点和锡铅焊点的自动X光检验（AXI）测量结果的不同之处，Flextronics测量了两种焊剂。我们发现在不同的测试条件下，无铅焊剂同锡铅焊剂的差别小于10%。根据这项研究，为获得准确的测量数据，建议每台AXI设备通过无铅或锡铅校准和调整面板，根据使用的制造工序予以校准。我们继续使用AXI数据验证无铅工序，特别是检查BGA气泡。

AXI Test on Fine-Pitch Components Using Pb-Free and SnPb Solder

Zhen (Jane) Feng, Ph.D., Eduardo Toledo, Dason Cheung, Jeff Newbrough and Murad Kurwa

In this analysis, Pb-free and SnPb TVs showed less than a 10% difference using a common test vehicle design.

Ed.: For the complete article please visit circuitsassembly.com /cms/content/view/3195.

Automated x-ray inspection (AXI) can detect most solder-related defects, including shorts, excess solder, misalignment, voids, insufficient solder, open/lifted solder joints and marginally accepted joints, which pass in-circuit and functional test but often result in field returns. Pb-free and SnPb are different materials, and their grey levels, or x-ray images, are different under AXI due to their composition. Pb-free solder joint defects detected by AXI are shown in **Figure 1**. One frequently asked question is, What is the difference of the measurement data between Pb-free and SnPb assembly? To determine the answer, we completed an experiment with a Pb-free test vehicle and a SnPb test vehicle using test condition 1 (Pb-free C&A panel) and test condition 2 (SnPb C&A panel).

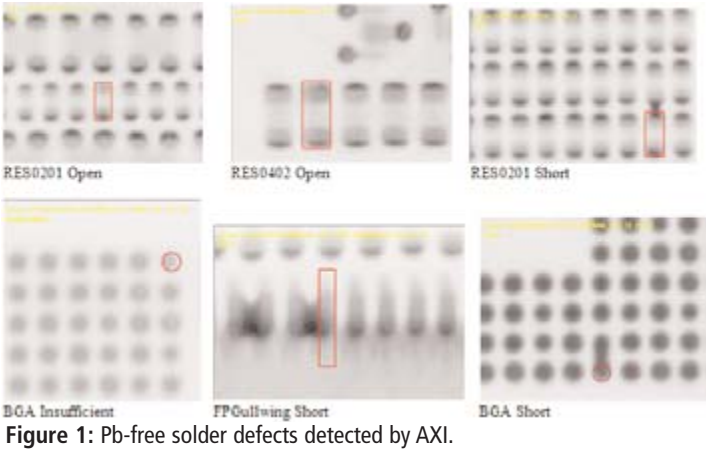

Figure 1: Pb-free solder defects detected by AXI.

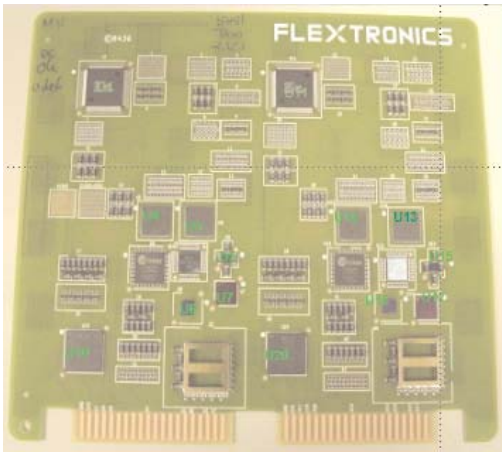

Figure 2: The Flextronics test vehicle.

Experiments and Analysis

The Flextronics test vehicle board (**Figure 2**) was chosen for this experiment. Board thickness was 1.2 mm with organic solder preservative (OSP) finish. We collected measurements for 12 CSP components, two fine-pitch gullwing and 443 resistors (0402) for measurement comparison (see **Table 1** for more information on selected components). The characteristics of Pb-free and SnPb solder are listed in **Table 2.** The Pb-

free solder (TLF-93-206) was from Tamura. All experiments were performed using an Agilent 5DX Series 3 system.

Gage R&R study. One weakness of AXI is the consistency of its results. Defect numbers are not the same when the same board is tested on the same AXI system several times for SnPb assemblies. We wanted to see how the Gage Repeatability & Reproducibility would differ for Pb-free solder joints. We tested one board with three operators, and the tests were repeated three times by each operator. The AXI machine was calibrated with the Pb-free C&A panel first. We chose 30 pins for data analysis on the specific components (BGA, fine pitch gullwing, RES0402) with SPC tool MINITAB. **Figure 3** shows Gage R&R results for the BGA diameter from MINITAB. The standard deviation [StdDev(SD)] for a source is the square root of the variance component for that source. Study Var is six times the standard deviation for a source, which means the calculation is based on 6 σ. The % Study Var is the % study variation, which estimates how well the measurement system performs with respect to the overall process variation and is independent of the Tolerance. The % Tolerance (SV/Toler) is the Precision/Tolerance (P/T)

Table 1. Test Components Information

Location	Part Name	I/O	Pitch
U3, U13	CSP (Amkor)	192	0.4 mm
U4, U14	CSP (Amkor)	288	0.4 mm
U5, U15	CSP (Unitive)	36	0.4 mm
U6, U16	CSP (Unitive)	144	0.4 mm
U7, U17	CSP (Unitive)	324	0.4 mm
U10, U20	CSP-M 2CSP	340	0.5 mm
U1, U11	FPG	128	0.4 mm

Table 2. Characteristics of Pb-Free and SnPb Solder

Item	TLF-206-93F	AIM NC 251
Alloy composition	Sn95.5/Ag3.9/Cu0.6	Sn62/Pb36/Ag2
	Tin 84.4%	Tin 54-60%
	Silver 3.5%	Lead 32-35%
	Copper 0.5%	Ag 2%
Melting point	216-221°C	179 °C
Boiling point	>250°C	N/A
Particle size of solder powder	20-41 10^{-6}m	45 10^{-6}m
Flux content	Modified rosin, Glycol ether 11.6%	Rosin 1-5%
Density	Approx. 4.2g/cm^3 (at 20°C)	8.421g/cm^3
Viscosity	200Pa•s	350-1200KcPs

Gage R&R

% Study Variance estimates how well the measurement system performs with respect to the overall process variation.

The P/T ratio is appropriate for evaluating how well the measurement system can perform with respect to the specification

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0065536	17.22
Repeatability	0.0062425	16.40
Reproducibility	0.0003111	0.82
Operator	0.0003111	0.82
Part-To-Part	0.0315106	82.78
Total Variation	0.0380642	100.00

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.080954	0.48573	41.49	10.84
Repeatability	0.079010	0.47406	40.50	10.58
Reproducibility	0.017637	0.10582	9.04	2.36
Operator	0.017637	0.10582	9.04	2.36
Part-To-Part	0.177512	1.06507	90.99	23.76
Total Variation	0.195101	1.17060	100.00	26.11

Figure 3. Gage R&R of BGA U3 diameter.

ratio that is appropriate for evaluating how well the measurement system can perform with respect to the specification, which is dependent on the process tolerance. We use the specification tolerance ±20% for the BGA diameter. The total Gage R&R is 10.84 for the % Tolerance.

We input different specification tolerance numbers (±20 to 65%) into MINITAB for Gage R&R and wanted to have the total Gage R&R number less than 30% (**Table 3**). We expected that Gage R&R results would be less than 30% with tolerance ± 20%. In Table 3, the reproducibility variations are less than 10% for all joint parameter measurements taken. However, the repeatability variation showed good results only for BGA diameter, BGA thickness, fine-pitch gullwing fillet length and resistor pad solder thickness with tolerances less than 30%. The results of the Gage R&R for BGA voiding percentages, fine-pitch gullwing heel thickness and center thickness need improvement. The results are not surprising since all our experiments for SnPb showed that the repeatability of measurements for these particular components was not a strength of AXI. The BGA voids of the Pb-free TV are very small (diameter less than 0.005"). It has not been proven that AXI can detect voids this small in size. For this particular size BGA, AXI can detect voids that do not meet IPC-7095. Therefore, some false calls are expected. We use a transmission x-ray as a complementary tool to verify these small size BGA voids.

Pb-free TV study. The team measured 12 BGAs (2648 pins) from nine Pb-free TVs with TC 1 (Pb-free) and 2 (SnPb). A total of 47,664 data points were taken for BGA diameter measurements, and another 47,664 data points were taken for BGA thickness. Analysis was performed using Mood Median test, with a 95% confidence level. If P <0.05, there is statistical difference; if P≥ 0.05, there is no statistical difference. Most BGA diameter measurements appeared different with different test conditions except U10, U20 and U15. U10 and U20 were the same package type with a pitch of 0.5 mm. The remainder of the BGAs had a pitch of 0.4 mm. (Note: U5 [P=0.041] and U15 [P=0.157] have only 36 pins.) By calculating the percentage difference, we concluded that the measurement data collected under TC 1 was almost the same as that collected under TC 2. The average difference observed was –0.62% using Eq. 1. The difference of other parameters is given using this equation. All BGA thickness measurements were statistically different under TC 1 versus 2. The measurement data with Pb-free TC 1 was larger than with SnPb TC 2. The average difference was 5.09% under different test conditions; the smallest was U3 (1.43%), and the largest was U10 (9.76%).

% difference = 100x (average test 1 - average test 2) / average test 2 *(Eq. 1)*

For fine-pitch gullwing, we tested two components with 256 pins on nine boards. A total of 13,824 data points were analyzed for heel thickness, center thickness and fillet length. The average measurement of heel and center thickness is listed in **Tables 4** and **5**. The last columns are the grand average and standard deviation, respectively. Using Mood's Median Test, fine-pitch gullwing heel thickness, center thickness and fillet length of the Pb-free TVs were different under TC 1 and 2. The average difference of TC 1 versus TC 2 was 8.89% and 7.35%, respectively, for the heel thickness and center thickness. It is not surprising that the average of difference is -1.46% for the fine-pitch gullwing fillet length because different test conditions should not affect to the fillet length measurement.

