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OCTOBER 2013

LEAD-FREE DEVELOPMENTS

Pushing the Limits of Lead-Free Soldering

by Tetsuro Nishimura–page 12

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LEAD-FREE DEVELOPMENTS

It's been more than seven years since RoHS became the law of the land in Europe. But many OEMs and EMS companies still find themselves facing increasing challenges related to lead-free processes. This month, *SMT Magazine* shines a light on the often murky world of lead-free assembly.

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THE WAY I SEE IT

The Market, Top 100 and EIT

by Ray Rasmussen
PUBLISHER, I-CONNECT007

Last month I wrote about China's economy and how they seem to be in a tough spot. Since that column was written, Marcy LaRont conducted an interview with Hamed El-Abd of WKK, where he provides insights into the Chinese market. WKK sells capital equipment to fabricators and EMS providers in China/Asia. His comments take what I wrote about some of the issues China's facing down to a more practical level, as he's in the trenches and has a keen sense of what's going on.

In an August report, MAPI says that China's export growth went from 19% in Q1 to 3% in Q2. It reaffirms what I wrote last month. Still, many see this as a blip and expect China's export growth to get back on track this fall. We'll see.

Europe out of Recession

Great news out of Europe: It's official—the recession is over. According to the EU's Eurostat, Q2 GDP grew 0.3% after a -0.5% decline in Q1. The Conference Board Leading Economic Index for the Euro area increased 1% in July and now stands at 108.4, after increasing 0.4% in both May and June. As the planet's largest consumer market, getting their economy back on track will have a profound effect on the rest of us. Along with the U.S. economy picking up speed, we have a solid start to a good global recovery. We need to keep an eye on the other two giant economies, China and Japan. Japan's latest economic indicators are down. Let's hope they turn around in the coming months. So, it's not all rosy, but it's better than it's been.

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THE MARKET, TOP 100 AND EIT *continues*

Naka's Top 100 for 2012

Although Hayao Nakahara's top 100 PCB listing appeared (as it always does) in Printed Circuit Design and Fabrication (a competing publication), I still have to mention it here. It's always an interesting piece and eagerly anticipated by many as they look to see how they rank in this $60 billion industry. The top dogs are all in Asia, of course, with Japan's Nippon Mektron taking the top spot with $2.8 billion in sales. Taiwan's Unimicron took second with $2.4 billion in revenue. TTM came in at #8 with about $1.4 billion, and Viasystems made the 12th spot at $1 billion. A total of six U.S. companies made the list for 2012.

Out of Europe, Austria's AT&S grabbed the 22nd spot, Germany's Wurth and Schweizer came in at #79 and #90 respectively. Italy's Somacis received an honorable mention at #104.

Keep in mind that the dollars reflect the country of ownership, not the volume of PCBs produced in each country.

Naka's commentary is always good to read. He has some good insights into the different markets. No one else has been willing to take on the daunting job of making sense out of this ever-changing industry.

I'm sure many of you know this, but although there are lots of PCBs being built in China, there are only a few purely Chinese companies on the list. Naka combines both Hong Kong and China into one group, which brings their total production to around $5.7B. Take away Hong Kong, and Chinese companies make very few PCBs. The Japanese, Taiwanese, Americans, Europeans or Koreans control the rest of PCB production in China.

EIT is Gone

For years, Endicott Interconnect Technologies seemed to be a shining star in the declining U.S. PCB market. They looked to be one of the only fabricators who were building products immune to the onslaught of PCBs out of China. They were above the fray. They had the right formula at the right time. Well, after filing for Chapter 11 bankruptcy protection in July, the company has auctioned off its assets to pay creditors. It seems that this privately held company hasn't been profitable since 2008, and now it is gone.

Back when IBM was looking to reduce costs in the early '90s, it gave its PCB division in Endicott, New York, a chance to make it on its own by expanding their capabilities to the broader market. Back then I took a tour of the facility. I was writing a feature on the company for CircuiTree and as part of the deal, I was given an in-depth look at what would later become independent EIT. It was the single largest PCB facility I'd ever been in by far. It wasn't something I was used to. It was a world-class factory as opposed to the PCB shops I was used to. Everything was engineered to IBM standards, which demanded only the best. Of course, the best is expensive to procure, maintain and operate, which made the division a cost-cutting target as IBM looked for ways to reduce cost and remain competitive.

> ***"It was the single largest PCB facility I'd ever been in by far. It wasn't something I was used to. It was a world-class factory as opposed to the PCB shops I was used to. Everything was engineered to IBM standards, which demanded only the best."***

Today, you can see these mega-factories all over China, which is what IBM's PCB factory looked like back then. And because they were IBM, the factory was filled with degreed engineers working on the equipment and processes to build the very sophisticated backplanes used for their huge servers. As I was told back then, when the factory was built, money wasn't an issue when it came to building the PCBs. That cost was absorbed into the price of the mainframes. The boards needed to be huge, dense and very reliable. That's all. Of course, as others (Hadco, Sanmina, etc.) came up to speed with their capabilities, delivering sophisticated boards on par with IBM's in-

THE MARKET, TOP 100 AND EIT *continues*

ternal resource at a lower price, the pressure mounted.

That transition from captive to merchant PCB business was an eye-opener for those IBM execs and engineers used to following IBM's business model. The effort to become a merchant supplier of PCBs (with support from the parent) went on for a few years, until IBM sold its Endicott facility in July 2002 to an investor group, who paid $65 million for the operation. From a November 1, 2002 press release, this quote lays out the group's expectations for the acquisition.

"We believe we have a diamond in the rough," commented Bill Maines, co-chairman of the board for Endicott Interconnect Technologies. "With the people skills and technologies we have in place, we believe we can not only continue to provide valuable support services to IBM, but expand into other untapped opportunities as well. This is the beginning of a new chapter for Endicott."

Of course there are lots of experts out there, offering their opinions on what when wrong at EIT. It's too bad. They seemed to have it all. The right people, the right markets, and the right facility—just the wrong strategy, I guess. **SMT**

Ray Rasmussen is the publisher and chief editor for I-Connect007 Publications. He has worked in the industry since 1978 and is the former publisher and chief editor of *CircuiTree Magazine.* To read past columns, or to contact Rasmussen, click here.

Spider Silk Becomes Electrical Wire for Medical Devices

Scientists at Florida State University have created microscopic wires out of spider silk that can conduct electricity, opening the door to medical devices and other electronics that are tough, but eco-friendly.

Many modern electronics are constructed with non-biodegradable plastics that, while durable, are harmful for the environment. Plastics that coat steel wires for suspension bridges are found in countless everyday gadgets.

Researchers have turned to spider silk as a possible replacement, given spider silk is as strong as steel and as impenetrable as Kevlar; however, it's not a great conductor of electricity. To instill this property, the researchers coated each strand of silk with carbon nanotubes, which are themselves nano-sized ropes made of the hardy element.

The sleek arachnid threads were collected from golden silk spiders, Nephila clavipes, which are common to the southern regions of the U.S. These spiders produce long strands—up to 3 feet—making their silk easier to gather. After being coated with carbon, the super-spider silk was 300 times stronger than before, and more flexible and versatile. It also has a lifting strength that is 50 times stronger than muscle. These strands should, in theory, be extremely resilient against wear and tear, but ultimately biodegradable.

In addition, it could conduct electricity, which the researchers demonstrated by creating a simple device that could measure a person's pulse. Such a conductor could function as a building block for electronics destined for implantation in the body.

Some kinks still need to be worked out. While the spider silk can stretch when pulled, scientists found that extending by more than 50% dampened its electrical conductivity. Humidity caused a similar problem, but they found that adding extra layers of carbon nanotubes could prevent this effect.

Pushing the Limits of Lead-Free Soldering

by Tetsuro Nishimura
NIHON SUPERIOR CO. LTD.

Summary: The formulation of lead-free solder alloys is an ongoing process and the challenge extends beyond the solders themselves to joint design, flux formulations, component design and materials, PCB design and materials, component and board finishes, and process equipment.

Editor's Note: This article was originally published in the Proceedings of the Pan Pacific Symposium, Kauai, Hawaii, February 14–16, 2012.

Abstract

Throughout the past 12 years, I've had first-hand experience in many countries of the challenges of implementing lead-free assembly. While I've seen both failures and successes, I believe passionately that lead free is the right course for the industry and am personally committed to its universal implementation. While there is much to be done in the formulation of lead-free solder alloys, the challenge extends beyond the solders themselves to solder joint design, flux formulations, component design and materials, circuit board design and materials, component and board finishes, and process equipment. And the challenges go beyond the materials and equipment to those involved in the production of lead-free electronics—a need for education exists on the issues that arise from lead-free implementation and for standards that define best practice.

While it is not appropriate to make comparisons with assembly technologies based around tin-lead solder, it must be acknowledged that lead-free implementation has created a mood of uncertainty as we move out of the comfort zone of established know-how. That uncertainty is understandable as we consider how lead-free materials are going to behave as joints in semiconductor packages become smaller and conditions, in terms of current densities and temperatures, become more severe. By sharing my experience, I am able to provide more confidence that lead-free technologies can success-

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While the conversion of the electronics manufacturing to lead-free technologies seems to be a forbidding challenge, we can be encouraged by the fact that much of what we have learned from our experience of lead-containing technologies in the past can provide a basis for dealing with the implementation of future lead-free technologies.

Introduction

Mother Nature's Impact on Japan

In 2011, natural disasters and a difficult global economy seriously damaged Japan's manufacturing industry (Figure 1). The inflexibility of the Japanese integrated manufacturing model developed to keep in-house know-how on high value-added products meant that the industry was not able to recover as quickly and effectively as hoped.

On the afternoon of March 11, 2011, a magnitude 9.0 earthquake struck the country, generating an enormous tsunami that swept away human lives and buildings along the coast. As a result of damage to the Fukushima nuclear power plant, the reactors exploded one after another—scattering radioactive material into surrounding areas.

The contamination emitted from the nuclear facility seriously affected residents, depriving them of their homeland and necessitating the removal of huge volumes of radioactive material. Emergency legislation introduced to limit electricity usage during that summer reduced the productive capacity of the entire nation with consequent negative effect on earnings.

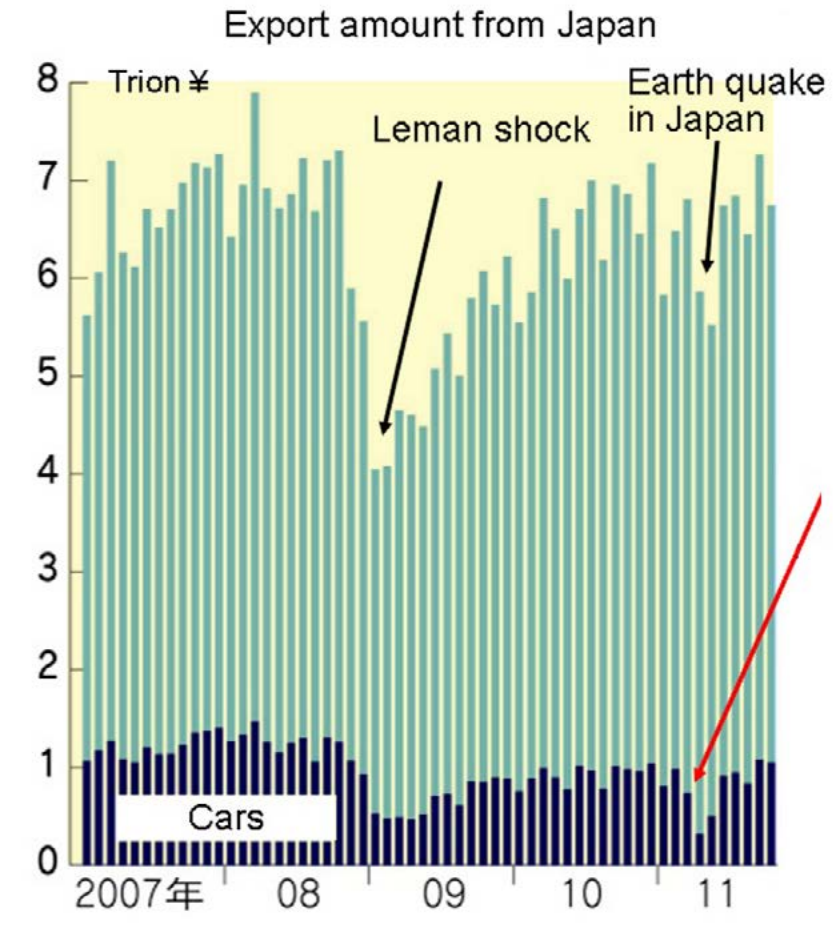

Figure 1: Nature's impact on Japanese exports.

To add to the nation's difficulties, the high value of the yen in relation to the currencies of important trading partners badly affected exports and accelerated the move of manufacturing from Japan to China and South East Asia where costs are much lower.

Further damage to Japanese business was done by the catastrophic flooding in Thailand which submerged many of the factories that had moved there from Japan. The result was reduced production and shortages of parts which affected the automotive and IT industries. This event served to highlight the fact that, for many critical items, only one manufacturer supplies several vendors. This realization made me understand that it is important to have a system that is better able to respond to unanticipated situations.

The traditional Japanese business model for high value-added products is history. That model, known as keiretsu, is characterized by centralized control of suppli-

ers, integrated manufacturing in large factories, and in-house distribution channels for domestic and overseas sales. This traditional model is being replaced by a system of decentralized manufacturing in cells, outsourcing manufacturing to contractors, and licensing technology to other manufacturers.

The de-industrialization of Japan is inevitable. Companies can no longer rely on profit from manufacturing know-how and must look for their profit from their brand name and marketing. Companies that have given up manufacturing no longer have production sites where they can engage in trial-and-error product and process development, resulting in a permanent deterioration in technical development and productivity.

As is the case in many advanced countries, reduced employment opportunities, resulting from the decline in manufacturing and a dysfunctional tax system, has led to falling birth rates and an ageing population which puts pressure on healthcare systems.

"Green" Electronics

According to the technical strategy map[1] released by the Ministry of Economy, Trade and Industry, electronic equipment will become easier to use and more friendly to humans in the future (Figure 2).

Such equipment will be applied to fields such as electric power generation, communication, daily life, transportation, manufacturing, and medical care. Serving in such severe

Figure 2: Technical strategy map for the future.

environments, if by any chance the equipment should be damaged and become deprived of its function, human lives could possibly be endangered. Exposed to high voltages, high direct currents, and high frequencies, electronic equipment may be required to endure such tough conditions.

My company's on-site support of our customers' production has given us the opportunity of accumulating considerable know-how in soldering technology which we, in turn, share each day with the industry worldwide to help push high-reliability lead-free soldering to the limits of its capability.

The key factors that determine whether or not a particular soldering material is sustainable in the long-term are properties, patents, and cost (Figure 3).

1. Properties

"Physical properties" characterize the product; "working properties" define how easy the product is to use; and "reliability" determines how long a product assembled with the solder is in service. Physical properties include those of the bulk solder such as melting point, specific gravity, hardness, and strength. While some researchers feel physical properties adequately define a solder, the properties that really matter are working properties and reliability—these are what determine true value.