For the resistor, 7,974 data points (joints) of 443 RES0402 components were analyzed with MINITAB. The resistor pad thickness was different under the different test conditions. The average difference was 8.81% using equation 1 under different TCs. The results indicated that the resistor pad thickness was larger with Pb-free TC 1.

SnPb TV study. Similar studies were completed with five SnPb TVs. Differences between TC 1 and TC 2 were obtained using Eq. 2. The average difference of the SnPb TV was -0.14% and -7.05%, respectively, for BGA diameter and thickness. The average difference was -8.85%, -6.25% and 1.51% for fine-pitch gullwing heel thickness, center thickness and fillet length. The average difference of resistor pad thickness was -7.49% under TC 1 and 2.

% difference = 100x (average test 2 - average test 1) / average test 1 *(Eq. 2)*

Table 3. AXI Gage R&R for Pb-Free Solder Joints, Tolerance ±20 to 65%

% Tolerance (Study Variation / Tolerance)							
(SV/Toler)	BGA Diameter	BGA Thks	Void Percentage	FPG Heel Thks	Center Thks	Fillet length	RES Pad Thks
Total Gage R&R	10.84	28.66	29.07	30	28.43	22.36	19.81
Repeatability	10.58	28.2	28.96	29.27	27.66	21.33	18.87
Reproducibility	2.36	5.09	2.5	6.55	6.57	6.72	6.05
% Of Tolerance	20	25	65	50	40	20	20

Table 4. Fine-Pitch Gullwing Heel Thickness Average Under Pb-Free TC 1 and SnPb TC 2

Test Condition	Heel Thickness	LF2	LF3	LF6	LF7	LF8	LF10	LF13	LF14	LF20	Average	StDev
U1_L	Average	2.51	2.43	2.41	2.45	2.40	2.33	2.39	2.39	2.39	**2.41**	**0.05**
U1_L	StDev	0.19	0.20	0.22	0.19	0.17	0.18	0.28	0.28	0.23	**0.22**	**0.04**
U11_L	Average	2.50	2.55	2.51	2.52	2.43	2.45	2.49	2.49	2.45	**2.49**	**0.04**
U11_L	StDev	0.22	0.35	0.25	0.17	0.27	0.22	0.18	0.18	0.29	**0.24**	**0.06**
U1_LF	Average	2.71	2.49	2.63	2.69	2.68	2.59	2.68	2.60	2.64	**2.63**	**0.07**
U1_LF	StDev	0.23	0.21	0.18	0.21	0.18	0.22	0.22	0.23	0.24	**0.21**	**0.02**
U11_LF	Average	2.76	2.69	2.79	2.70	2.66	2.61	2.71	2.68	2.71	**2.70**	**0.05**
U11_LF	StDev	0.22	0.35	0.28	0.24	0.32	0.24	0.22	0.22	0.30	**0.26**	**0.05**

Table 5. Fine-Pitch Gullwing Center Thickness Average Under Pb-Free TC 1 and SnPb TC 2

Test Condi	Center Thickness	LF2	LF3	LF6	LF7	LF8	LF10	LF13	LF14	LF20	Average	StDev
U1_L	Average	2.11	2.06	2.03	2.07	2.02	2.04	1.90	1.90	1.95	**2.01**	**0.08**
U1_L	StDev	0.15	0.13	0.13	0.13	0.15	0.10	0.17	0.17	0.15	**0.14**	**0.02**
U11_L	Average	2.11	2.06	2.04	2.13	1.98	2.08	1.94	1.94	2.01	**2.03**	**0.07**
U11_L	StDev	0.11	0.31	0.21	0.11	0.32	0.18	0.19	0.19	0.19	**0.20**	**0.07**
U1_LF	Average	2.18	2.14	2.20	2.22	2.19	2.22	2.16	2.07	2.08	**2.16**	**0.06**
U1_LF	StDev	0.22	0.15	0.11	0.13	0.18	0.13	0.15	0.15	0.13	**0.15**	**0.03**
U11_LF	Average	2.16	2.10	2.21	2.24	2.17	2.22	2.21	2.13	2.14	**2.18**	**0.05**
U11_LF	StDev	0.18	0.33	0.22	0.14	0.28	0.19	0.19	0.17	0.24	**0.21**	**0.06**

Summary

AXI is a powerful tool for process characterization during the transition to Pb-free solder. There is less than a 10% difference for both Pb-free and SnPb TVs under different TCs. Based on this study, to get accurate measurement data, each AXI machine should be calibrated with either a Pb-free or a SnPb C&A panel in accordance with the manufacturing process being used. We continue to use AXI measurement data to verify our Pb-free process, especially to check BGA voids to optimize the profile. ■

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本文描述基于SAC的焊膏的开发和实现，以用于不使用氮气、大范围温度分布的回流，也说明这一代焊膏包括分子链较长的有机材料，因此需要助焊剂系统。热电阻研究显示出这些材料的优点。本文还提供了增强这些材料的流动性的方法，从而影响基于SAC的焊膏的印刷特性。无铅SAC合金的温度曲线得到提高，因为这些合金的液态温度大约为217，但这个温升本身不会破坏很多无铅焊膏配方的回流性能。

Running Pb-Free Reflow Profiles without Nitrogen

Eli Westerlaken

TGA/DSC data show paste can be used in extended reflow profiles with reduced ΔTs even at fast printing speeds.

The widespread use of SnAgCu-based solder paste drives manufacturing toward reflow profiles considerably longer than those used for Pb-bearing products. This is due to the minimized process window that results from higher reflow temperatures, and also the limited thermal resistance of the current generation of components. The tighter process window requires a significant reduction of ΔTs between the small and large components. The most common way to minimize ΔTs is to extend the soak or ramp before the reflow phase.

The thermal breakdown of most materials is impacted more by prolonged dwell times at higher temperature levels than by temperature level itself. The consequence for the solder paste is thermal breakdown of the organic material, loss of the protective flux blanket and inferior reflow performance. Industry sectors that typically have assembly designs with major differences between small and large components have the option to reflow these assemblies in a Pb-free process with nitrogen to protect the solderability of the assembly. However, nitrogen adds cost.

This article describes the development and implementation of SAC-based solder paste for reflow processes with extended temperature profiles and without nitrogen. It explains the need for flux systems in this generation of solder paste that incorporates organic materials of longer molecular chain length. Thermal resistance studies show the advantages of these materials. Also, solutions for enhancing the mobility of these materials are provided, impacting the printing properties of SAC-based paste.

The heat profile for Pb-free SAC-alloys is elevated because the liquidous temperature of these alloys is approximately 217°C. This temperature rise by itself, however, does not jeopardize the reflow performance of many Pb-free solder paste formulations.

The Pb-free production of mobile phones is a good example. This technology may be leading the trend toward fine and ultra-fine pitch technology. Therefore, printing solder paste for that type of board may be a challenge. In the reflow process, however, these assemblies are relatively easy compared to other types of assemblies. The components on a mobile phone board generally have a relatively small and uniform thermal mass throughout the entire collection. Thus, perfect reflow results can be obtained without nitrogen by using relatively short profiles.

The real problem is that many PCBs – such as those for automotive and machine controls – have components with significant variations in thermal mass. The fact that many components cannot survive even a short-term exposure to temperatures beyond 250°C stipulates a smaller process window. Since the higher liquidous of SAC-alloys, and the 10° and 5°C margins, respectively, for diffusion and measurement inaccuracies are a given, the implication is that tighter

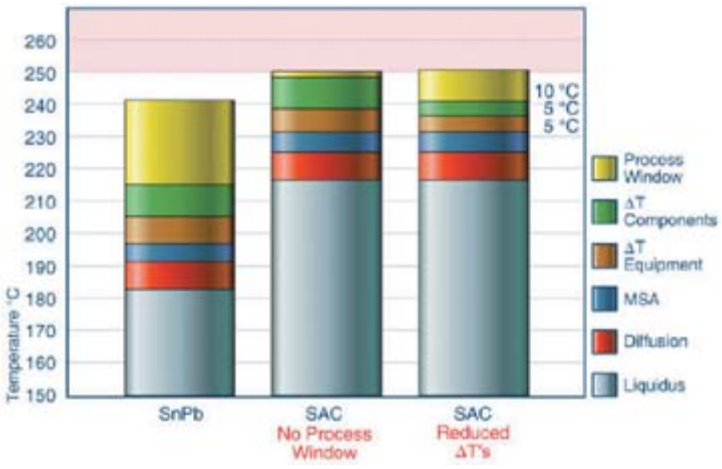


Figure 1: The Pb-free process has a reduced the process window, and calls for smaller ΔTs (courtesy EMPA).

ΔT's between the smallest and the largest components are key to creating an adequate process window (**Figure 1**).[1] The target maximum ΔT in Pb-free processes is generally 7°C.

The only way to achieve this is by extending the reflow profile, so that the temperatures of the largest components are permitted time to rise well beyond the liquidous temperatures, with a safety margin permitting the diffusion of the metals and for equipment and instrument variations.

Effects on Paste Chemistry

Longer exposure time to the elevated temperatures will cause accelerated melting, driving the active ingredients in the paste-flux away from the solder joint where they are supposed to react with the oxides on the metallic surfaces of the paste, board and components.

Thermal properties of a solder paste have an affect on:

- Separation.
- Printing speed.
- Open time.
- Tack time.
- Smearing.
- Beading.
- Wetting.
- Flux spattering.
- Pin-in-paste.
- Voiding.
- Residues (contact errors; SIR/electromigration; equipment contamination).

Absent a nitrogen environment to prevent materials from further oxidation, the wetting performance in the process will progressively deteriorate as the profile is extended. This will also cause thermal breakdown to the organic system of the paste-flux. Depending on their molecular structure, the flux materials will sublimate or decompose to an extent that they can no longer help the soldering process.

Nitrogen blanketing. The benefits expected from nitrogen blanketing the reflow process vary. Data from the field show that nitrogen will compensate the smaller thermal window of flux materials to a certain extent, but not entirely. The melt viscosity of the flux materials, impacting the dripping of solder paste in pin-in-paste applications, cannot be controlled by nitrogen blanketing.

Larger molecules. Solder paste is a suspension metal powder in a flux vehicle. The metal percentage as well as the particle size distribution has a significant impact on some of the rheological properties of a solder paste, such as slumping[2], print definition, smearing and shorts.

Paste-flux is a complex composition of multiple polymer species ranging from relatively simple, slightly modified wood rosins to larger molecular-weight resin systems, solvent(s), activator(s), rheological and numerous other property modifying additives (**Figure 2**).

Generally, larger molecules may offer more thermal bulk and therefore could better withstand demands of an extended

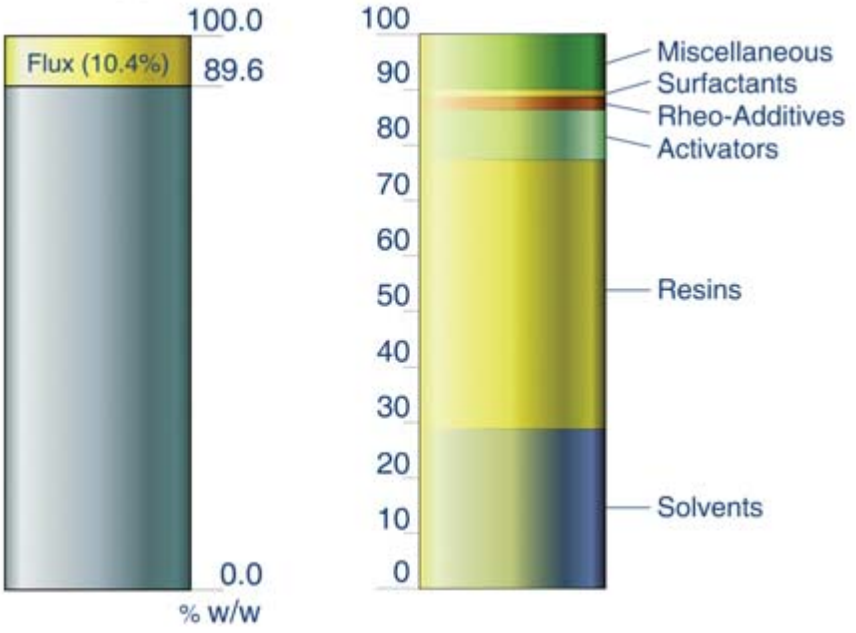


Figure 2: The main functional components in a solder paste and paste flux in percentage by weight. The resins form the bulk of the system followed by the solvent system and the activators.

profile. However, simplifying the solution to a replacement of the flux constituents, such as ordinary rosin, by materials of a larger structure in many cases appears to be a shortcut to problems in areas such printing. To understand why there is a conflict between the formulation of paste-flux with higher molecular weight materials, generally yielding a higher thermal resistance and a smooth printing performance of the solder paste, we shall first discuss some basics of solder paste composition.

The flux vehicle of a solder paste consists of functional groups such as resins, rheological and other property modifying additives. They affect the mobility of the system, solvent retention properties, long- and short-term dielectric properties and thermal behavior. The entire formulation forms a complex of short-chained linear substances, long-chained linear and even branched molecules. Some of those substances will truly dissolve in the solvent system, while others will swell to form a colloidal structure.

The printing of solder paste, in particular the cutting of the wet deposit by the squeegee, occurs in the high shear rate range. In this context it is important to realize that rheological additives alone do not determine the overall rheology of a paste. All constituents contribute to the flow properties of a product. Besides the load and size of the metal particles, the resin system, solvents and some property modifying additives primarily affect the high-shear rate viscosity of a paste and thus its printing properties. Generally the high-shear rate viscosity will increase as the metal content or molecular weight of the resin system increases. Also, when the particle size of the metal powder or the strength of the solvent system decreases, the high-shear rate viscosity of the paste increases (**Figure 3**).

The short-chained fractions in the network are only physically and relatively weakly entangled. This in particular is the case with solder paste with a distinct yield point. In such cases the rheological network has a more physical nature characterized by dipole forces, hydrogen bridges, electrostatic and/or Van Der Waals forces. The bonds are easy to break and will rapidly restore the structure of the network. A matrix of surfactants can boost the instant restructuring of the rheological network. Upon full development of the mix of substances in the solvent system, the molecules will entangle and form the rheological network.

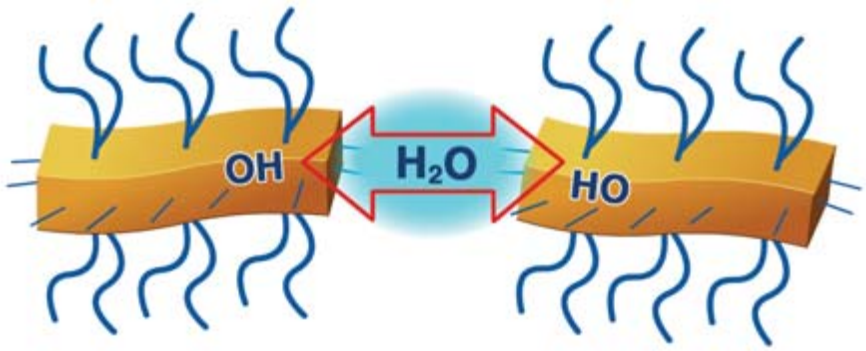


Figure 3: Two adjacent particles of rheological additives bridged by a water molecule..

Each rheological network has specific requirements with regard to its processing temperatures to develop its optimal degree of entanglement. The processing temperatures required are related to the solvent system that is used. The rheological network impacts the required printing properties. The solvent system is predominantly a function of both the required stencil life and tack time of the solder paste as well as the solubility power required with regard to the substances selected to form the rheological network. Furthermore, the heat profile in the reflow equipment and the post-reflow properties of the organic residue are determining factors in the selection of the chemistry that builds the flux vehicle for solder pastes.

Stencil life and tack time of 8 hrs. or longer requires a solvent system with extremely low volatility at ambient temperatures. Even without this prerequisite, the solder paste formulator has to tackle many problems to select the right solvent system. That is, because – as with most other functionalities in chemistry – there is no such thing as the ideal universal solvent when it comes to solubility power for the considerable number of different types of organic materials that may form the flux vehicle.

To ensure maximum consistency and efficiency – regardless of the usual tolerances of physical and chemical properties of the raw materials, and the loss of traces of the solvent during production and application of the paste – the window for solubility power should be adequately large to deal with all aforementioned tolerances and still provide consistent printing properties.

Low processing temperatures during production of the flux usually results in incomplete development of the rheological network. Excessively high processing temperatures during production, storage or transportation may partially dissolve some groups in the rheological network and will cause disentanglement and the formation of agglomerates, causing inconsistencies in the visco-elastic behavior of the paste.

Thermal Resistance and Printing Properties

The first step in any development of the thermal properties of a solder material is to gather data on typical thermal histories of soldering processes. This can be done by wiring a test board with thermocouples at precise top- and bottom-side points with varying thermal mass. In one study, using scans from a compact telemetric thermal indicator, it was easy to see from profiles 4 and 5 in the diagram a substantial amount of thermal energy going into the assemblies during preheat/soak that could effectively burn out many organic materials before they can do their job in the reflow process.

The key to maximizing the thermal resistance of the paste-flux materials as well as printing performance lies in a thorough understanding of interactions between these polymers and certain property-modifying additives.

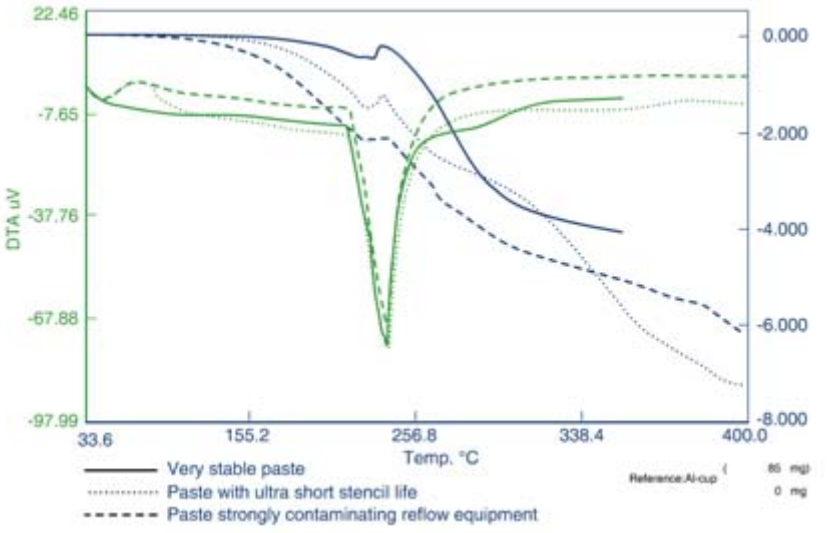


Figure 4: A combined TGA/DSC image of three prototypes of paste. The type on the top (with the continuous line) clearly appears to be the most stable under reflow and has a good printing performance.