2. Patents

In all countries where electronics equipment is manufactured or used companies should avoid the risk of legal problems by checking to see whether or not the alloys they are considering fall within the scope of a patent. Investigations indicate that between 1978 and December 5, 2011, 275 applications for patents relating to solder alloys have been made to the World Intellectual Property Organization. Out of those 275, 261 are for lead-free solder. Since the number of applications has been consistently increasing since 2001 it can be inferred that competition in the development of lead-free solder alloys has intensified over that period (Figure 4).

It is interesting to note that 151 applications, more than half of the total, were from Japan. Fifty-five came from the U.S., 21 from

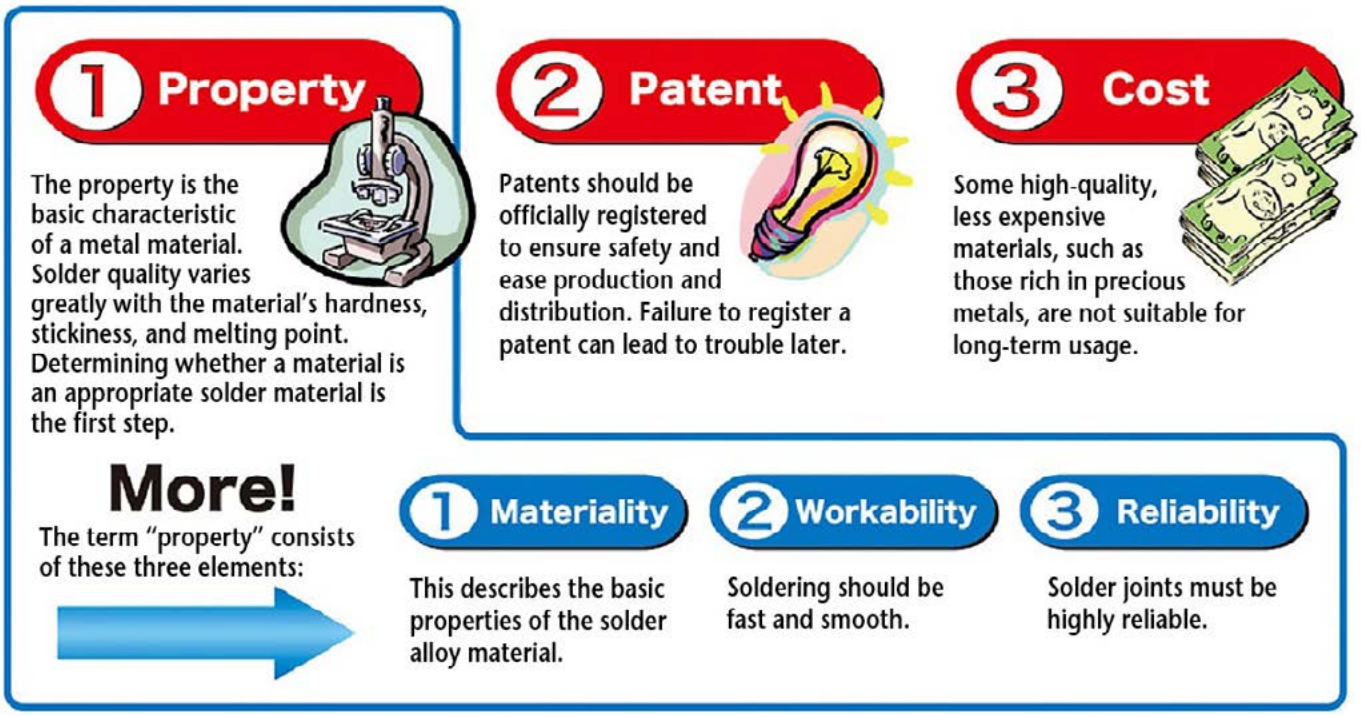

Figure 3: Three key conditions for success.

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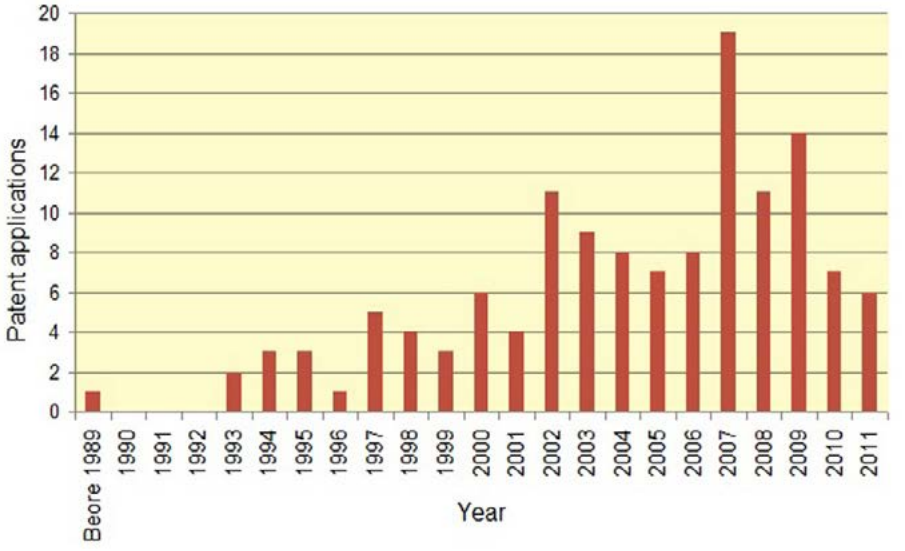

Figure 4: Patent applications by year.

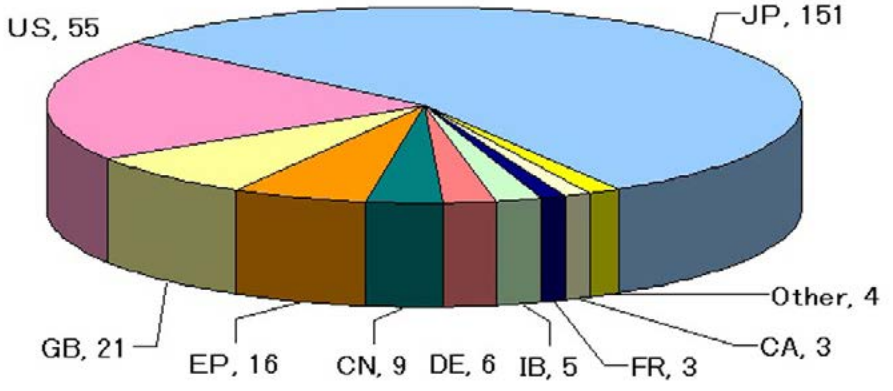

Figure 5: Patent applications of solder alloys by World International Patent Organization (WIPO), 1978–December 5, 2011.

the UK, 16 from the EU, and 9 from China (Figure 5).

Together, these five areas account for 71% of all solder applications. In terms of technical content 132 (48%) related to solder alloys (International Patent Classification B23K35/26), 47 to other soldering materials (B23K35/02), and 16 to soldering methods (BK23K1/00). There are also applications for solder paste, flux, and solder powder, but the three previous categories make up 71% of the total. It is presumed that most of these applications are accepted and passed on to all the member countries of the WIPO.

A study of these patent applications shows that in recent years there has been a drift away from simple solder alloy compositions to technology related to the soldering of semiconductors and area array packages such as BGAs and CSPs.

For users of soldering materials, it is worth noting that, regardless of the country in which they are manufactured, if a product falls within the scope of a patent of country in which it is used there is a risk of patent infringement. To avoid such problems, solder makers should conduct a search for any patents that might apply to the solders they intend to manufacture and, when necessary, apply to the patent holder for a license in advance.

3. Cost

The cost of a soldering process is much more than just the cost of the materials. Total cost takes into account ease-of-use, process yield, and recyclability. Many in the industry made a mistake by failing to consider the rising price of metals such as silver and indium which are in relatively short supply. These raw materials are also vulnerable to natural disasters, such as earthquakes and floods, and political issues, such as human rights violations in mining conflicts. Strategies must be in place for diversification of risk appropriate to the particular issues affecting each raw material.

Performance

Solder works as a joining material because of its ability to wet joint substrates with the formation of intermetallic compounds (IMCs)—

evidence that wetting has occurred. Because intermetallic compounds have a composition and crystal structure very different from either the solder or the joints substrate they have been the subject of much study and discussion as the industry adopts lead-free soldering.

It is not possible here to consider everything from first principles, but since solder constitutes the bulk of material between the two surfaces being joined, the characteristics of that alloy are the main determination of joint reliability (Table 1)[2, 3, 4].

IMC	Hardness(GPa)	Young's Modulus(GPa)
Cu_3Sn※	8.7	182
Cu_6Sn_5※	7.5	140
$(Cu,Ni)_3Sn$※※	9.4	182
$(Cu,Ni)_6Sn_5$※※	7.2	136
Solder	0.28	58

※: No treatment, ※※: Electroless Ni-P(0.1 μm)/Pd/Au

Table 1: Hardness and Young's Modulus of IMCs.

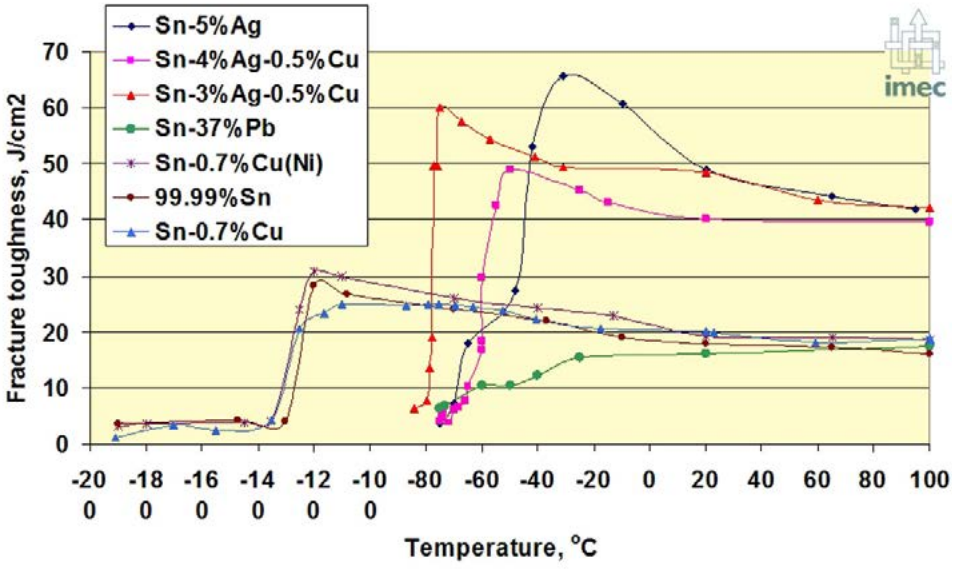

Figure 6: Modified Charpy impact test results.

When density is high, a joint is likely to suffer deterioration because of thermal cycling resulting from Joule heating; mechanical stress resulting from differences in the coefficients of thermal expansion (CTE) of various materials in the assembly; corrosion when there are ionic contaminants present; and even accelerated diffusion of material under the influence of the electron wind. All of these factors must be taken into account in the accelerated testing used to determine the likely reliability of the solder.

The main constituent of solder, tin, is highly reactive toward most substrate metals with a strong tendency to form IMCs—sometimes more than one—and this tendency is accelerated at elevated temperatures. Fortunately, the relative ductility of tin means that it can accommodate mild strain, but, as the cumulative strain to which it is subjected increases, cracking and total joint failure are possibilities. There are cases where high strength is not necessarily an advantage in a solder. Multilayer ceramic chip capacitors mounted with an unyielding high strength solder have been known to crack and fail due to stress generated by a CTE difference that could not be relieved by solder deformation.

The high strain rate and sensitive flow stress of high silver lead-free solders means that joints made with these alloys are vulnerable to drop impact, where board bends with severe

Analytical points	Elements					Estimated structure
	Sn	Cu	Ag	O	C	
1	0.2	79.3	0.1	0.9	19.6	Cu
2	33.5	42.4	0.8	4.9	18.4	Cu_6Sn_5
3	71.9	1.4	1.8	5.3	19.7	Sn
4	25.2	2.6	1.8	57.4	12.9	SnO_2
5	24.2	2.4	1.9	58.1	13.4	SnO_2
6	23.8	1.4	0.5	58.9	15.4	SnO_2
7	65.4	2.7	10.3	7.3	14.3	Ag_3Sn*

Table 2: Chemical composition of solder fillet (Figure 7).

tensile stresses applied to area array package joints. At low temperatures that sensitivity to impact loading increases for high silver alloys (Figure 6)[5].

As the trend to miniaturization continues and joints become smaller, current densities can become very high even with the relatively small currents that flow in microprocessor circuitry, exposing the solder to high temperatures. Under these conditions, diffusion processes are accelerated so that even at temperatures below the alloy solidus, rapid growth of interfacial IMCs can occur with an increase in the electrical resistance of the joint. Voids, probably the result of the Kirkendall effect, also develop at the interface under such conditions[6]. This phenomenon has been observed in other situations, such as fuses in high power electrical supply lines where they are a cause of premature failure.

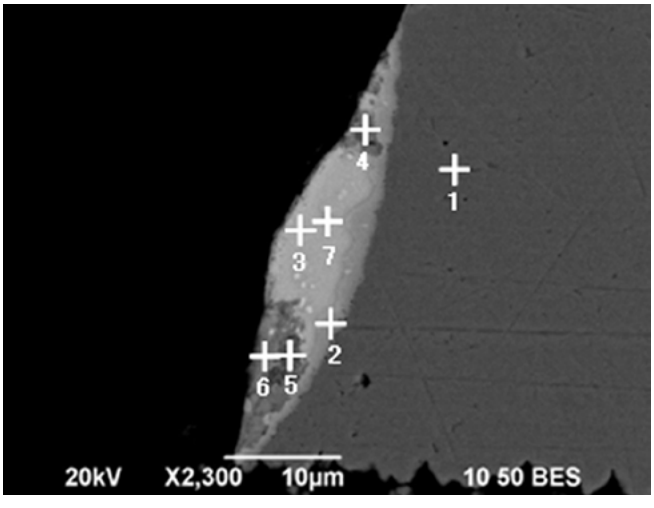

Figure 7: Spots of chemical composition analysis.

Solders used in the internal connection of semiconductor packages are also subjected to increasing stress because of the miniaturization trend. IMC layers that are usually approximately 1–5 microns thick can grow to 10–20 microns at the high temperatures obtained in these packages. That means very small joints are made up entirely of IMC so that their properties are no longer determined by the physical characteristics of the original solder[7].

Studies of whisker growth have found that one source of the compressive stress driving this process could be the increase in volume as solder is replaced by products of corrosion sustained by flux residues. Whisker growth can be avoided by using some, but not all, halogen-free fluxes and because of that, we have developed a solder wire, solder paste, and liquid flux (Tables 2 and 3; Figures 7 and 8)[8].