Using thermo-gravimetric analysis (TGA) and differential scanning calorimetry (DSC) techniques, we have characterized the crystallization behavior, sublimation energy and optimum activity range of several organic systems suitable for use as filmformers, rheological additives and flux activators (**Figure 4**). With this information, it is possible to tailor the key materials such as resins and activators for a specific thermal profile and reflow atmosphere. Properly applied, these techniques – in conjunction with the tuning of ratios of property modifying additives – permit substantive improvements in thermal resistance while maintaining exceptional rheological properties such as resistance to slumping and smearing, and optimum printing performance.

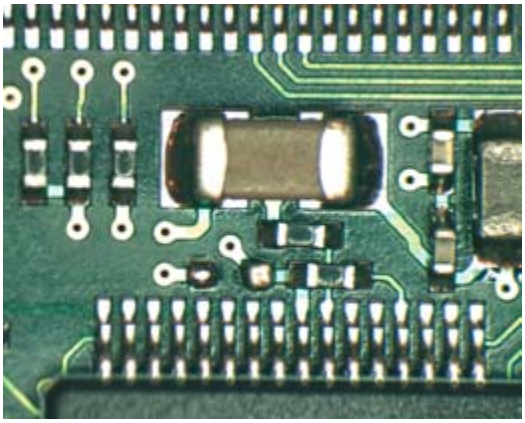
The TGA/DSC techniques readily adapt to different atmospheres such as nitrogen. The formulation of no-clean, Pb-free solder paste by its nature requires defining the optimum balance between two main objectives that initially seem to conflict: thermal stability and printing performance.

Additional requirements such as certain pin-in-paste applications require a specific melt viscosity of material along the temperature time line to prevent paste from dripping from connector pins before reflow has begun.

There is an analogy between a racing car with a strictly controlled weight limit and a no-clean Pb-free reflow process. The way to make performance improvements in the racing car is not to design bigger and bigger engines, but rather to tune an engine of optimum size as carefully and precisely as possible and boost performance by technical skill rather than brute force. With paste flux we cannot just add another shovel of activator to the tank. We must carefully and accurately characterize the behavior of the paste flux as it travels along a known thermal history. We can eliminate chemical dead weight and optimize ratios between the key constituents and – by the same techniques – define the balance between maximized printing performance and the highest thermal resistance to withstand the rigors of the Pb-free and N_2-free reflow processes.

Larger molecules will create a stronger entanglement in the rheological network. Therefore, substantial ratios of this material contribute to a solder paste that may survive virtually any extended reflow profile, but will require a tractor to move it across the stencil during the printing process.

We have seen that some resins and activators are better than others in certain applications, but no single resin nor activator is universally better than all others in all applications and in all soldering systems.



A combination of the right paste and profile can result in perfect joints in an air atmosphere.

If in the ramp or soak zone we can continuously optimize the cleaning of the metal surface at lower temperatures with organic materials that are relatively more volatile, the surface will become substantially more solderable, whereas, on the other hand, we can incorporate a sufficient ratio of materials with an adequately high melt viscosity, thus preventing the paste flux from early migration away from the solder joint. When the most thermally stable part of the organic materials in the paste flux finally kicks in, the joint formation at the end of the extended high temperature profile can successfully be accomplished, leaving a relatively clean surface that features excellent dielectric properties.

When using TGA/DSC, it is important to study the resolidification behavior of the flux materials which details the temperature, time and place where fumes from these substances will resolidify and deposit on the board in the reflow oven. Resins and many organic acids, unlike halide salts, are only weakly ionic in solvent solution. Their metal cleaning horsepower is increased when they enter the more mobile liquid melt phase. Therefore, a rough correlation between melt range and cleaning efficiency exists. While the sharpness of the melt range is an excellent indicator of the purity of the starting material (an essential parameter to reduce product variation in today's solder materials), the position of the peak is important because it gives a "quasi empirical" indication of the temperature range at which the activator kicks in.

TGA/DSC permits tailoring of systems, such as solvents, resins, activators and surfactants enhanced by the addition of several synergistic non-acid materials, to improve solvent retention times and to broaden the melt peak substantially or some additional peaks at a certain temperature level. One can also manipulate the melt temperature of resins and the bulk activator, indicating an earlier availability of the soldering power of these major constituents. The modified temperature peaks assist in initial cleaning of the substrate and provide a larger window for the fluxing reaction. A well-designed system preferably exhibits a single, very narrow and sharply defined peak upon cooling. That implies a single highly ordered (crystalline or amorphous) resolidification. Ideally most of the synergists have been volatilized at the reflow temperatures. This facilitates the design of a flux management system by reflow equipment suppliers.

The more complex mixture survives the Pb-free reflow process by a small but safe margin. According to its no-clean objective, a reduced but effective amount of the material survives the reflow-soldering process to complete joint formation.

The Importance of Surfactants

Solder paste is a complex suspension with a substantial number of different liquid/liquid and solid liquid interfaces in terms of surface chemistry. Our understanding of interfacial chemistry lies in instantly restoring the rheological network after shear rates have been removed and in perfect wetting of materials to be soldered. Not only is it necessary to deposit material in a precisely defined area and precise shape to promote the wetting of the metallic surfaces, but it is also important to ensure that the molten solder mass smoothly, reliably and completely parts from the nonmetallic upon reflow.

As with most other functionalities in chemistry, there is no ideal, universal surfactant suitable to meet all requirements

and morphologies. Obviously, different surfaces have different morphologies, yielding different surface energy states, and no single type of surfactant will interact with all types of surfaces. Advanced surface chemistry in a no-clean Pb-free solder paste uses a range of chemically different surfactants at carefully tuned, relatively low ppm ratios to interact with many types of different morphologies. Many surfactants perform better and in a more universal way when they can work with other carefully-selected surfactants.

A properly designed surfactant system will assist in repelling the hot liquid solder mass from nonmetallic areas, thereby reducing the occurrence of beading and solder balling, and will also improve paste printing or dispensing performance.

Additions in the low-end ppm range of an advanced, well-designed system of surface chemistry will contribute to higher SIR values. However, high ratios of surfactants would create more cons than pros:

- Air bubbles in the wet paste deposit.
- More residue.
- Reduced SIR values.
- Increased costs.

The surface chemistry in solder paste should improve (and not jeopardize) the dielectric properties of the assembly after reflow. The surface chemistry needs to survive the process to such an extent that it can perform the task it has been formulated for. In addition to printability, chemical and thermal stability are the keywords in this context.

Conclusions

Using the data from TGA/DSC, we adjusted the retention time of our solvent system and modified our resin, activator and synergist system to remove the paste flux constituents that caused the anomaly, replacing them with more effective systems. Further, the developed flux system displays exceptional reflow soldering ability as well as strict compliance with world standards with regard to reliability criteria. With advanced rheometry such as specially defined sweep tests[2], we were able to predict the printing performance in application testing.

Therefore, solder paste can be designed for use in Pb-free applications using extended reflow profiles to achieve reduced ΔTs while avoiding the use of nitrogen blanketing, even if it requires substantial printing speeds. ■

Ed. This paper was first presented during IPC Apex in February 2006 and is reprinted with permission of the author.

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A Comparison of Convection and Condensation Pb-Free Reflow Soldering

Dr. Hans Bell

Convection runs at faster cycle times, while condensation is superior for heavier PCBs.

Ed: For the full article please see circuitsassembly.com/cms/content/view/3204.

Within a range of 3.0 to 4.7% silver and 0.5 to 3.0% copper, the SnAgCu alloy demonstrates a narrow melting temperature range of 216° to 217°C.[1] Precise proportioning of the constituents of this alloy does not play a significant role with regard to reliable solder joints, as indicated by a recently published IPC study concerning 96.5Sn3.0Ag0.5Cu, 95.5Sn3.8Ag0.7Cu and 95.5Sn4.0Ag0.5Cu solders.[2]

The fundamental upper temperature limit for the process window is dictated by the processing limitations of the utilized materials and components. In particular, moisture-sensitive components are critical. IPC/JEDEC J-STD-020C classifies moisture-sensitive non-hermetic components (MSDs) according to package dimensions, among other factors, and restricts the maximum reflow temperature for package thicknesses of ≥2.5 mm and package volumes of ≥350 square mm to 245°C.[3] Warm-up and cool-down gradients (+3 K/s, -6 K/s), as well as limiting dwell times above certain temperature levels, represent additional restrictions. **Figure 1** shows the working window for the maximum temperature of 245°C.

Against this backdrop, the right reflow technology must be selected for the PCB to be soldered. This article reviews the differences between convection and condensation (vapor phase) soldering. ■