Other research has shown that the transformation of pure tin from beta to alpha form at

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PUSHING THE LIMITS OF LEAD-FREE SOLDERING *continues*

	Test condition	Soldering method	Flux	500h	1000h	2000h	3000h	5000h
Maximum length, μ m	85C/85%RH	Dip	A	0	6	52	87	-
			B	43	57	114	220(T)	-
		Hand	C	0	0	14	100(T)	-
			D	0	0	0	115(T)	-
		Reflow	E	0	0	0	413(T)	-
			F	0	0	20(T)	373(T)	-
	60C/90%RH	Dip	A	0	0	0	23	71
			B	0	0	14	32	63
		Hand	C	0	0	0	0	53
			D	0	0	0	124	143
		Reflow	E	0	0	55	71	71
			F	0	0	15	37	167
	40C/95%RH	Dip	A	0	0	0	0	0
			B	0	0	0	0	0
		Hand	C	0	0	0	0	0
			D	0	0	0	0	0
		Reflow	E	0	0	0	0	0
			F	0	0	0	0	0

Flux A: ROL1, Solid: 16%, Halide: 0.09%
Flux B: ROL1, Solid: 15%, Halide: 0.09%, organic acid activator
Flux C: ROL1, Halide: 0.05%
Flux D: ROL0, Zero Halide
Flux E: ROL1, No Halide,
Flux F: ROL0, No Halide
(T) indicates longest whisker occurred on the top surface of the trace, not the edge
"Zero" indicates that it should not contain halide
"No" indicates that it may contain a hidden halide

Table 3: Maximum whisker length at fixed inspection times (SAC305).

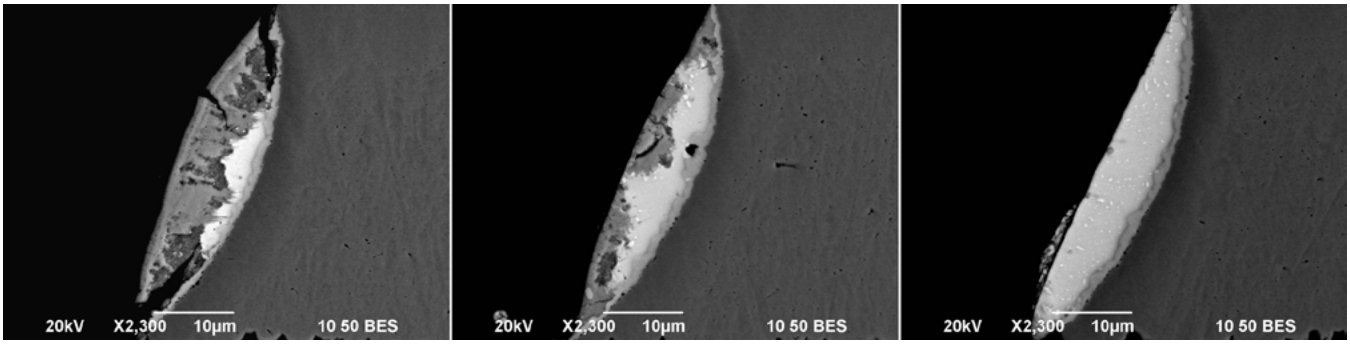

Figure 8: SEM images (x2,300) of solder applied by hand with (flux C) cored solder wire after 1,000 hours of exposure to 85°C/85%RH: Cross-section of conductor with large amount of flux residue (left); cross-section of conductor with small amount of flux residue (center); cross-section of conductor with a very small amount of flux residue (right).

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PUSHING THE LIMITS OF LEAD-FREE SOLDERING *continues*

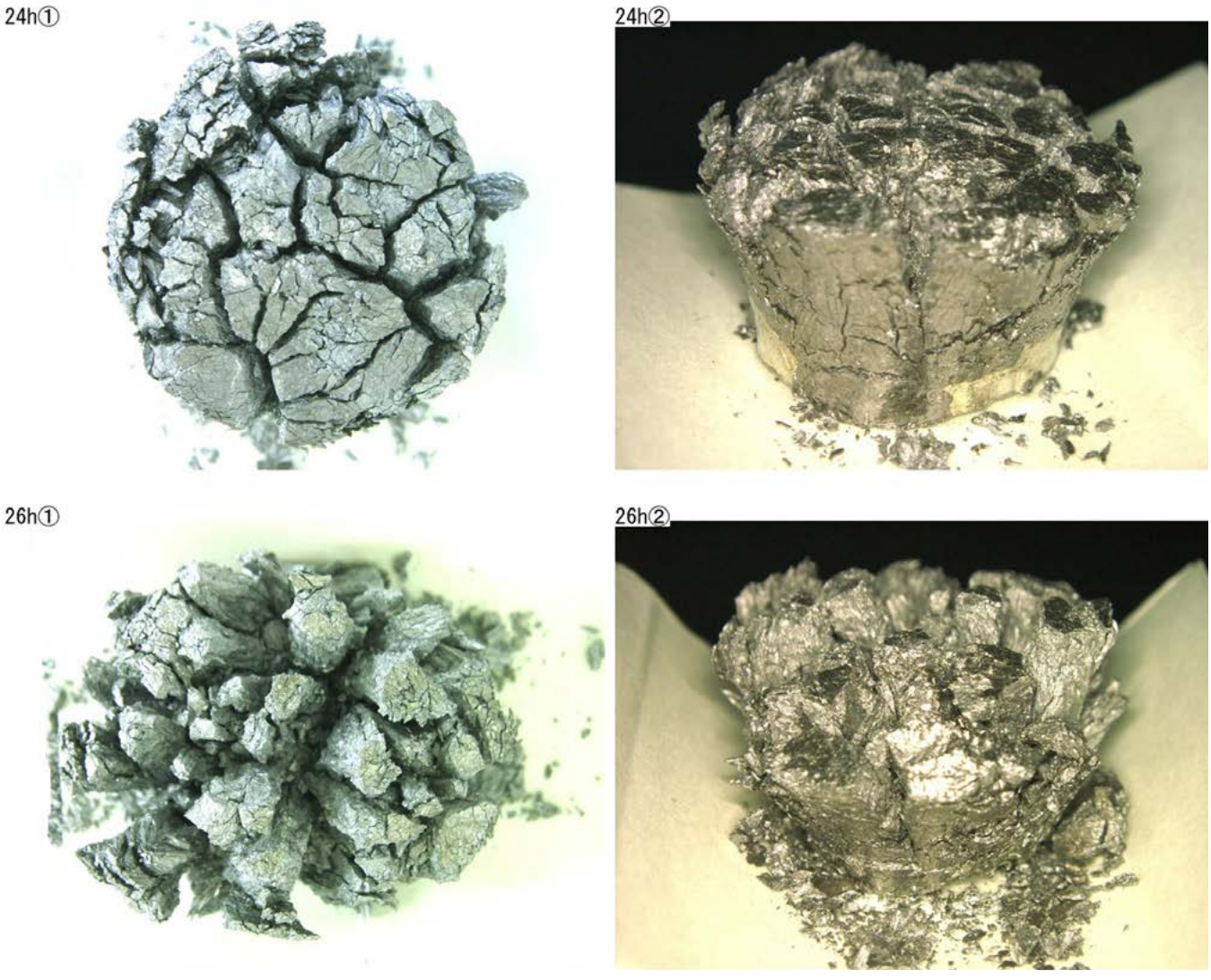

Figure 9: Tin pest phenomena (at -45°C).

low temperatures, known as "tin pest," can be suppressed by the presence of certain elements at trace level, some of which occur naturally in commercial purity tin (Figure 9)[9].

An important discovery that emerged from my company's 10 years of experience with practical soldering and scientific research is that the partial replacement of nickel with copper in the crystal structure of the intermetallic Cu6Sn5 stabilizes the hexagonal form (Figure 7). Reports on this finding, and on the kinetics of the phase transformation in the un-stabilized intermetallic compounds, have been published in peer-reviewed journals[10].

Breakthrough discoveries such as these will make it possible for lead-free soldering technology to meet any challenge as green electronics assembly moves to the next level. **SMT**

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Tetsuro Nishimura is recognized as the pioneer in the development of micro-alloyed solders, holding patents on the use of trace additions of nickel that have made it possible for the tin-copper eutectic to be used for the production of reliable solder joints in mass production. He may be reached at tetsuro.n@nihonsuperior.co.jp.

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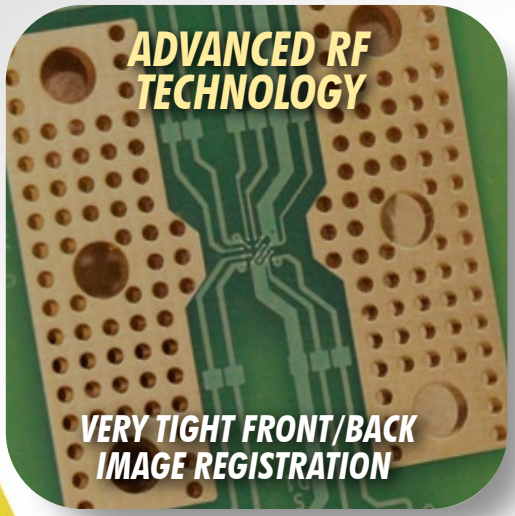

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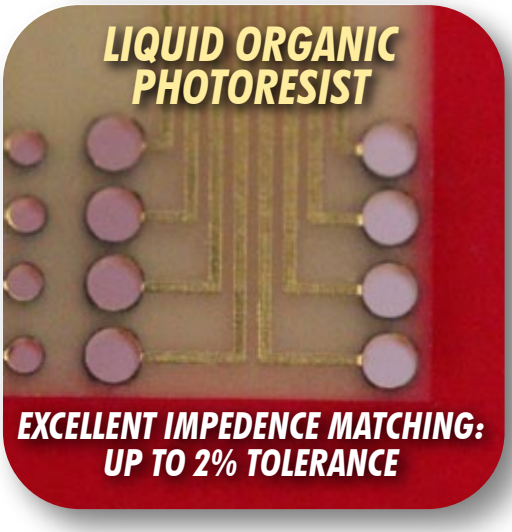

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TOF SIMS Analysis for Sn_xO_y Determination on Lead-Free HASL PCBs

by José María Servín Olivares and Cynthia Gómez Aceves
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SUMMARY: A lead-free HASL PCB presented the authors with several wetting issues. A variety of analyses were performed, but TOF SIMS provided the most valuable insights.

During the production of lead-free hot air solder leveling (LF HASL), non-wetting issues in several components were found, including BGA pad. The common visual aspect of the suspicious pads was the typical yellowish and bluish colors. However, during traditional scanning electron microscopy/electron dispersive X-ray spectroscopy (SEM/EDX) analysis for wetting issues, only a small increasing of copper was found, but not related to the problem. Because of that, time-of-flight secondary ion mass spectroscopy (TOF SIMS) analysis was proposed; using this technique, we could achieve better surface analysis in which we found the root cause on non-wetting just in nanometers of penetration.

With this uncommon tool, the results showed something not detected before: The yellowish were zones with different thick oxide layers (about 250 nm) undetectable by SEM/EDX—four times higher than a normal oxide thickness. Consequently, solder paste flux was not able to clean that oxide thickness and joints were not formed properly. The oxide is expected to be Sn_2O_3, not SnO_2, the most common tin oxide. In this part, we would also conclude the activation level of solder paste flux depends on the type of oxide. With this information, an investigation was conducted to remove the oxide layer as much as possible, so a solder paste with a flux more suitable to eliminate it was implemented and a cleaning process was designed to reduce it. These actions decreased the defects. In conclusion, TOF-SIMS analysis is a tool to help us understand better the solderability topics in the electronics industry.

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Scanning Electron Microscope and SEM/EDX for Analysis

SEM uses a focused beam of high-energy electrons to generate a variety of signals at the surface. When the primary electron beam interacts with the specimen, the electrons lose energy with a repetitive and absorption volume known as interaction volume. Its size will depend on the electron´s released energy, the atomic number, and the specimen density. The energy exchange between the primary beam and the sample electrons' released energy results in the reflection of electrons with high energy and electromagnetic radiation that are detected by a specialized screen that collects the information.

The imaging is created by multiple scanning on the surface. Figures 1a and 1b show the principle of SEM interaction with the surface and the internal functionality of the equipment. SEM can analyze secondary and backscattering electrons depending on the type of detector. The first ones generated by a primary beam are collected by a Faraday cathode with +/-300 volts and interact with the photographical medium to obtain the image. The 3D appearance comes from the number of electrons generated. The backscattered electrons are ejected with an angle greater than 90°; their reflection occurs as results of several collisions, and the generated image shows contrast due to the variations of the elements content in the specimen.

EDX is used together with the SEM to acquire the spectrum of elements. To obtain the information from the electrons, what is required is an interaction of some source of X-ray excitation and the sample´s surface. The EDX principle is that every element has its unique atomic structure and the element atom emits a particular X-ray energy peak. In order to release this energy from the atom, an energy beam (X-ray or electrons) is conducted into the studied atom, reaching internal energy levels bound to the nucleus; the beam excites the electron and removes it from the shell. This "missing" electron is replaced by another electron coming from an external level; the "jumping" electron releases X-ray energy (the difference between a higher energy level and a lower energy level). The energy is measured and it is possible to determine its composition.

TOF-SIMS for Analysis

Time-of-flight secondary ion mass spectrometry (TOF-SIMS) uses a primary ion beam to desorb and ionize species from a surface (Figure 2). The resulting secondary ions are accelerated into a mass spectrometer, which measures the ions time-of-flight from the sample surface to the detector.

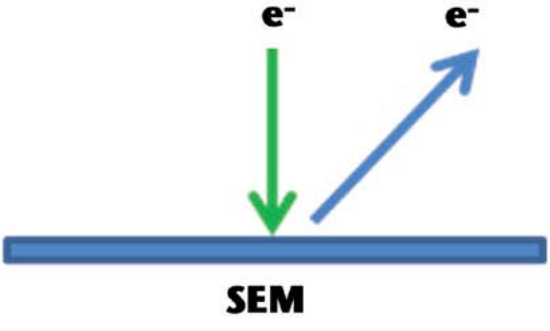

Figure 1a: SEM schematic showing the ion attack to release surface ions.

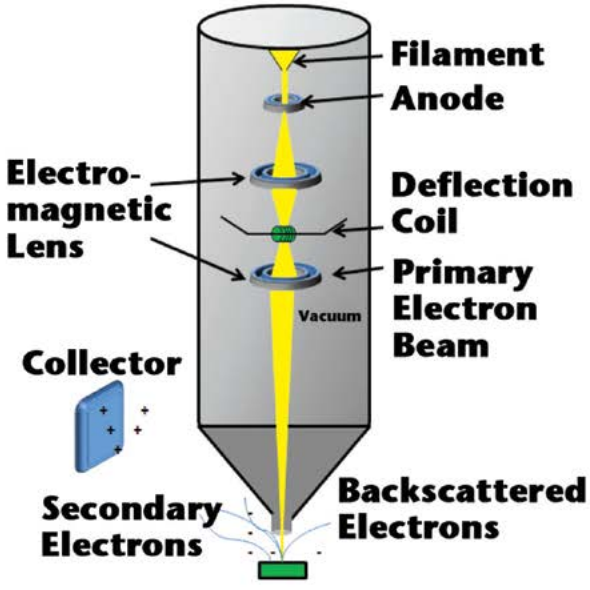

Figure 1b: SEM schematic for beam signal.

TOF-SIMS features three types of analysis modes: 1) mass spectra acquired to determine the atoms and molecular elements of a surface; 2) images to visualize the distribution of individual species on the surface; and 3) depth profiles to determine the distribution of different chemical species as a function of depth from the surface, analyzing every thin layer for its characterization. This profile allows us to determine only one or two atomic layers. The ions and molecules desorption is caused by a collision cascade that it is started by hitting the surface with ions that are normally Ga (but Bi or C could be used to increase the efficiency). Ions are generated, focused and transported to the target in the form of ion packages with well-defined arrival times. The detached elements are extracted into the TOF analyzer using high-voltage potential, and they have different velocities depending on their mass-to-charge ratio ($KE=1/2mv^2$). The mass and the profile are used to determine the elements or components, which are contained in the analyzed area.