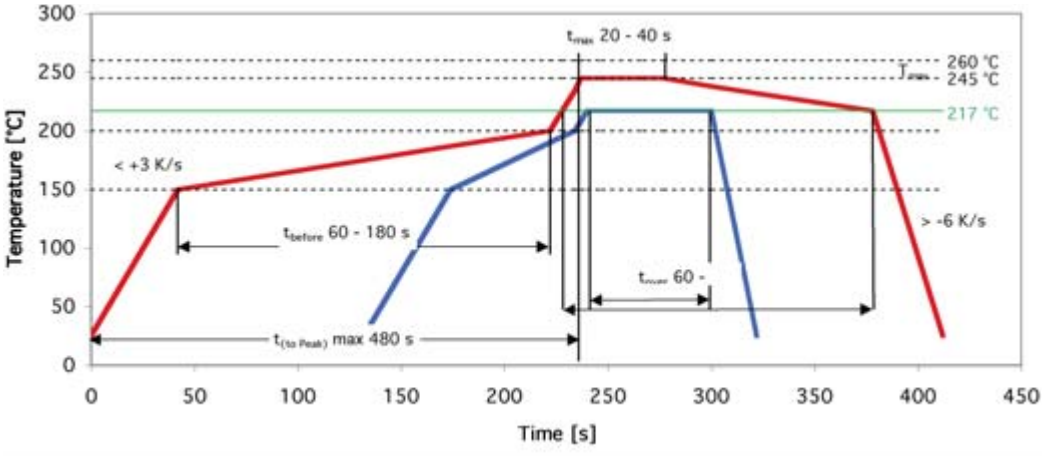
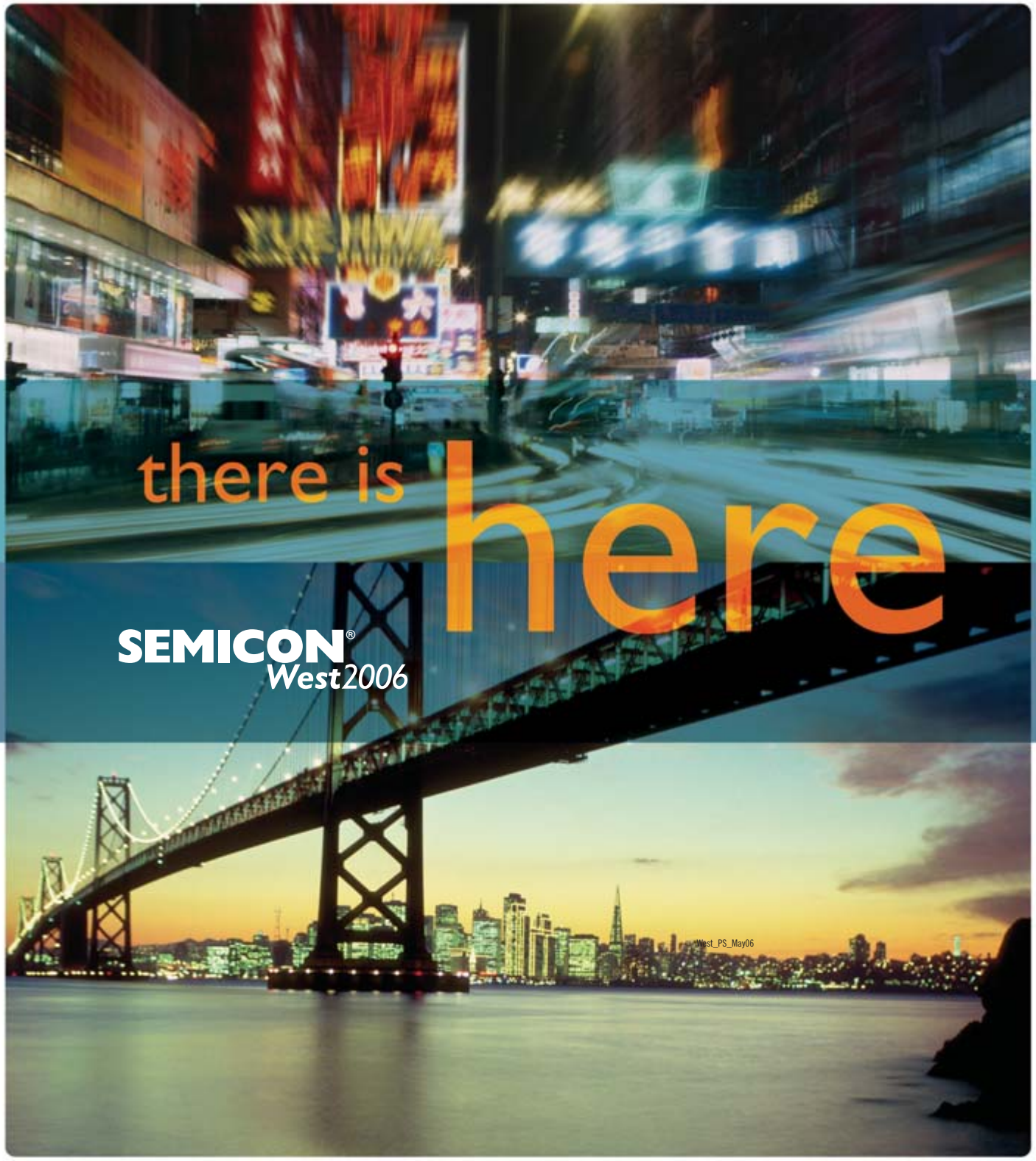


Figure 1: Working window for MSDs per J-STD-020C.



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在经受热试验或震动试验时，底层填料可改善BGA的可靠性。最佳材料和加工程序的开发常常受到可见度的妨碍：你看不到你在做什么。通常如果不破坏昂贵的硬件，就无法确定流动、气泡、混合、涂层均匀度等等的特性。这个非专利夹具可能有所帮助：简单的铝板和一个可调卡箍环绕的带强化玻璃板的槽。

A Fixture for Characterizing Underfill

Tom Clifford

This inexpensive and adaptable non-proprietary hardware aids visibility.

Underfill can improve the reliability of BGAs during exposure to thermal cycle or vibration. The development of the best material and processing is often hampered by visibility: you cannot see what you are doing. Flow fronts, voids, mixing, coverage and uniformity typically cannot be characterized without destroying expensive hardware. This fixture might help: a simple slab of aluminum, a slot to contain a little pane of tempered glass, ringed by De-Sta-Co or other adjustable clamps (**Figures 1** and **2**).

To use it: Set the BGA, adjust the clamp height and pressure just enough to hold the BGA in place, dispense the underfill material, cure (if necessary or if part of a study), unclamp the glass and view the underside. Clean and try another variant.

Studies could include characterization of flow behaviors: temperature vs. viscosity; perimeter-fill processing; flow-around a center heat slug or adhesive dots; damming, mixing and sequencing, etc; or they could involve processing details: dispense nozzles and pressures; access, interference and traverse patterns; studies of damage to columns; remove and repair-replace processes; displacement of the part or spacers due to side filling, etc.

Other studies could concentrate on materials properties and effects: location and extent of voids before and after cure; CTE deformation; z-axis geometry effect of cure frothing and voids; degassing effects; chemical compatibility; effect of simulated PWB surface roughness on flow, etc. Or they might cover other special objectives: component keep-outs and adjacent-

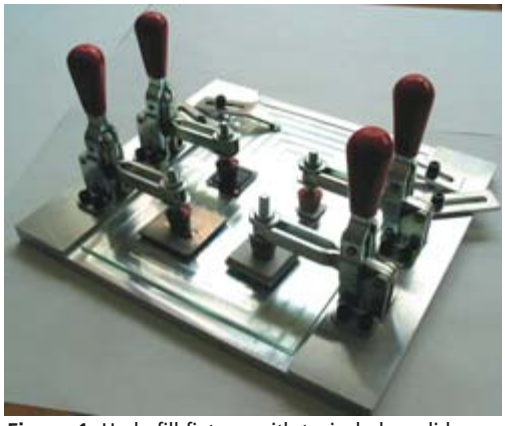

Figure 1: Underfill fixture, with typical glass slide.

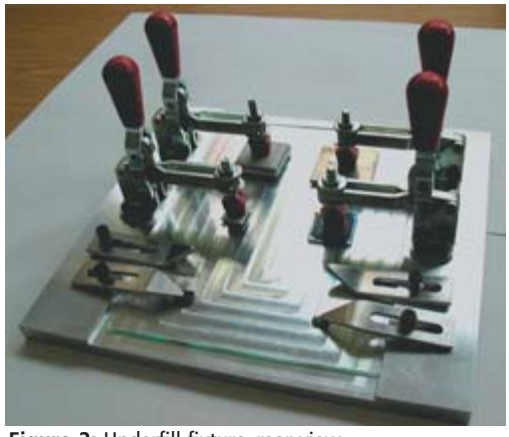

Figure 2: Underfill fixture, rear view.

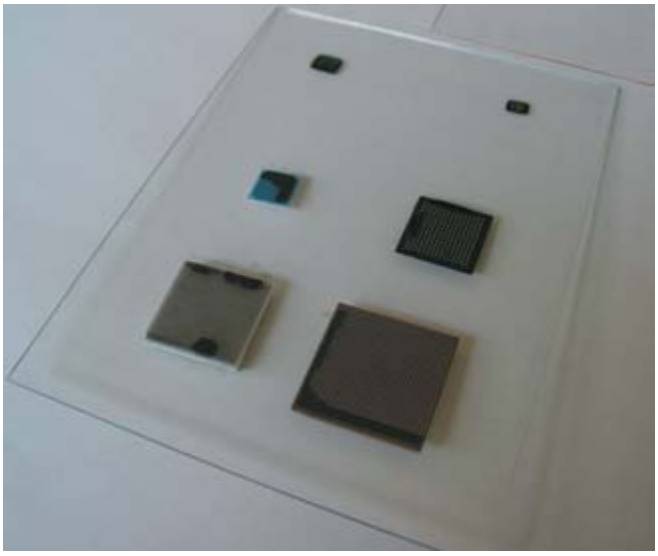

Figure 3: Bottom-side view of a typical exploratory study.

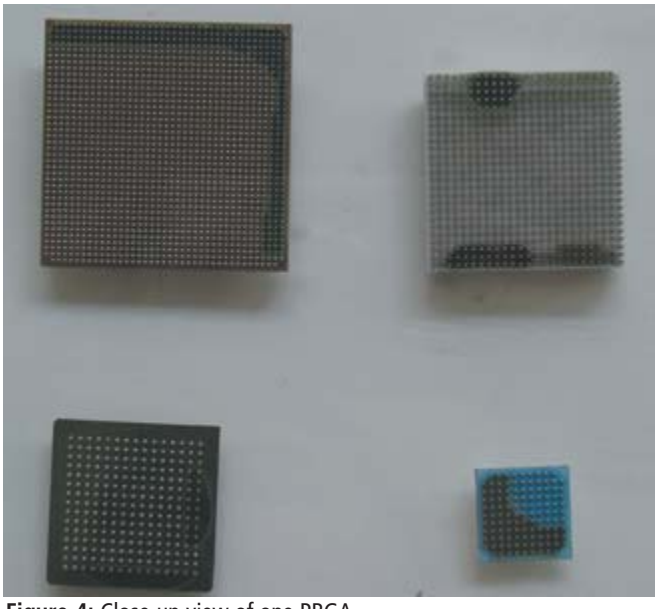

Figure 4: Close-up view of one PBGA.