Table 1 shows the main characteristics between both techniques. SEM is the most affordable, common and known tool for surface char-

	Type of results	Type of analysis	Signal Detected	Elelments detected	Organic information	Depth resolution	Imaging / mapping
SEM	Quantitative	Stains, surface roughness, morfology, feature size, buried defects, particles, layers	Secondary and backscattered electrons and X-ray	B- U	NA	1 to 5 microns (EDS)	Yes
TOF-SIMS	Matrix (semi-quantitative)	Particles, residues, low concentration, metallic and dopand surface contamination, "survey technique"	Secondary ions, atoms, molecules	H-U	Molecular ions to mass 10K	1 monolayer	Yes

Table 1: SEM & TOF-SIMS techniques comparison: Application.

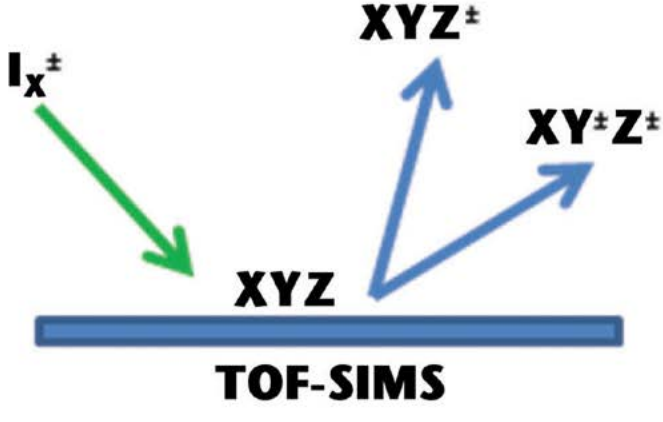

Figure 2a: TOF-SIMS schematic that shows the ions desorbed from the surface.

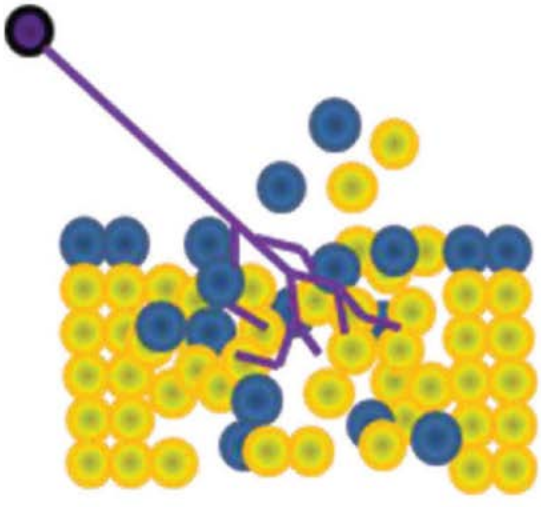

Figure 2b: A "collision cascade."

TOF SIMS ANALYSIS FOR SN_xO_y DETERMINATION ON LEAD-FREE HASL PCBS *continues*

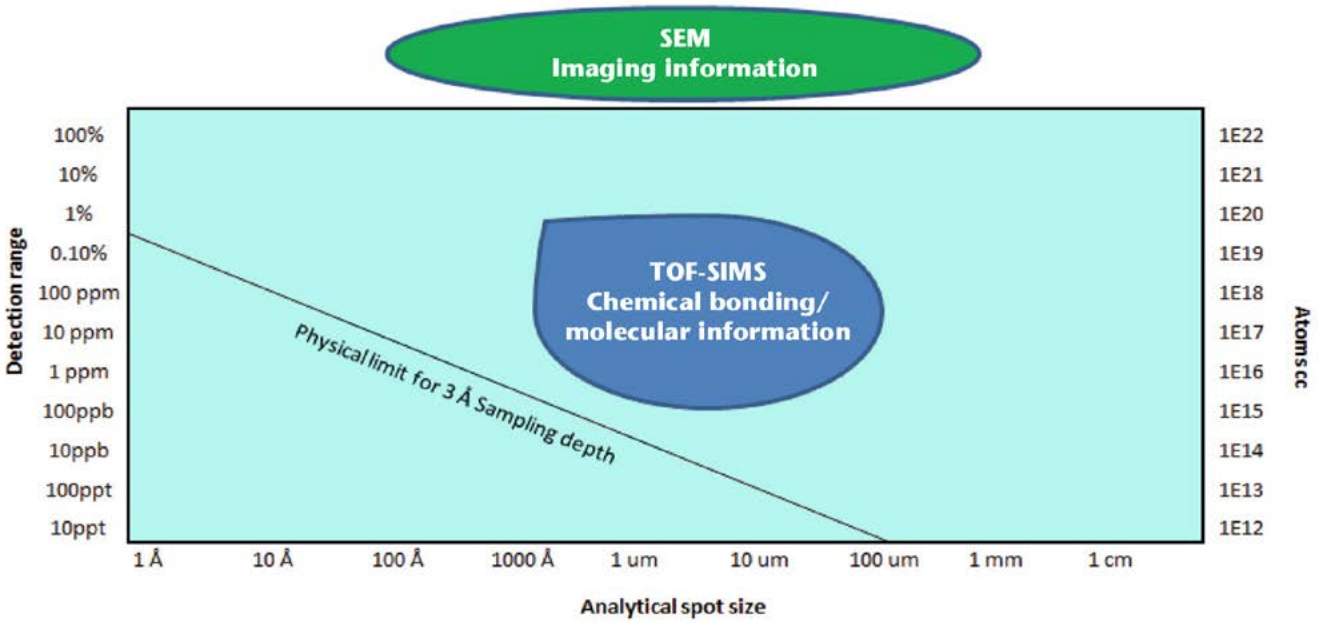

Figure 3: SEM & TOF-SIMS techniques comparison showing range of detection.

acterization; however, during failure analysis the researcher should consider the advantages and disadvantages of the technique's application and its detection limits, depth and lateral resolution. In Figure 3, both techniques are set in a detection table that illustrates the analysis coverage.

Case Study

A printed circuit board with LF HASL finish showed poor solderability in random areas. It was analyzed in order to find the origin of the non-wetting. The initial hypothesis was low HASL thickness; however, after the measurements, the pads had acceptable level of thickness (> 2 µm). The investigation was conducted to find another source of contamination. Figure 4 shows the issue.

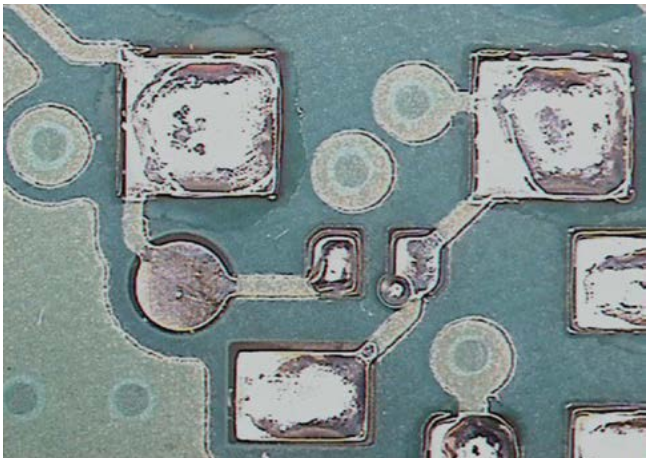

Figure 4: Non-wetting areas on LF HASL.

Stage 1: Metallographic Comparison

Figures 5a, 5b, and 5c show a comparison of the pads with discoloration and a normal LF HASL pad. A yellowish aspect was seen using a stereoscope microscope, but dark areas and brown spots were found with the metallographic microscope. Therefore, a second hypothesis was that some kind of intermetallic or foreign materials were present on the surface.

Stage 2: SEM/EDX

After the metallographic inspection, the next step was SEM/EDX analysis. In the good PCBs, the common concentration of impurities was found and the surface looked smooth and homogenous; the only significant difference with respect to bad parts was that higher copper concentration was found without any surface abnormality. Although Cu could form oxides that are hard to clean with fluxes, the oxygen

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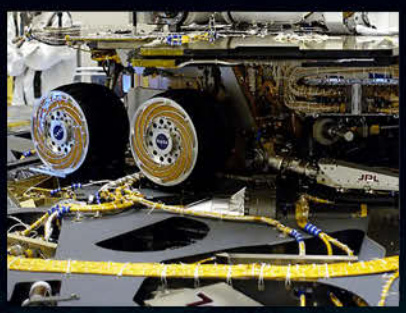

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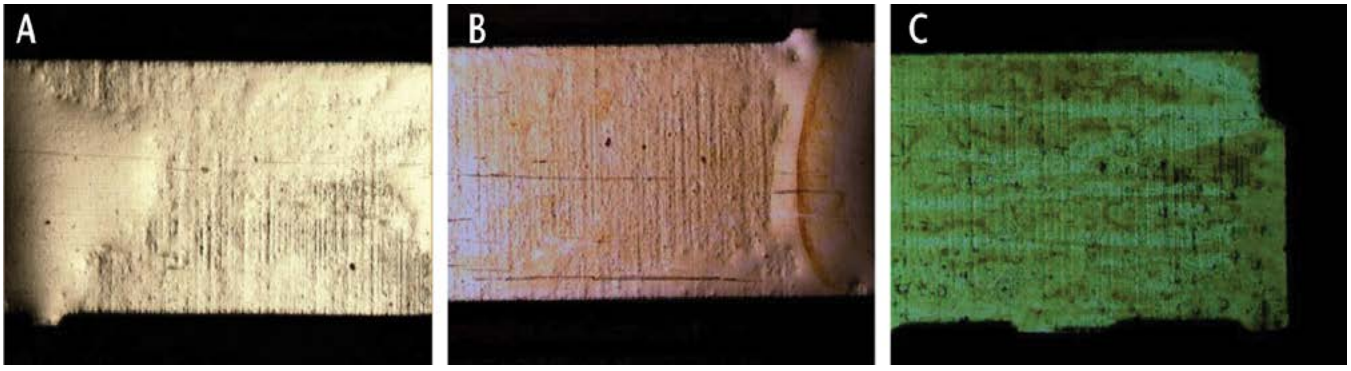


Figure 5a, 5b and 5c: These images were taken with a metallographic microscope: a normal LF pad (5a), and two problematic pads (5b and 5c) using two different polarized lens. These show dark areas and brown spots.

	C	O	Si	Br	Sn
Reference sample	3.3	8.8	1.2	0.6	86.5

Figure 6: Normal PCB pads under SEM/EDX.

concentration was low and in some areas, and no oxygen percentage was detected. Nevertheless, the areas with higher visual discoloration presented more surfaces with non-wetting. The oxygen (related to possible oxides) content was approximately the same percentage in both samples (not problematic/problematic PCBs); additionally, nitrogen content could come from the HASL environment, because HASL is performed in a nitrogen atmosphere (Figures 6 and 7).

The SEM has a depth resolution of 1–5 µm, and the material that was provoking issues on the PCB pads could be less than 0.1 µm thick. Sometimes a failure is detected by the human eye, but may not be visible to the SEM microscope; if you cannot see failure in an SEM, you cannot analyze it. In Figures 5 and 6, normal

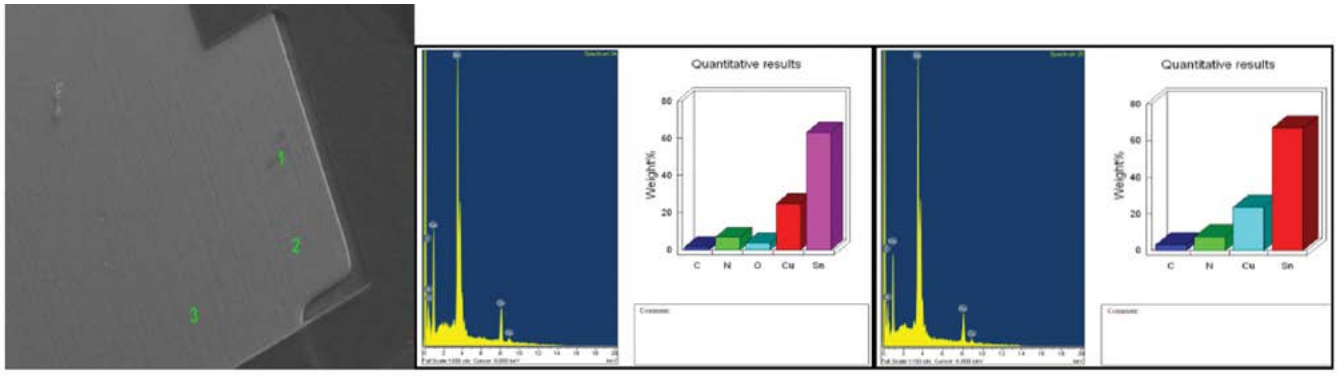
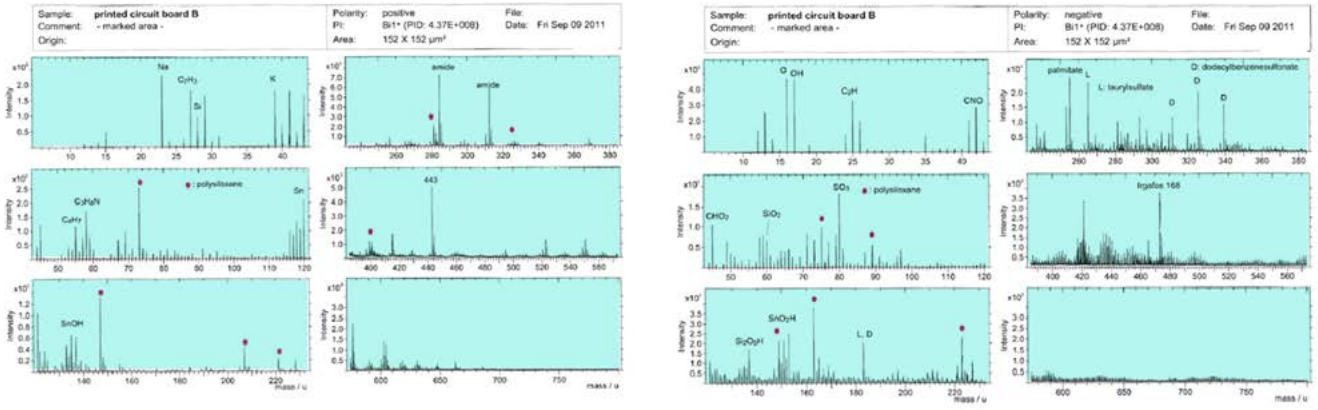


Figure 7: Problematic PCB pads under SEM/EDX.



A **B**

Figures 8a and 8b: Mass spectrum: positive-negative secondary ion polarity: normal pad.

and problematic pads are shown; the elements found on the surface are considered typical on a HALS lead-free PCB finish.

An analysis of the upper surface layers (less than 1 µm thick) is required to check if there are any others wetting inhibitors that are not visible to SEM/EDX.

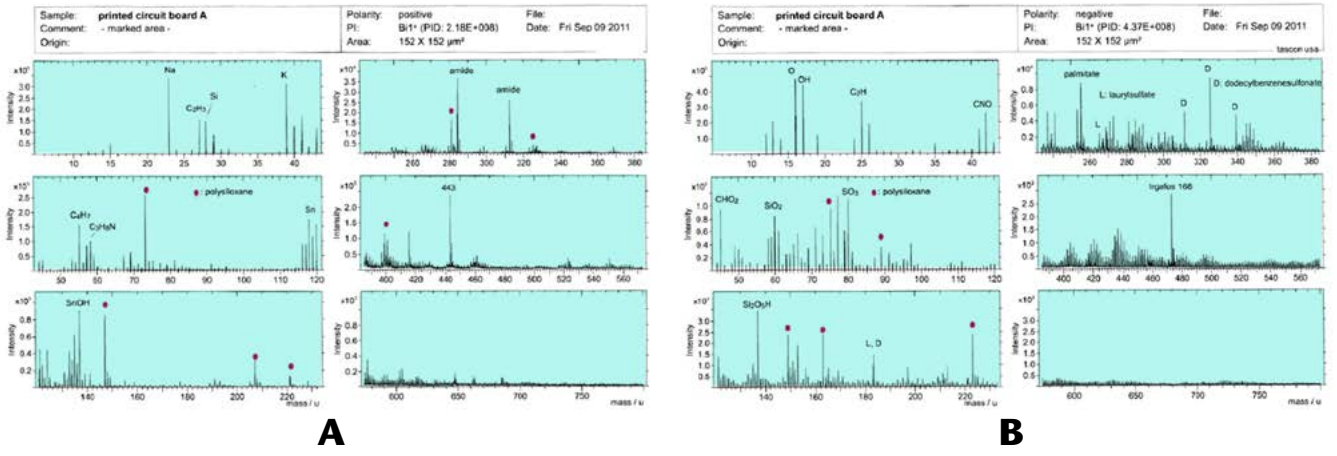
Stage 3: TOF-SIMS

The analysis consisted in a sputter erosion of the surface (approximate 100 μm^2) reaching approximately 100 nm of lateral resolution. Two different ion beams are used for data acquisition. A sputter beam (e.g., O_2+ or Cs+) is applied to erode the sample while a second ion beam (analysis beam e.g., Bi_1+) is used for to chemically characterize the resulting crater bottom. It is possible to have two different type of information: the first atomic layer, which recompiles information from the primary ions and the depth profile, which obtain data from inner layers.

In TOF-SIMS investigation using spectrometry mode (first atomic layer), a total mass spectrum of the surface region is acquired. These spectra are usually recorded with high resolution and use a low number of primary ions; the limited number of primary ions guarantees that detected signals are representative of the original composition of the sample surface (static SIMS limit).

A normal pad was included in the study in order to compare the results and locate the main differences between the surface that was inhibiting the soldering and the one without wetting issues. Figures 8a and 8b show the normal pad

TOF SIMS ANALYSIS FOR SN_xO_y DETERMINATION ON LEAD-FREE HASL PCBS *continues*



Figures 9a and 9b: Mass spectrum: positive-negative secondary ion polarity: problematic pad.

spectrometry, while Figures 9a and 9b show a bad pad. Both of them had similar elements on the surface; however, some of them had higher concentrations on problematic pads.

Some of following elements found in the samples could be initiators or catalysts of wetting problems. The most significant ions detected in the bad and normal pad spectra in Figures 8 and 9 are indicative of the following elements and compounds on the sample surface:

- Sn and Sn oxides
- Aliphatic hydrocarbons
- N-containing hydrocarbons especially amides, e.g., Kemamide
- O-containg hydrocarbons, e.g., fatty acid residues
- Polysiloxane
- Laurylsulfate
- Dodecylbenzenesulfonate

N-containing hydrocarbons would come from flux residues. Laurylsulfate and dodecylbenzenesulfonate are compounds that would signal detergents residues, and all of these components could come originate in the PCB manufacturing process. Moreover, most of these substances seem to be contaminants from handling and packaging, not genuine components of the pad such as fatty acid residues. Polysiloxanes can be detected only on the top layer of atoms. The presence of these compounds, therefore, can be rooted in the processes after HASL application.

In some cases, depth profile shows only the distribution of elements because the massive sample erosion causes a destruction of molecular structures. In addition, in a few selected cases, organic information can be obtained. Although the resulting intensities are not inherently quantitative, comparing semi-quantitative analysis of chemically similar samples are possible after a suitable normalization. As it was mentioned, Cs in the surface is sputtered as positive ion Cs+, which easily attaches to other sputtered particles forming Cs-cluster ions. Elements M are generally detected as MCs+. Electronegative elements are simultaneously detected as MCs2+.

Some of the wetting issues could be explained by the thick Sn-oxide layer of about 250 nm. In SnPb components, the common oxide thickness is in average 40 nm (Figure 10). Over that number, serious wetting issues would appear according to investigation done in SnPb metallizations.

According to the generated graphics, both normal and problematic pads are covered with a tin oxide layer; however, the second ones have a significantly thicker layer. Additionally, as shown in the top layer spectra, it has a significant amount of Ca and a higher Cl content was found on them. It is known that Cl, under some circumstances, can be an oxidation accel-

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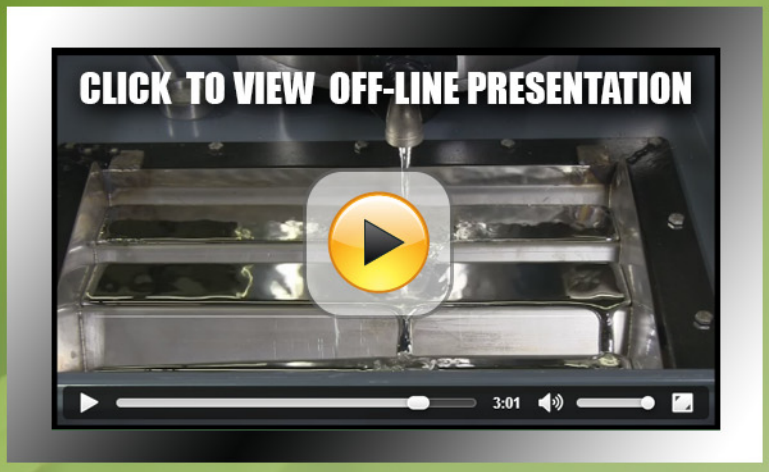

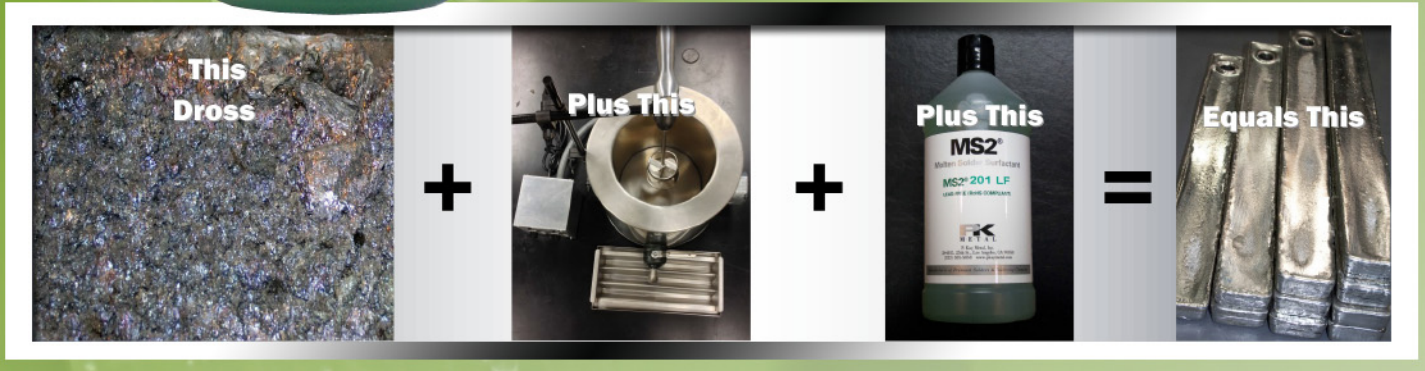

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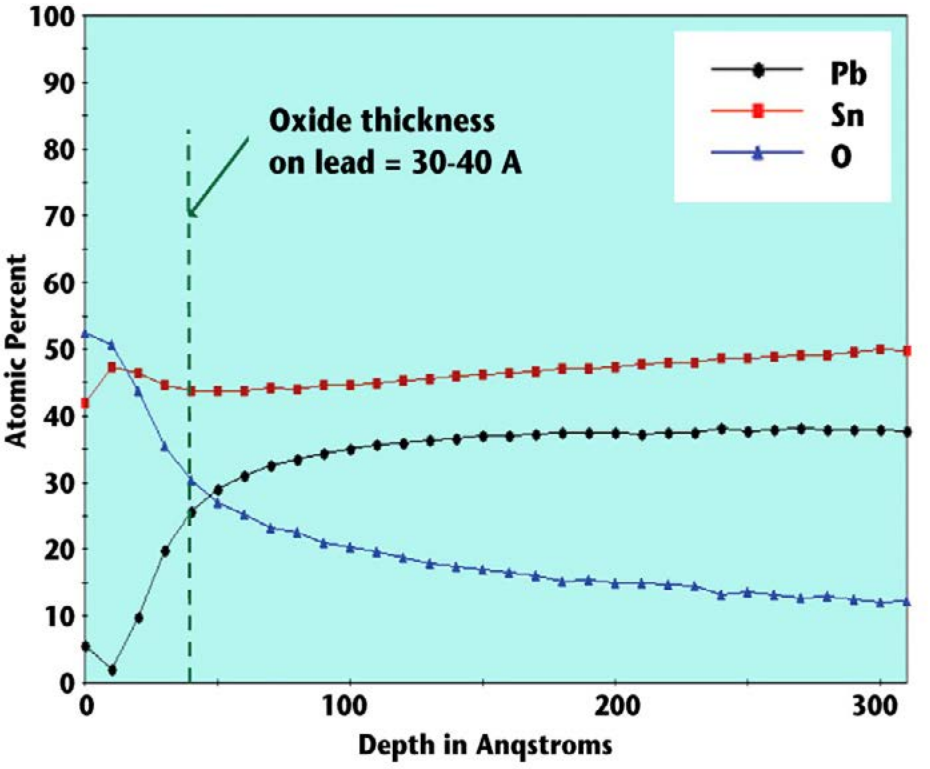
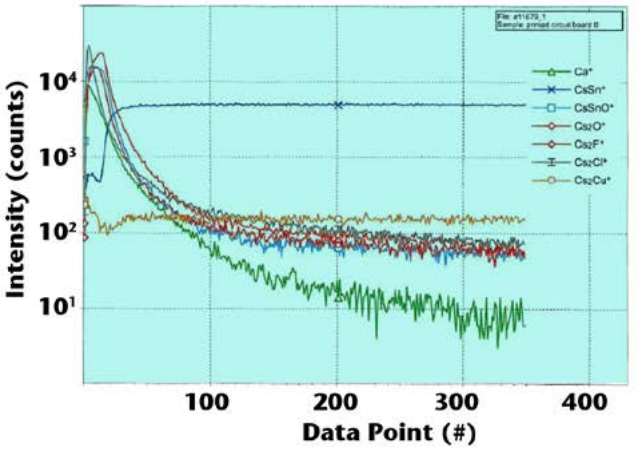
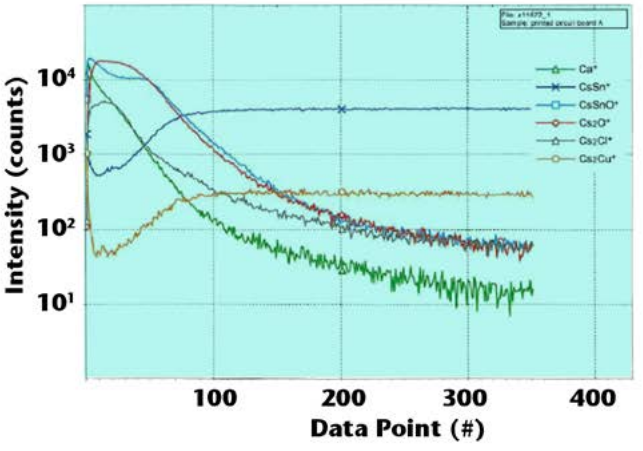


Figure 10: Common oxide layer on SnPb finishes.



A

Figure 11a: Normal pad depth profiling.



B

Figure 11b: Problematic pad depth profiling.

erator. This element would explain why the Sn oxide layer is bigger when Cl is present (Figures 11 and 12). It is interesting to observe the higher amount of copper on the discolored zones below the oxide layer, although its presence cannot completely explain the discoloration, because Sn oxide can also create this effect.

According to the surface element finding, the idea of removing this layer of wetting inhibitors was proposed: "washing" the pads by

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applying detergents, DI water and brushing them. This cleaning would improve the surface conditions.

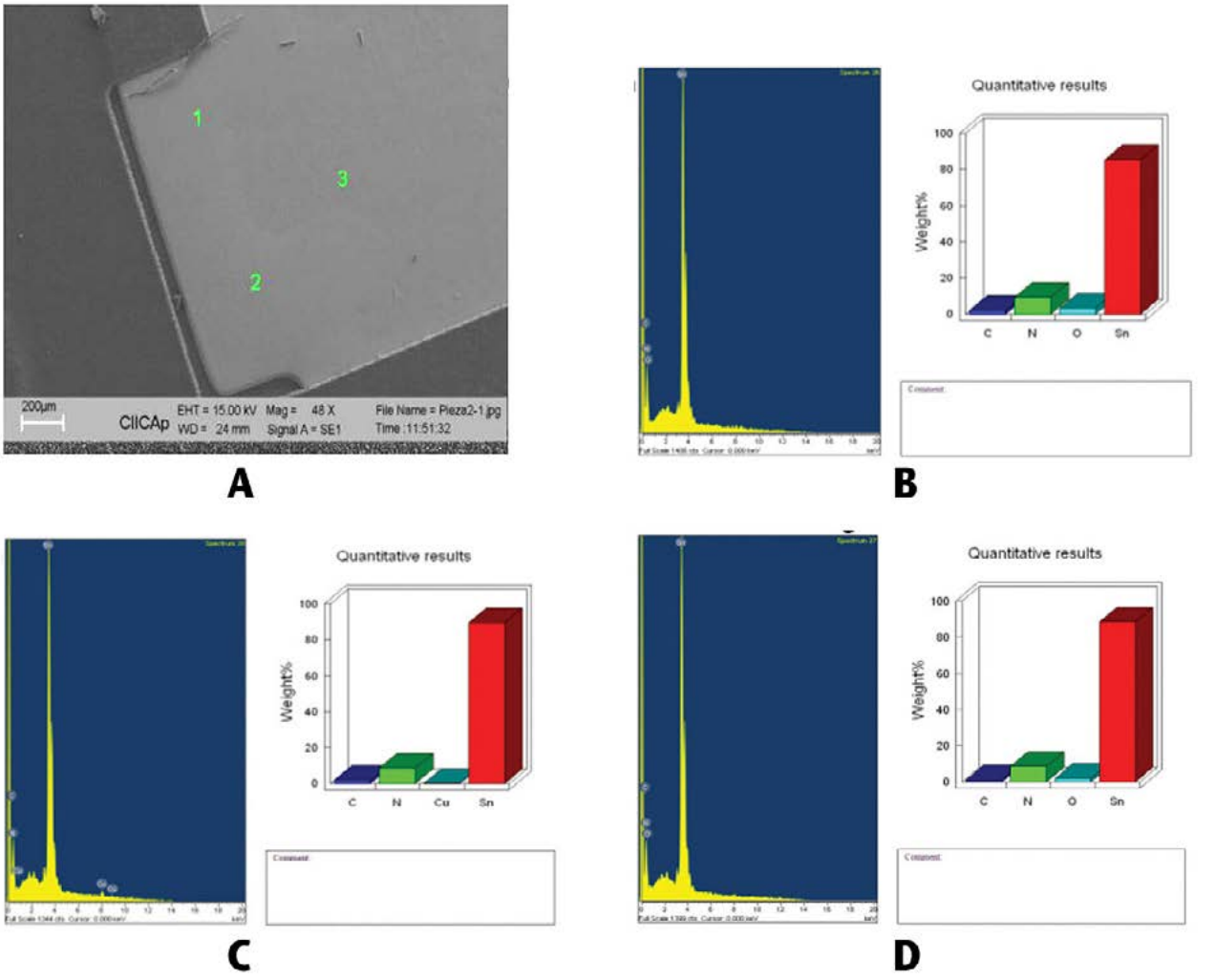
Stage 4: Analysis after cleaning

In order to close the hypothesis that a mechanical removing of these oxides could improve the wetting, SEM/EDX & TOF-SIMS analysis were performed. The results demonstrated that the thick oxide layer was eliminated or significantly reduced.