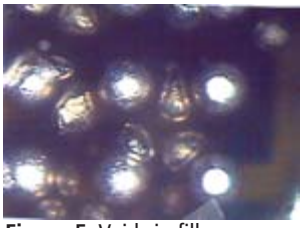

Figure 5: Voids in fill.

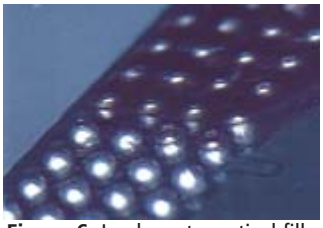

Figure 6: Inadequate vertical fill.

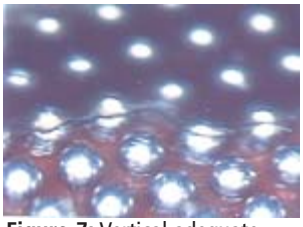

Figure 7: Vertical adequate, but poor x-y fill.

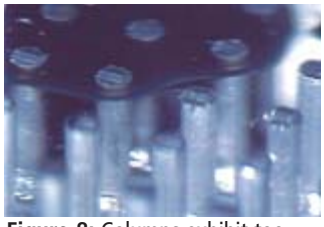

Figure 8: Columns exhibit too-low viscosity.

part interference; investigation of special rework/removal issues; simulations of varying collapse geometries due to different levels of temperature/ time/weight, as that affects underfill flow, etc.

These special objectives go beyond the usual demonstration of viscosity, gap, extent and fill location, and could also benefit from adaptations of this simple glass-slide fixturing approach. A possible side benefit: simple show-and-tell visuals based on glass specimens from this fixture could be used to illustrate development issues and status.

The design is not critical, and the value is in ease-of-use and the visualization capability. The fixture shown is for maximum adaptability. Alternate designs could be tailored for small-size (first-level flip-chip, inside-the-package technologies) or high-temperature clamps for cure studies; designs with adjustable side x, y or z features to study dispense-access or removal constraints; calibrated vertical stops and loading to study z-axis CTE effects. For simple tasks, the clamps need not be articulated: simple bucktooth cleats, with finger-tightened knurled- nuts similar to those shown **Figure 2**, could offer clearance and size options to suit the task.

Figure 3 shows the results of a study on several types of BGAs (a large ceramic column grid array, PBGAs, a medium-sized CBGA and [U]BGAs) in an exploratory dispense test of a candidate underfill formulation. The closeup (**Figure 4**) of underfill on a PBGA shows clearly unacceptable results but illustrate the visualization and characterization capability. These typical bottom-side seen-through-the-glass images demonstrate the ready visibility of the extent and characteristics of the flow. Certainly, the development engineer's tasks, process controls and results would be much more precise, discriminating and relevant, embodying precise dimensional and photo documentation.

Figures 5 to **8** show more dramatic examples, for demonstration purposes only, of the underfill processing characteristics that can readily seen and documented by using the bottom-side see-through capabilities enabled by this fixture.

This fixture concept is not new, and certainly is not revolutionary, but is offered to possibly benefit industry development of underfill materials and processes. ■

Acknowledgments

Appreciation is extended to the Sunnyvale SMT manufacturing and materials & process engineers for their support and utilization of this project.

Tom Clifford is group lead, advanced electronics packaging, Lockheed Martin (lmco.com); tom.clifford@lmco.com.

BGA Repair for Mixed Assemblies

Arm yourself with knowledge of the material construction.

Just as the industry is becoming familiar with BGA assembly technology, another challenge in the form of Pb-free solders has presented itself. Companies are phasing in Pb-free technologies at different times and using different metallurgies, and industry will have to learn to work with mixed solder technologies. BGA devices are especially sensitive to mixed solders in the rework process.

Studies of BGAs assembled with mixed solder technologies show successes and some areas of concern. The biggest problem arises when attaching a BGA device with Pb-free interconnect balls using SnPb solder paste at reflow temperatures below 217°C.[1] Solder interconnects solidify in zones, and uneven stresses tend to develop in the SnPb rich areas. Early cracking has also been reported in PWB interconnects in SnPb rich areas.

Successful interconnects can be made with Pb-free BGA interconnects using SnPb paste, but only if complete mixing of the BGA solder interconnect and the SnPb paste occurs. Industry studies indicate that full mixing is required to prevent yield and reliability reduction.[2,3] Reflow profiles should be above the Pb-free solder alloy melting point to ensure full mixing of the metallurgy. As industry continues to work with Pb-free materials and more data are collected, the best approach is to not mix solder technologies.

"Full mixing is required to prevent loss of yield and reliability."

Before starting the rework process, understand the BGA component solder ball composition and the PWB finish. Material certifications may be requested from the component and PWB manufacturers. Ensure that they identify the construction materials used in their products (solder alloy, coatings, etc.) If the BGA interconnect ball is the same material as the PWB solder, then proceed using a solder paste with the same alloy composition. If certifications are not available prior to reworking the device, several techniques can be used to identify the solder alloy.

PWB solder joints may be easily analyzed with x-ray fluorescence spectroscopy (XRF). Other methods such as optical emission spectroscopy (OES), energy-dispersive x-ray spectroscopy (EDS), x-ray photoelectron spectroscopy (XPS) and auger electron spectroscopy (AES) can also help identify solder compositions. Time and budget contraints might be concerns with analytical tools like these.

Table 1. Pb-Free Solder Comparison[4]

Solder Type	Composition	Melting Range (°C)
SnAg eutectic	SnAg3	221°C
	SnAg2	221° to 226°C
SnCu eutectic	SnCu0.7	227°C
SnAgBi	SnAg3.5Bi3	206° to 213°C
	SnBi7.5Ag2	207° to 212°C
SnAgCu eutectic	SnAg3.8Cu0.7	217°C

A simple analysis technique is to place solder shavings on a controlled hot plate set to 195°C (verified with a calibrated thermometer). If the solder reflows, there is a good chance that the solder is SnPb eutectic and can be reworked with standard SnPb eutectic solder using a new device with SnPb solder interconnects. This method may be used for Pb-free solders by identifying the melting range (**Table 1**) and setting the hot plate to the melting point. However, this is more difficult for Pb-free solders as the melting temperatures are similar and have overlapping ranges.

After identifying the solder composition, rework the BGA using a solder paste alloy identical to the BGA interconnects ball and PWB coating.

If time and access to equipment are limiting factors, it is best to carefully rework the device. Ensure that the old solder is removed as thoroughly as possible from the PWB before proceeding with the reattach process. Match the solder paste with the BGA device interconnects solder alloy and proceed with rework. SnPb solders contaminated with Pb-free solders of <1%, reflowed at >225°C, should not create any reliability concerns. ■

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Avoiding Solder Spikes

Shorter leads will prevent solder from being trapped in 'oxide envelopes.'

After dip or wave soldering, solder spikes or solder flags can often form on longer leads (e.g., those that protrude more then 2 mm on the solder side of the PCB). If the protruding leads have a relatively large surface area, such as with shielding frames, this effect will be more prominent. Typically, playing with the process settings will not eliminate this phenomenon.

During soldering, the flux on the parts to be joined will be flushed off as solder wets and covers the metal parts. After wetting with solder, the only flux that might be left on the PCB surface is that which has been trapped between the PCB and the solder source. When a PCB separates from the solder source (wave or nozzle surface), the flux that remains on the PCB surface must create an atmosphere that will prevent oxidation of the solder. If the space between the joints is limited, not much flux will be present at this stage of the process, so almost no oxide-reducing activity remains during this process phase. As a result, solder will begin to oxidize as it separates from the joints and an oxide film will cover the solder that is draining.

At the final separation, the part of the breaking solder column that remains on the lead will wick up to the lead by the surface tension of the solder, provided the solder is molten. If that part is covered with an oxide layer, however, the solder will remain in this oxide envelope, forming a spike or flag. This effect will be more pronounced if a relatively large area is covered with solder, while on the other hand almost no flux is left to assist the process. It is therefore understood that longer leads will be more vulnerable, because the flux that should be active is the flux that remains on the PCB surface. During the separation, this surface and therefore the flux moves to a greater distance from the solder source, thus the flux's influence lessens as the distance increases.

It should be noted that the same underlying conditions are the reason that peaks often remain on large metal areas on the PCB that are soldered. There is simply not enough flux surrounding such an area to assist in proper drainage. Solder joints on shielding frames may also cause solder spikes due to another reason related to a heat sink effect. If the heat that the solder brings to the joint is drawn off rapidly to the mass of the frame, the solder begins to solidify almost immediately upon separation from the wave. As a result, solidifying solder separates during the drainage stage and the non-liquid solder cannot flow back to the joint.

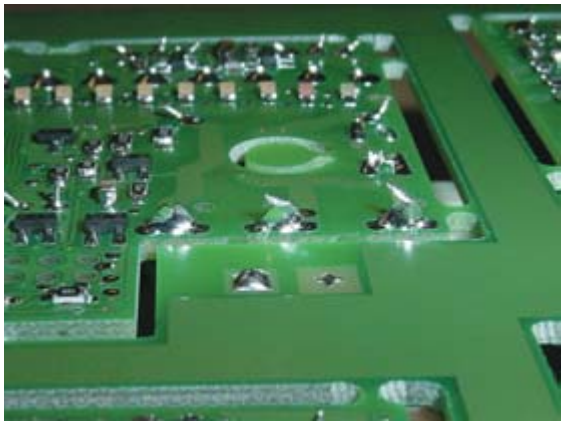

Figure 1: Leads covered with an oxide layer could capture solder and form a spike or flag.