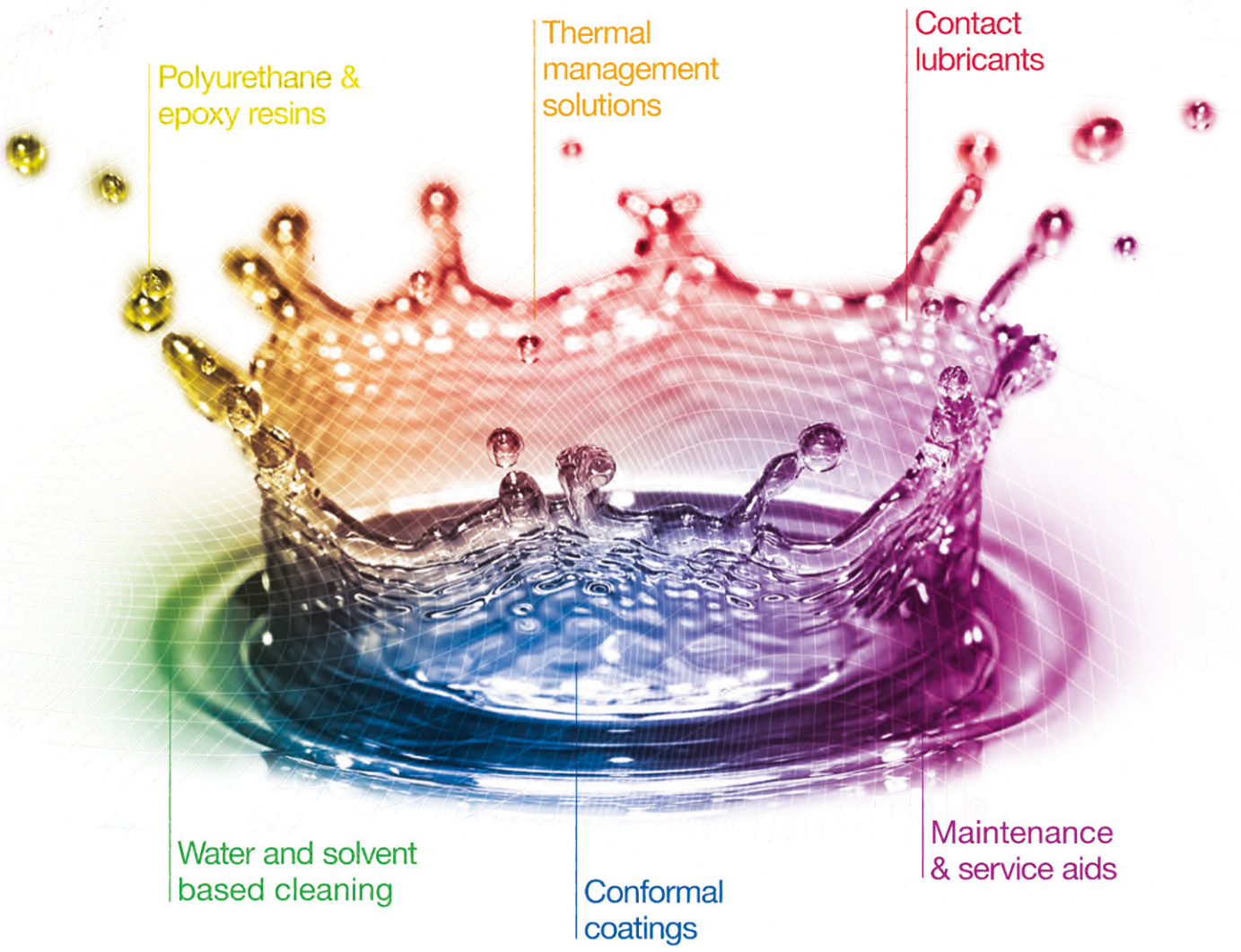
Figures 12a to 12d corroborated the low oxide and Cu content on the surface; however, this information could be corroborated with TOF-SIMS because SEM is showing only average deep layers of the pad.

The use of detergents and water during cleaning increased the content of some other elements on the primary ion layer shown in Figures 13a and 13b. Ions of the following compounds were detected:

- Sn and Sn oxide
- Na, Mg, Al, K, Cr, Mn, Fe, Ni, Cu, Zn, Pb, Cl, Br, I
- N-containing hydrocarbons especially amides, e.g., Kemamide
- Sulfates
- Phosphates, especially Irgafos 168
- Laurylsulfate
- Dodecylbenzenesulfonate
- Flourocarbons



Figures 12a to 12d: SEM analysis show the surface condition after special cleaning. The Cu and oxides are significantly reduced.



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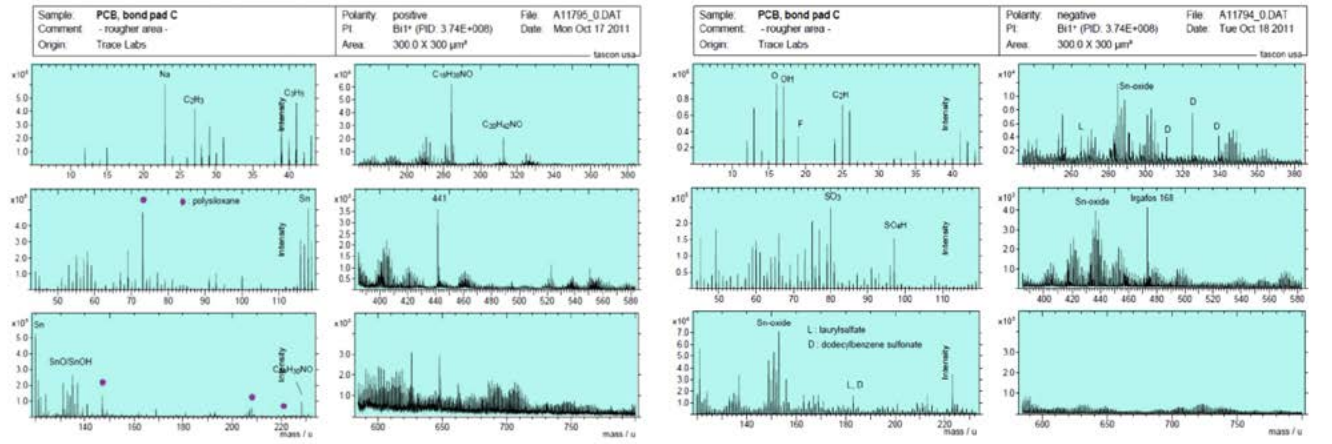
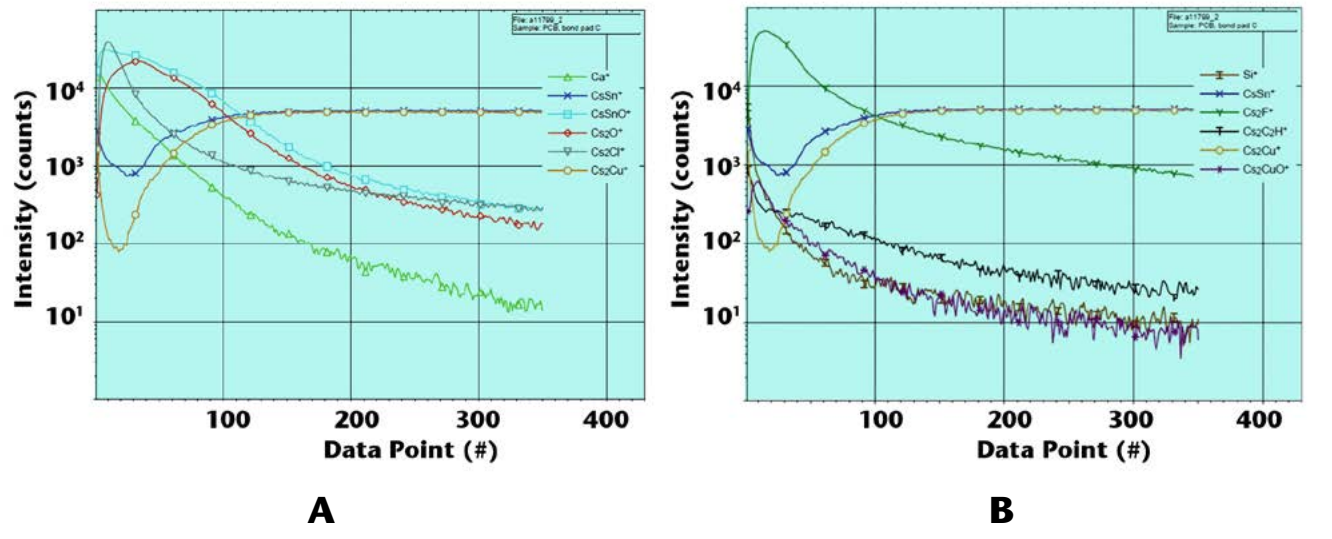
TOF SIMS ANALYSIS FOR SN_xO_y DETERMINATION ON LEAD-FREE HASL PCBS *continues*



Figures 13a and 13b: Mass spectrum: positive-negative secondary ion polarity showing a cleaned pad.



Figures 14a and 14b: TOF-SIMS analysis (Note: the sputter rate in these analyses is four times slower than that of the depth profiles in Figure 11.)

Nevertheless, the presence of these components in the spectra does not mean that the surface will be altered in wetting. Their percentages will determine the level of possible wetting change. It should be noted that the values are only semi-quantitative and absolute concentrations cannot be derived from the data.

In the depth profiling graphics, the oxide layer reduction is noticed. Even a few other elements were added during the washing, and the impact on the oxides was demonstrated. Also, consider that the F content increased after cleaning. Compare Figure 11 with Figure 14.

Conclusions

Wetting issues are related to oxidation or oxide layers on the surface of metallizations. However, its detection and quantification are hard because oxide layer is too thin (<1 micron) in many cases. This type of thickness can be shad-

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owed by the presence on the element in deeper layers when SEM/EDX is used to analyze. In our case, a LF HASL PCB presented several wetting issues. Several analyses were made but the one which gave important insights was TOF SIMS. This tool can sputter and remove material layers measured in atomic thickness and determine the presence of inorganic and organic compounds in orders of ppm or lower. The results showed the oxide layer was thicker in problematic areas compared to good ones. Cleaning actions were carried over to eliminate this oxide layer therefore. A good reduction of its presence and reduction of wetting issues were obtained. **SMT**

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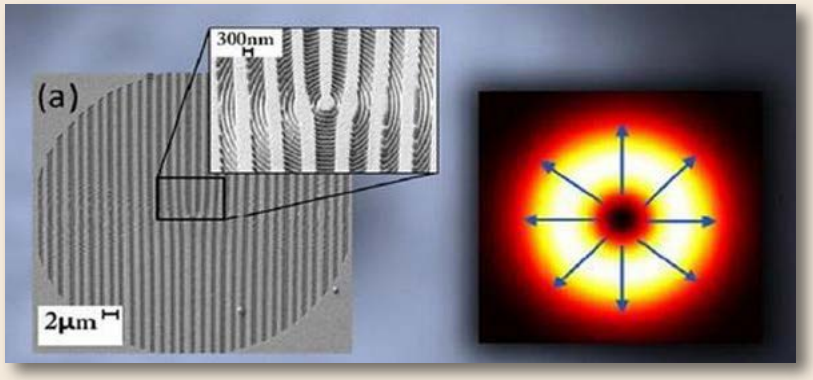
Nanostructured Device Controls Light for Optics Applications

Applied physicists at the Harvard School of Engineering and Applied Sciences (SEAS) have demonstrated that they can change the intensity, phase, and polarization of light rays using a hologram-like design decorated with nanoscale structures.

As a proof of principle, the researchers have used it to create an unusual state of light called a radially polarized beam, which, because it can be focused very tightly, is important for applications like high-resolution lithography and for trapping and manipulating tiny particles like viruses.

This is the first time a single, simple device has been designed to control these three major properties of light at once. (Phase describes how two waves interfere to either strengthen or cancel each other, depending on how their crests and troughs overlap; polarization describes the direction of light vibrations; and the intensity is the brightness.)

"Our lab works on using nanotechnology to play with light," says Patrice Genevet, a research associate at Harvard SEAS and co-lead author of a paper published in Nano Letters. "In this research, we've used holography in a novel way, incorporating cutting-edge nanotechnology in the form of subwavelength structures at a scale of just tens of nanometers."



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Production Automation Revolution—Are We Nearly There Yet?

by Michael Ford
MENTOR GRAPHICS CORP.

As more people come to understand 3D printing, some key underlying principles of the evolution of manufacturing come into sharp focus. A lot of excitement around 3D printing comes from being able to create what you want, when you want it. For some time now, the discrete mass-manufacturing market, especially in electronics, has also wanted to do that.

How great would it be to take a product blueprint and simply command the production facility to "make it for me now!" Will we ever get to the stage where the production operation has the ability to reply and say, "Sure, I'll figure out how to do that and have it to you within the hour"? We may be closer than we think. The base elements to do this have recently been quietly moving into place. Is a revolution about to happen? How should we prepare?

Instant Prototyping

The arrival of 3D printers in industry happened many years ago in the form of large and expensive machines. Technology advancement, as always, brings size and cost reductions until a "critical mass" is reached where wider applications of the technology become viable. This is the point at which the technology takes off, where many more people start to look into further development as commercial aspects are revealed.

The evolution of 3D printing will surely evolve into a multi-element dispenser, alternating and combining materials to build products with complex textures, finishes, colors and functions. Today, metal elements can be 3D printed. How about printing semiconductors in the future? Can we imagine an

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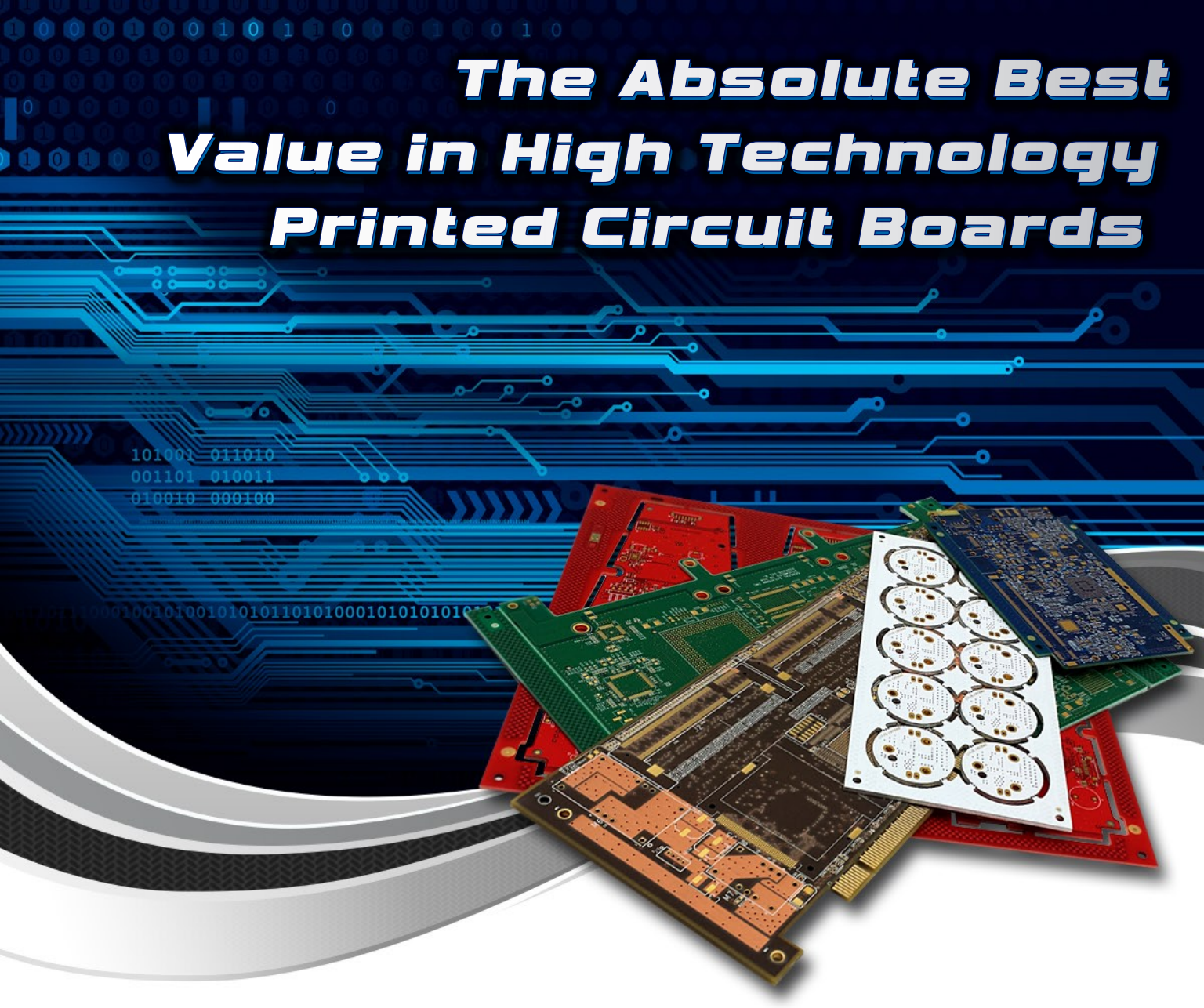

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PRODUCTION AUTOMATION REVOLUTION *continues*

"iProduct" made on a 3D printer? Perhaps not in the immediate future; we are not done with discrete production—for a while at least.

The electronics factory today is already under pressure from the market to deliver something like a 3D printer. Long-term planning has been made almost redundant for many companies due to the growth in the number of product variants, the reduction of time between product cycles, fashion and competition, plus the shortened distribution chain from the factory to the point of sale with Internet shopping.

Many factory operations adapt simply by storing stocks of finished goods within the factory itself, effectively defeating the point of cost saving in the distribution chain, while attempting to keep a non-responsive factory productive. This is not at all an optimum solution for the business. The existing barriers that prevent the operation from being able to cope with higher mix and unexpected changes can be addressed effectively today with established techniques and tools available, as I wrote about in The Opportunity to be Agile (*SMT Magazine,* April 2013). Many companies now are adapting their processes; the change has started.

Many factory operations adapt simply by storing stocks of finished goods within the factory itself, effectively defeating the point of cost saving in the distribution chain, while attempting to keep a non-responsive factory productive. This is not at all an optimum solution for the business.

Looking Far into the Future

This time, we are looking further ahead, in a practical sense, to see how a production operation of the future might work assuming that current market trends continue. Expectations of performance and response will be the most significant changes. The factory will simply be able to produce any quantity of any product with a very short lead-time. To see how this could work, we can consider each of the key axes of manufacturing, comparing what we have today, with what we need in our future factory.

As in the 3D printing case, the first axis is design data, which simply expressed is a complete digital representation of the product to be made. For 3D printing, this takes the form of a 3D model plus, I expect, factors such as different material characteristics and requirements at each mapped point of the structure.

For PCB-A design today, it is quite similar. Today's design systems are capable of representing the complete product, in electronic and mechanical detail, including the dimensions and layout of the PCB, the nominal characteristics of all of the components materials, casings, etc. It is the complete definition of what should be done to create the product. Without this, the production operation cannot work, and even without part of it, production cannot be set up effectively. Not all design systems are the same, nor is the level to which they are utilized, so it is likely that production sites will not currently receive all of the possible information. We do, however, see best practices emerging in the industry to transfer more value from the design through to manufacturing using intelligent data formats, such as ODB++, so as to provide production with what they need to know without the overhead of essential data reconstruction. With the relevant product data available for the factory, the preparation of the processes can start.

The best process preparation tools available already reduce the new product introduction (NPI) overhead to a fraction of what it once was. We see already that the effort for each new model is reduced to a couple of hours when it used to take several days. The success of the automation process is influenced by the focus in the engineering team to refine the accuracy of rules and library data which enables the intelligence in the software to be more accurate and consistent. For our future factory, the entire product-by-product related tasks need to be automated, with production engineering firmly focused on mapping of process capabilities and dealing with material libraries. Then, not only

can products be set up fast enough, but it is also possible to prepare all products over all possible choices of operations. This is the significant point, as the specific assignment of product to operation will no longer be decided in advance; it may only be decided immediately before the product is due to be produced. Machine programs and data, instructions and documentation are then prepared together at the time that the planning decision is taken.

The next axis of production to consider then, is the shop-floor planning. This is where some big changes must be made. Traditionally, the factory follows a production plan derived from a long-term schedule created by ERP. This is infrequently revised even though the customer needs change. It is linked to the timed arrival of materials with long lead times. Even today on the shop-floor itself, it is generally accepted that ERP production plans get thrown out of the window as production knows best how to manage and adapt the completion requirements to the operations. Most actual shop-floor schedules are managed in Microsoft Excel, with a key person continuously at the helm.

In our future factory, we expect the shop-floor to schedule itself. There is already a tool today that takes the current status and progress of production on the shop-floor, a list of requirements, and engineering data to create and optimize work-orders and minimize changeover time between products. This tool can be run as often as required, as requirements or circumstances change. In our future factory, this tool runs continuously and automatically, taking on-board changes as they happen, ensuring that every asset is utilized and completion demands are always hit.

Production Tracking

The success of continuous planning is dependent on understanding the current state of progress of the production process. Today, we can track progress with individual barcodes on PCBs with enforced routing, ensuring that the correct sequence is followed. Routing can be dynamic, such as in the case where a test fails and the product has to be inspected or repaired.

Barcoded IDs, however, has limitations for automated reading in certain conditions, leading to manual scanning in many cases. PCBs can also easily get "lost" if they are stuck somewhere away from a reading position. Product WIP reports can tell you which PCBs have gone missing and from where, but it can be hard to find them.

A better technology for tracking is the RFID chip, which, like a barcode can store a simple ID in a small chip placed on the PCB. The ID is readable without any power supply or connection requirement other than the chip is mounted across a small slit in an existing track. With RFIDs, depending on antennas and frequencies, the IDs can be read and located from a distance, and, using triangulation, be pin-pointed with some accuracy. This removes a lot of the pain of tracking products to the extent needed for accuracy in the live operation.

A further tempting option that RFID brings with it is to work as more than just a simple ID. These devices are also capable of storing significant amounts of data. This can include information gathered during the course of production, but it can also contain the definition of the manufacturing operation that should be executed. For example, when a base model with many variations according to customer orders is assembled, the RFID can allow them to be run in the same line at the same time. It can be effectively a pre-programmed entity such that once released into a production system, could route itself to the appropriate processes, negotiating with each one of them on arrival exactly what needs to be done.

This could lead to a self-managing system on a local basis without the need for such a detailed higher level production management system. In cases of high degrees of commonality of products, especially in respect of materials, this model of operation could be viable. In most cases however, the variation of different products will be too great, demanding process changes between products. In this case, the planning system needs to be the one to make decisions to provide optimisation of routing.

There will be a lot of debate in the future about the difference between these scenarios in terms of variation, risks, optimisation, and management, as well as system tolerance to failure. The merit of storing data on the RFID chip

PRODUCTION AUTOMATION REVOLUTION *continues*

is more realistic at completion, defined as the point where the production system hands over the responsibility to the distribution system, and beyond. On-board production information in the RFID chip can be extremely useful for proof of compliance, enable traceability searches, and also support after-market servicing and repair.

Material

With the future factory up and running, there are two axes of production left to cover. The first of these is materials. For planning, making any product in any quantity at any time assumes that any and all materials are available. This can sound like a huge overhead cost for the factory of the future as compared to today's factory operation, where materials are ordered to satisfy plans for specific quantities of products to be made at specific times, minimising the stock of raw materials.

The fact is that the factory of today is optimized around a fixed schedule and a long distribution chain, which are the two things that can no longer be depended upon. Being able to remove the huge amount of stock on the distribution chain can balance a corresponding increase of raw materials.

In reality though, the amount of raw materials stock does not need to increase so drastically. Most of the raw materials are common to many products, and so in many cases duplicated stock can be avoided. Key components on the other hand, especially those where lead times cannot be shortened, will remain in the realm of the traditional MRP cycle. MRP needs to work for our future factory at a more "macro" level to provide support for these materials.

With no decisions of production work-orders months into the future, a reasonable forecast of quantities linearly over time should be forecast. Again, this already exists today with reasonable accuracy, as the expectation of customer demand which is the input into the traditional ERP engine. The part of the ERP engine dealing with distribution chain simply needs to be short circuited. There are risks in doing this of course but, compared to the risks of having redundant stock in long distribution chains, it is a significant step forwards. Simple commercial tools can be used to "manage" demand of products towards end of life where the majority of the risk would be. Replenishment of the majority of materials then becomes more of an intelligent live min-max Kanban system, tools for which are available today, plus the macro management of the key materials by the more traditional MRP process.

People

The final axis of production we will consider is people. At every stage of the evolution of automation, there have been concerns raised of the effects that it can have on people and their jobs, as people perceive that they are to be replaced by the automation. Superficially, this is true: Many day-to-day jobs being done today will no longer be needed in our factory of the future that we have described.

"At every stage of the evolution of automation, there have been concerns raised of the effects that it can have on people and their jobs, as people perceive that they are to be replaced by the automation. Superficially, this is true: Many day-to-day jobs being done today will no longer be needed in our factory of the future that we have described."

What is often forgotten, or is not understood, is that the actual underlying contribution that people make cannot be replaced by the automation. People continue to make their contributions, but in a different way. Take for example the process preparation engineers. Instead of spending their time every day setting up specific products on specific operations, they now spend their time managing and engineering the rules and specifications for the setup operation, continually refining the accuracy and efficiency of the specifications and capabilities of the production equipment. It is higher value work, as one simple improvement

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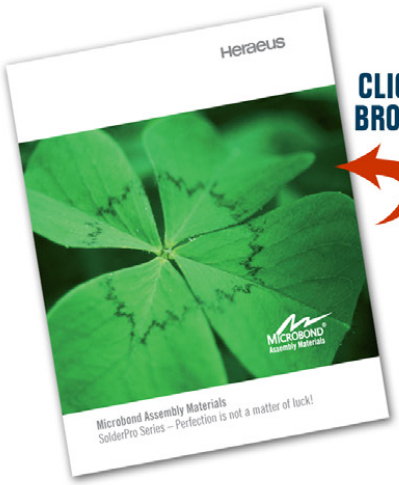

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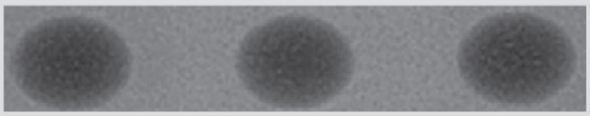

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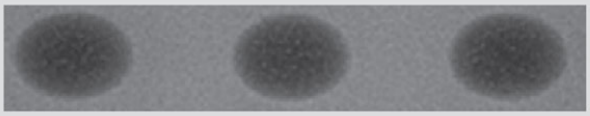
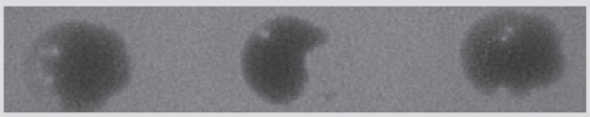
F640 powder type 4

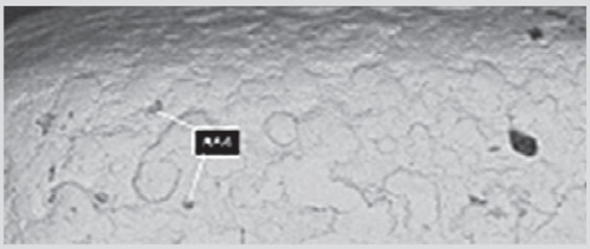


Competitor wetting on nickel plate in air

Poor wetting, fail



Example of a chipcomponent with an imperfect Sn surface finish – darkspots are exposed nickel



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can create a significant general performance improvement, so it should be much more satisfying than "fighting fires" in a day-to-day repetitive process.

The shop-floor planning team is another example. Instead of "playing" with Excel—often in high pressure scenarios to create and keep the schedule on track—the planning team now refines production flows and operational models, such that the automated planning tool can see every opportunity for optimization. This is again an added value strategic job, replacing a repetitive one. Materials and quality teams are also affected as operations and flows are optimised. Here are the opportunities for these teams to work in real-time, reacting to issues, creating opportunities for improvement as they happen, rather than spending their time coping with the effects of issues left unattended.

How Far in the Future is the Automated Factory?

For many years, there has been discussion over the merits and issues surrounding automated factories. It is a quite common reaction to jump to the image of a "lights out" operation, running completely on its own. This has been tried, and clearly will never be practical, as materials and product changes will remain a fact of life as market demands head in the direction of flexibility rather than simplistic volume. The real automated factory of the future automates the flow and operations, not necessarily the processes, though doubtlessly machines will have to also step up to be less dependent on human operations, especially for new product introduction. The interesting point today is that this future factory model is within sight. There are tools available today that already have started to address the need for agility and flexibility. Extending these now to create the automated operation of the future needs some discussion and cooperation, mainly to connect the technologies together rather than create them. It all looks quite close and quite achievable.