"Adding flux generally does not help, as it will be washed away."

Keep Leads Short

Keep protruding leads short, so that the flux on the PCB surface can still be effective. More flux generally will not help, since this extra flux will in most cases be washed from the PCB surface as soon as the PCB contacts the solder source. This extra flux might assist in better wetting of the parts being soldered. A flux that has a better adhesion to the PCB surface and has a better "tail activity" might facilitate drainage. (Per Klein Wassink, tail activity, or the protective capability of a flux, can be tested.[1])

Provide an inert or an oxide-reducing environment at the point where the solder separates between the PCB and the solder source. Only then can spikes and flags can be avoided. If the spikes are forming due to a strong heat sinking effect of the mass connected to the joint, then attempt to optimize joint design. Klein Wassink shows examples of such optimizations.[2] ■

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2. Klein Wassink, chapter 3.4.1., figure 3.29.

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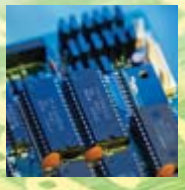


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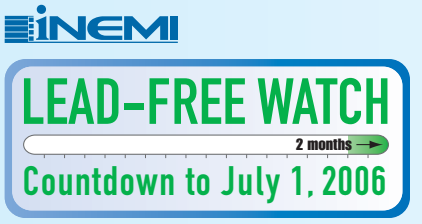
China's Evolving RoHS Legal Regime

The new law goes into effect March 1, 2007 (maybe), and could be even broader than Europe's version.

Ed.: For a more in-depth discussion, details about development of the legislation and background on rulemaking in China, please visit circuitsassembly.com/cms/content/view/3206.



China's Management Methods for Controlling Pollution by Electronic Information Products, often called China RoHS, was promulgated on Feb. 26, and is scheduled to take effect March 1, 2007. This law, developed by China's Ministry of Information Industry (MII) to address growing concerns about electronic waste, is similar to the EU RoHS Directive in terms of currently restricted substances; however, it also includes a significant number of labeling and information disclosure requirements and requires pre-market compliance certification. Furthermore, China's law has the potential to be more broadly applied than EU RoHS.

China RoHS is the primary regulation that, when supplemented by additional implementing measures, forms China's emerging RoHS legal regime. However, most of the legal measures that will form the details of the law are still to be drafted: knowing what the final requirements will be is a challenge.

Here we discuss major aspects and key challenges of the law, focusing on those provisions that depart from EU RoHS, and consider implementation issues as well as future challenges associated with the evolving China RoHS regime.

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Major Aspects of the Regulation

Scope. China RoHS essentially applies to the design, manufacture, sale and import of "electronic information products" containing "toxic and hazardous substances or elements."

In Article 3(1), "electronic information products" are defined as "electronic radar products, electronic communications products, radio and television products, computer products, home electronic products, electronic instrument measuring products, specialized electronic products, electronic components and parts, electronic applications, electronic materials, and accessories."[1] This definition presents the potential for a regulatory system that is far more broadly applied than EU RoHS and does not take into account business realities, including the availability of restricted substance alternatives. "Toxic and hazardous substances or elements" are defined in Article 3(4) to include "lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ethers, and other toxic and hazardous substances or elements as specified by the State."

However, a deeper review of China RoHS reveals that certain requirements are to be focused on listed electronic information products. The list will essentially take the form of a "catalog" of electronic information products that will be issued in batches over an unspecified period of time.[2] In China RoHS, this catalog is referred to as the "Catalog for Priority Control of Pollution by Electronic Information Products" ("the Catalog"). Further, MII is considering a number of exemptions that may significantly affect the scope of China RoHS application. The challenge at present is that work has not yet been completed and, in some cases, has not yet started, on the implementing measures. Until these measures are completed, the true scope of China RoHS will be unclear. However, the potential scope is as broad as the definition of electronic information products.

Substance restrictions. Electronic information products listed in the Catalog will be subject to restrictions of listed toxic and hazardous substances or elements per China RoHS and associated implementing measures. Work is currently underway on standards to identify maximum concentration values (MCVs) for such substances, as well as exemptions from the substance restrictions. At present, it appears that the MCVs set forth in the draft Chinese standards are similar to those described for EU RoHS. However, the current approach that the Chinese authorities and standards drafters are taking includes notable differences. In particular, the Chinese MCV standards presently address four categories: 1) homogeneous materials comprising electronic information products; 2) metal plating materials comprising electronic information product parts; 3) small elements/parts/materials of electronic information products that, under current conditions, are not readily further disassembled, with a size no bigger than 1.2 mm^3 (the size of an 0805 chip); and 4) specialized materials or parts in electronic information

products (this category reflects exemptions also reflected in the current EU RoHS Annex).

Pre-market certification. One of the most challenging and potentially disruptive aspects of China RoHS is set forth in Article 19, requiring that electronic information products incorporated into the Catalog undergo compulsory certification. Hence, electronic information products that are listed in the Catalog must undergo conformity assessment testing and certification procedures governed by the Certification and Accreditation Administration (CNCA), an agency under the Administration for Quality Inspection, Supervision and Quarantine (AQSIQ). Discussions are currently underway concerning the possible merger of the China RoHS pre-market certification system with the existing China Compulsory Certification (CCC) mark safety-licensing regime.[3]

Labeling and information disclosure. The labeling and information disclosure requirements associated with China RoHS constitute some of the most detailed and unique aspects of this regulation. These requirements are not linked to the Catalog but, rather, to the definition of electronic information products. Hence, the application of labeling requirements would not be limited to a particular list of products. The development of exemptions to, and interpretations of, the labeling and information disclosures will be critical issues for the regulated community.

In particular, there are five types of labeling and information disclosure requirements applicable to manufacturers and importers:

- Marking of the "environmental protection period" for the electronic information product (defined as "the period during which toxic and harmful substances or elements contained in electronic information products will not leak or mutate") [Article 3(5)].
- Marking of the content of toxic and hazardous substances or elements in electronic information products (Article 13).
- Marking of the recyclability of electronic information products containing toxic and hazardous substance or elements (Article 13).
- Marking of the content of packaging materials used for electronic information products (Article 14).
- Marking of the country of origin of the electronic information product. [Proposed in the draft standards on Marking for the Control of Pollution Caused by Electronic Information Products (SJxxx-200x), reflecting the Management Regulations on Marking of Country of Origin, issued by AQSIQ March 5, 2001 and effective April 1, 2001].

Exemptions. Exemptions form a critical part of ensuring that the regulation can be effectively and practically implemented. At present, the China RoHS regulation itself only clearly references one scope exemption. This is in Article 2, which provides that products destined for export from China are exempt from the law. That said, a number of measures under development reflect MII's intention to address the need for certain flexibility, via exemptions, in the China RoHS implementation process. Key exemptions under consideration include:

Substance restriction exemptions. MII and related technical groups have identified a number of potential product exemptions from the substance restriction requirements in China RoHS. Fourteen such exemptions have been proposed, drawn from the exemptions set forth in the Annex to the European RoHS Directive.

Labeling exemptions. MII and related technical groups have proposed a number of exemptions from product labeling requirements, which focus on several factors, including whether the size and functional limitations of the electronic information product make it impractical to mark on the product itself. MII and the related technical groups are still revising the implementing measures governing labeling and related exemption issues, so exemptions will merit close monitoring.

Effective dates. China RoHS as promulgated indicates an effective date of March 1, 2007. Three factors make this date confusing.[4]

"Until the implementing measures are completed, the true scope of China RoHS will be unclear."

First, March 1, 2007, essentially comprises the date for implementation of the labeling or information disclosure measures in China RoHS.[5] Second, the date or dates for implementation of the substance restriction and pre-market certification requirements in China RoHS will be set forth in the Catalog, which MII will promulgate separately.[6] Third, gradual implementation of China RoHS will make compliance as of the effective date challenging. Regardless of whether compliance is expected as of a particular date, ability to comply may depend on whether MII finalizes key China RoHS implementing measures in a timely manner, and whether the regulated community is given sufficient time to understand and implement the measures by that date.

Enforcement and compliance surveillance. The pre-market certification requirements constitute only one aspect of the enforcement and compliance surveillance system contemplated for China RoHS. The State Administration of Industry and Commerce will likely have a significant role, joining with AQSIQ, in compliance surveillance.

Penalty provisions applicable to the private sector are set forth in Articles 22 and 23 of China RoHS. Although the types of penalties for violations remain ambiguous, these penalties typically include warnings, fines, product seizures, product repatriation orders (for

imports), import or manufacture prohibition orders or facility shutdown orders.

China RoHS Implementation

A considerable amount of work is now underway to develop China RoHS implementing measures. For technical measures, particularly those involving issues such as MCVs, Pb-free solders and labeling specifications, MII established a Standards Working Group in 2004. This group, via subgroups with responsibility for particular subject areas, is charged with developing proposed standards for MII consideration, revision and promulgation. A positive aspect of the group is that MII permits the private sector, including multinational corporations, to join the group as long as the organizations in question are registered in China as legal persons.

A selection of key implementing measures currently being drafted or proposed for drafting follows. A detailed discussion of these measures is beyond the purview of this brief article. Further, the constant changes to the measures currently being drafted limit the usefulness of such a discussion.

Rules or guidelines.

- Catalog for Priority Control of Pollution by Electronic Information Products.
- Measures governing compulsory certification for electronic information products.
- Technical guidelines for environmental protection period marking.

Standards.

- Marking for the Control of Pollution Caused by Electronic Information Products (SJxxx-200x).
- Lead-free Solders: Chemical Composition and Forms (SJxxx-200x).
- Requirements for Concentration Limits for Certain Hazardous Substances in Electronic Information Products (SJxxx-200x).
- Test Method for Lead-free Solders (SJxxx-200x).

Patience Needed

Understanding the implications of China RoHS for particular products and industry sectors will require patience, constant monitoring and explanations of the unique aspects of the Chinese legal system. All this activity will no doubt intensify as we approach the initial effective date of March 1. Current projections, subject to change, are that MII and affiliated technical bodies will continue drafting implementing measures for another 12 months or more.

Following typical rulemaking practice, the implementing measures would be issued not in one batch, but in pieces as the drafting, reviewing and approving work is completed. Take, for example, labeling. The labeling standards and environmental protection period technical guidelines both provide critical compliance details concerning the labeling aspects of China RoHS. However, it is likely that these will be issued successively, rather than together. ■

Resources

China RoHS can be downloaded in English at aeanet.org/GovernmentAffairs/gabl_ChinaRoHSpage0905.asp and in Chinese at mii.gov.cn/art/2006/03/02/art_521_7344.html.

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EuroPlacer's Adaptive Positioning Software

3DPS adaptive positioning software and contact sensor system is used on placement machines to optimize pick and place of components with turret heads fitted with accurate contact sensors. This permits the machine to know precisely when it contacts a component or the board.

The 12-position turret head, called Tornado, uses the 3DPS adaptive positioning software and contact sensor system.

Component pickup is compensated in x, y and z for each part type individually. During the picking sequence, the APS system compensates different picking heights. The system is said to eliminate the need for manual picking adjustments. By automatically adjusting the pick height, there is less chance of nozzle bounce and hence, fewer miss-picks. The result is greater reliability. Feeders incorporate their own fiducial mark, enabling fast, automatic calibration of pick-up position when loaded to the machine. Additionally, this feature provides fast product changeovers.

3DPS also compensates for board bow and twist on placement. Placement height is adjusted to reflect a similar board height to adjacent components. The placement force is optimum, even on a warped PCB. More precise placement height gives greater placement accuracy. The automatic z placement adjustment feature divides a board into zones. After a component is placed in one zone, the possible correction will apply on this zone. If the correction is significant, a partial correction will be done on the adjacent zones, increasing reliability. There is no derating and the automatic optimization of z travels reportedly results in improved throughput and speed.

Benefits of the system include no-stress and smooth axis movements, and continuous adjustments in real time.

The software can be integrated with a package that include traceability tools for full data logging for component-level build traceability; component outline auto-generation, a GUI that automatically creates any type of new package, reportedly in less than a minute; and wireless real-time communication between feeders.

Available from Europlacer, europlacer.com.

JTAG Flying Probe

Second-generation Flying Prober Condor 500 has drive technology via linear motors, for high speed and high accuracy. Reportedly 30% faster and 25% less expensive than previous version. Comes with a "Soft Landing" tool and optional integrated boundary-scan.

Digitaltest GmbH, digitaltest.net

Booth 3041

Benchtop Selective Soldering

TR300 is a PC-programmable table robot for automatic selective and point-to-point soldering. Said to offer precise, flexible automated soldering. Each process is optimized through customizable parameters via Windows on this benchtop system.

Global Automation, globalautomation.com

Booth 6024

Tabletop Laser Soldering

EFD's auger valve and UltraTT tabletop dispensing robot applies solder paste and reflows pin-in-hole and SMT assemblies. Laser reflow of paste combines the precise, rapid deposition of dispensable solder paste with the high-speed, noncontact, localized heating of diode laser systems. SolderPlus paste is formulated for fast, clog-free dispensing and can survive sub-second reflow cycle times.

EFD Inc., efd-inc.com

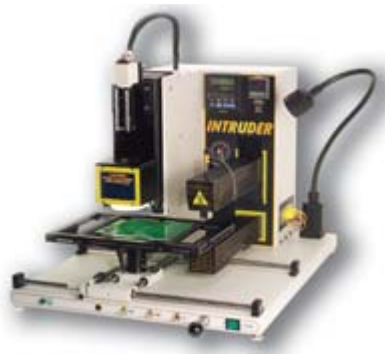
Booth 5037

Pb-Free SMT Rework

Intruder Vision series SMT Pb-free rework machines feature an open nozzle design that projects low-velocity, high-volume air with power to spare, and reflows as the convection oven used in the original manufacture. These low-maintenance systems will not scorch the PCB or disturb small components during reflow.

APE, ape.com

Booth 2037



Selective Soldering System

Juki 400 offers batch or inline selective soldering of conventional components after reflow. Three-stage in-line system can be customized with options. Multiple solder pots run leaded and Pb-free without changing hardware. Includes up to four mini-wave nozzles; a full wave up to 457 mm can be installed. X-Y fluxer option permits the system to flux, preheat and solder simultaneously. Tenifer nitrate process protects from aggressive alloys. Forced hot air N_2 can be used for additional preheat, lowering solder pot temperature and decreasing contact time.

Juki Automation Systems, jas-smt.com

Booth 4009

Flexible Pick-and-Place

FLX2010-LCV flexible pick-and-place system for high-mix production offers intelligent feeders, large feeder capacity, and offline programming and job planning. Starts at 5,000 cph, with 150 feeders inline; can expand to 15,000 cph with over 470 feeders. MIS software offers production planning, inventory control, quality control through bar code verification and traceability. Requires 110V of power. Has laser and vision alignment.

Essemtec USA, essemtec-usa.com

Booth 2031

In Case You Missed It

Adhesives

"Measuring the Effect on Isotropic Electrically Conductive Adhesive Reliability of Substrate and Component Finishes"

Authors: Martin Wickham, Ling Chunxian Zou and Dr. Christopher Hunt; npl.co.uk/ei/publications/

Abstract: Isotropic conducting adhesives (ICAs) are being considered as replacements for conventional SnPb solder in certain applications. In earlier work a suitable test regime was identified to generate relevant reliability data. In this work, those tests have been employed to investigate whether the finishes on the components or PCBs have any effect on the reliability of ICA joints after exposure to damp heat conditions.

The effect of different finishes has been found to be adhesive material dependent. Two adhesives were studied. For one, the reliability of the joints produced was relatively unaffected by changes in component or PCB surface finish. For the second material and components with PdNi metal finish, joints displayed a more stable resistance than those made using components with a high Sn-content plated finish. Performances could be further improved by cleaning components prior to assembly. The PCB finish was found to have a lesser effect than the component finish. Again, results were dependent on the adhesive material, with joints using the better-performing material exhibiting little difference regardless of PCB finish. In the case of the second material, PCBs with ENIG finishes produced joints that performed as well as those with ImSn or ImAg finishes. (NPL Report DEPC-MPR 031, August 2005)

Solder Bumping

"C4NP: Lead-Free and Low Cost Solder Bumping Technology for Flip Chip and WLCSP"

Authors: Klaus Ruhmer, Eric Laine and Dr. Peter Gruber; info@suss.com.

Abstract: C4NP (C4-New Process) is a novel solder transfer technology where molten solder is injected into pre-fabricated and reusable glass templates (molds). Mold and wafer are brought into close proximity and solder bumps are transferred onto the entire 300 mm (or smaller) wafer in a single process step. C4NP technology is capable of fine-pitch bumping while offering the same alloy selection flexibility as solder printing. This paper discusses relevant process equipment technology and a manufacturing cost model, and includes manufacturing data provided by IBM's packaging operation. (SMTA Pan-Pacific Microelectronics Symposium, January 2006)

Solder Joint Reliability

"Effect of Voiding on Lead-Free Reliability"

Authors: Martin Wickham, Milos Dusek, Ling Chunxian Zou and Dr. Christopher Hunt; npl.co.uk/ei/publications/

Abstract: Seven different solder pastes from three manufacturers were evaluated through a range of reflow profiles. No paste exhibited voids in any PBGA joint greater than 15%, despite attempts to produce higher voiding levels. Three different voiding levels were produced and samples subsequently subjected to 2,000 thermal cycles (-55° to +125°C). Despite these samples having higher voiding levels than those stipulated for Class 3 of IPC BGA assembly and inspection guidelines, no adverse effect on reliability was seen. Shear strength deterioration during thermal cycling of chip resistors was also unaffected at these levels of voiding. (NPL Report DEPC-MPR 033, April 2005)

"Measuring the Impact of Component Solderability on Lead-Free Solder Joint Reliability"

Authors: Martin Wickham, Ling Chunxian Zuo, Milos Dusek and Dr. Christopher Hunt; npl.co.uk/ei/publications/

Abstract: Previous NPL work demonstrated relationships for SnPb solder between component solderability, solder fillet rise and process yield, and also between solderability and thermal fatigue. This report summarizes similar work on assembly yield and subsequent reliability of joints made using Pb-free soldering systems, employing visual inspection, microsectioning, electrical conductivity and shear testing to evaluate the solder joints. Components with Pb-free finishes (R0603, R1206, SOIC and BGA) were artificially aged to produce a range of reduced solderability and assembled into test vehicles using Pb-free solders. For resistors and SOIC components, the reduced solderability had little effect on process yield. For BGAs, the artificial aging process significantly degraded the component substrate, causing warping during assembly, and reduced yield for the most severely aged components.

Solder joint reliability was again examined after thermal cycling. No electrical failures occurred with the R0603 or SOIC components, and only a few with the R1206 components. In the case of BGAs, as thermal cycling progressed, the number of electrical failures increased for the most severely aged components, particularly in the outer rings of the BGAs. After 2,000 cycles, joint cracking was present close to the component interface in samples from all aging groups (i.e., differences in solderability). This is attributed to stress concentrations associated with soldermask definition of the pads. Thus, the normal range of solderability associated with quality Pb-free components, there should be no adverse effect on assembly yield or subsequent reliability in a controlled Pb-free assembly process. (NPL Report DEPC MPR 038, November 2005)

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