Will this be a revolution? Yes, looking back, it will be, and we will see that the start has already been made, by those people who have already adopted software tools for agility and flexibility. **SMT**

Michael Ford is senior marketing development manager with Valor division of Mentor Graphics Corporation. To read past columns, or to contact the author, click here.

Polymer with Tunable Colours

By inserting platinum atoms into an organic semiconductor, University of Utah physicists were able to "tune" the plastic-like polymer to emit light of different colors—a step toward more efficient, less expensive and truly white organic LEDs for light bulbs.

"These new, platinum-rich polymers hold promise for white organic light-emitting diodes and new kinds of more efficient solar cells," says University of Utah physicist Z. Valy Vardeny, who led a study of the polymers. Certain existing white light bulbs use LEDs, or light-emitting diodes, and some phone displays use OLEDs. Neither is truly white LEDs, but instead use LEDs made of different materials that emit different colors, then combine or convert those colors to create white light, Vardeny says.

The new polymer could also be used in a new type of solar power cell in which the platinum would help the polymer convert sunlight to electricity more efficiently.

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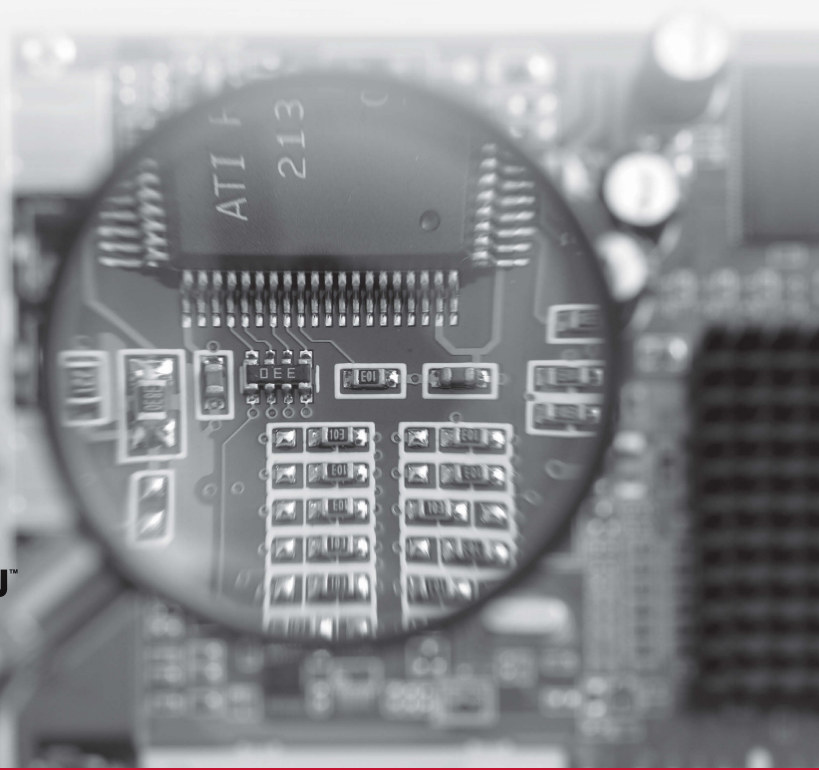

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SMTonline Supplier/New Product News Highlights

Rehm Technology Forum to Focus on Sustainability Initiatives

Rehm Thermal Systems will host a major technology forum September 19–20, 2013 at their new facilities in Blaubeuren, near Stuttgart, Germany. Speakers from Infineon, Fraunhofer Institute, Volkswagen Varta, and several Universities will join Dr. Hans Bell and other Rehm technologists presenting a series of topics surrounding new ideas for sustainability in electronics manufacturing.

Europlasma, Uyemura Form Partnership

The partnership will be focused on the use of Europlasma's low-pressure plasma technology for conformal coating of electronics and surface finish of PCBs. The partnership will also cover medical and automotive applications, as well as technical textiles.

Dymax Unveils New Spot-curing System

BlueWave 200 version 3.0 offers the highest intensity and most user-friendly operation in the industry. The automatic, controlled power-up sequence ensures proper lamp operating temperature to minimize scrap, and the unit's new, easy-to-clean faceplate design features an improved operator interface for easier setup, programming, and operation.

Nordson ASYMTEK Launches Spectrum S-820-C

The Spectrum S-820-C stainless steel dispensing system is third-party certified for Class 100 cleanroom use. It can be used in applications that are extremely sensitive to contamination by submicron-sized particles, such as wafer-level packaging, or for dispensing a controlled amount of adhesive in precision cleanroom manufacturing operations.

Burton Industries Celebrates 35 Years of Success

"In a time of economic adversity for many U.S. manufacturers, Burton Industries is pleased to be able to celebrate 35 years of successful business growth. Our success is due to the quality of our team and their willingness to go the extra mile for each of our customers," said Gary Burnett, Sr., president and CEO.

Nordson's Q3 Sales Up 6% to $403 Million

"Through the first nine months of our fiscal year, Nordson delivered organic growth of more than 4%, a level outpacing global GDP," said President and CEO Michael F. Hilton. "On a sequential basis, sales, operating income, operating margin, net income and diluted earnings per share have improved in each quarter of fiscal year 2013."

SEHO, IVT Debut Automated AOI of THT Assemblies

SEHO Systems GmbH, a worldwide leading manufacturer of automated soldering systems and customer-specific solutions, introduces an AOI system for optical inspection of THT assemblies that has been developed in cooperation with partner company IVT Industrial Vision Technologies GmbH.

Ellsworth Adhesives Adds New Dymax 9100 Range

Dymax Dual-Cure 9101, 9102, and 9103 are resilient, chip-encapsulant materials designed with a UV/Visible light and secondary ambient moisture-cure system, making them perfect for encapsulation applications where shadowed areas are present.

Intertronics Launches New Variants of Opti-tec 4200

Intertronics have recently introduced two new variants of their high-performance Opti-tec 4200 polyurethane encapsulating/potting compound and adhesive. Opti-tec 4210 is "water white clear" and is very hard (Shore D 80), giving it excellent scratch-resistance.

Microtronix Boosts Productivity; Adds New Universal Line

Microtronix Manufacturing recently added two Universal Advantis® AC-90T Platforms, one Genesis GX-11S Platform with a Direct Tray Feeder, and a Line Manager software module to its production facility in Johannesburg, Gauteng, South Africa.

NEW Technology Collection: Understanding Dispensing, Jetting, and Coating

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Learn about key technologies for fluid dispensing, jetting, and conformal coating in these white papers you can download now.

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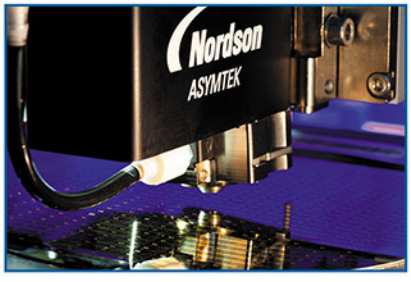
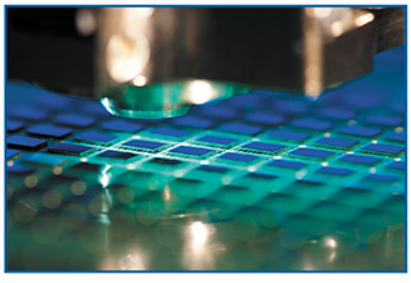


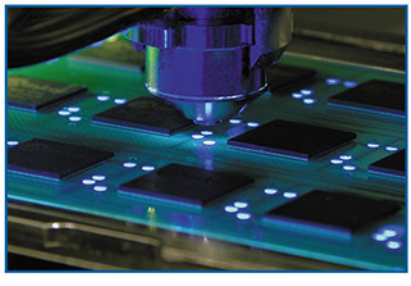
Sealing Dispensing for MEMS Wafer Capping

Wafer capping MEMS devices presents challenges and specific requirements for dispensing sealant, volumetric accuracy, and motion systems that can be met with the correct dispensing equipment and methods.
By Heakyoung Park



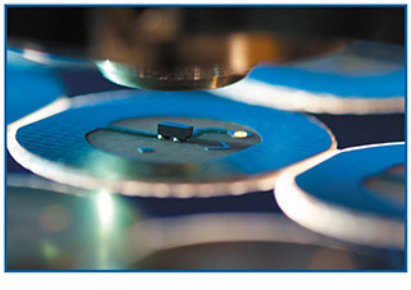
Underfilling Using Continuous Path Motion Control

New device configurations change the amount of fluid needed for underfill and the dispensing techniques for depositing it. Using a continuous motion of the dispense head avoids backtracking and improves units per hour by 27%.
By Akira Morita



Conformal Coating Process Characterization Considerations

Selective coating coats specific areas. Using properly characterized automated equipment is a reliable way to increase yield, throughput, and reduce the cost of the conformal coating process.
By Brad Perkins



Process Improvements in Fluid Dispensing

Speed and throughput have increased exponentially over the years, yet are still factors challenging the existing dispensing systems as fast never seems to be fast enough. Increasing throughput involves more than just speeding up the actual act of dispensing.
By Dan Ashley

See Nordson ASYMTEK at SMTAI, Booth #509 and productronica 2013, Hall A2, Stand 339

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Making Sense of Bringing Manufacturing Back Home

by Sjef van Gastel
ASSEMBLÉON NETHERLANDS B.V.

Most electronic consumer goods in our house bear the Made in China label. Recently, though, Royal Philips moved its electric shaver production from China back to the Netherlands, where the high-quality shavers will be assembled in the same highly automated factory where development, manufacturing and logistics processing takes place. Does moving back home mean sense and simplicity?

The move by Philips is not the only one. More companies are considering bringing their product manufacturing back to Europe or the USA. The Chinese economy is growing so fast that it shows some signs of overheating: Skilled labor is becoming scarce and that translates into fast growing wages (last year's average annual salary increase in China was 15–20%).

Factory workers in China are used to long hours and regular overtime, working in enormous factories (often more than 100,000 workers per factory) under harsh conditions. In the last couple of years, for example, multiple incidents were reported in the Foxconn factories where Apple products are manufactured for the American and European markets. These incidents often relate to long (boring) working days, bad working conditions and poor living conditions. Under pressure from Apple, Foxconn doubled all wages and improved working and living conditions.

Increasing Wages: Fueling Demand

The Chinese people have worked for many years to earn a better living and better living conditions (including housing, education and

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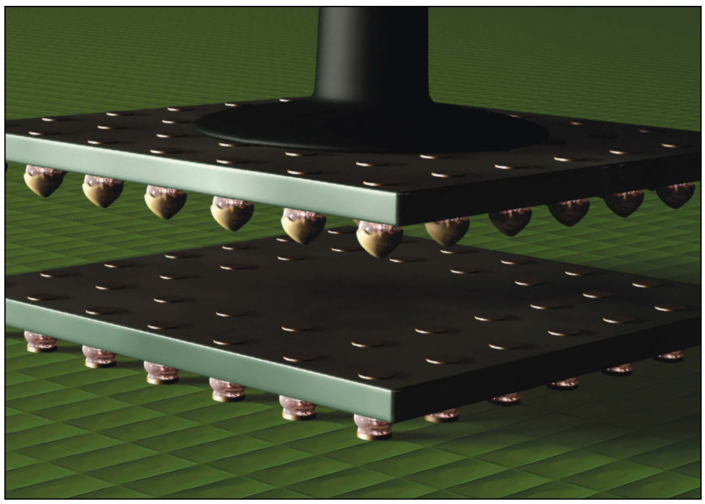

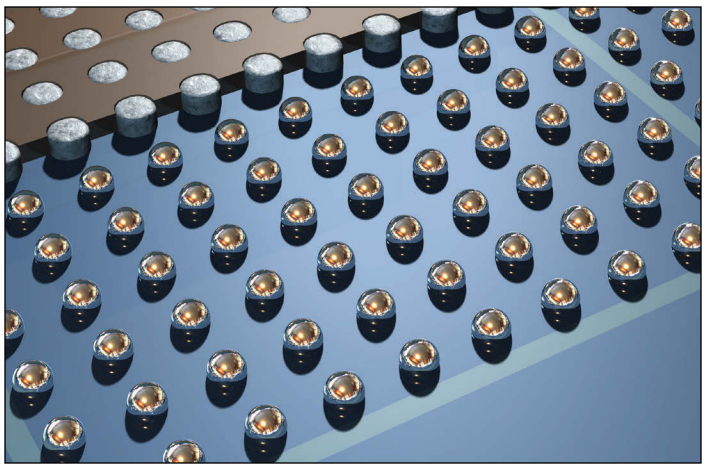

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MAKING SENSE OF BRINGING MANUFACTURING BACK HOME *continues*

health care). They now understandably want a larger portion of the prosperity cake: their own consumer electronics goods, fashion products and ultimately, their own car. This is how increasing wages fuel domestic demand.

The Chinese economy is now developing so fast that the capacity of power plants is insufficient and electricity is becoming scarce. There are frequent power shortages and power cuts. As a result, China is importing more and more energy, and energy prices are rising. Following complaints from the U.S. government, the value of the Chinese yuan renminbi (CNY) currency against both the U.S. dollar (USD) and Euro (EUR) has increased by more than 10% in the last three years.

More factors are influencing production costs in China. As a result of scarcity in trained production personnel, most operators frequently change jobs, further increasing salary costs. At the same time this movement of workers worsens production process quality, since each new worker needs to be trained and become familiar with the specific process and its production parameters. This leads to more rework and higher scrap costs.

Stock Now Stored by OEM

Another often hidden factor relates to ownership and payment of stock. In the consumer electronics supply chain it was until recently common for all goods to be in stock at the store. The store paid the distributor, who eventually paid the manufacturer (OEM). So, the money for the goods was available as cash at the OEM who in turn had to pay its supplier (EMS). However, this payment was not made until the due date (60–90 days). This situation favored the OEM (free money), since it helped minimize the need for working capital. But the risk of obsolescence in heavily fluctuating markets (influenced by fast changing technology, fashions and economic crisis) has forced retail stores to minimize their stocks. This has benefitted the retailer at the expense of the OEM.

OEMs now have to keep the goods in stock (especially when manufacturing is in China), since demand fluctuates heavily (at retailers) while goods supply from Asia has long shipping times (by sea, 3–4 weeks; by air, 1 week). All goods stored in OEM warehouses cost them money. So, shortening the supply chain by bringing goods manufacturing back home will save money! OEMs do, however, need to take care that their supply chains are lean and responsive.

Mostly, bringing manufacturing from China back to the U.S. or Europe will mean facing higher wages and manufacturing costs. The electronics manufacturing supply chain is highly automated, though, requiring a limited number of operators. There are several other ways to limit manufacturing costs:

- Build to order: minimize stocks and WIP
- Eliminate waste: optimize process quality ('first time right')
- Limit human labor needed: automate as much as economically possible

A return of profitable electronics production to the U.S. or Europe will, however, need careful selection of manufacturing equipment to help reduce manufacturing costs. Important to keep in mind is the following:

- Reduce batch sizes to reduce the chance of obsolescence, WIP, etc. That means frequent changeovers, so changeover time (COT) should be reduced by minimizing equipment downtime. Some examples: by for example:
  - Implement dual (independent) lane product transport in the flowline
  - Keep all component inventory on line or ensure fast feeder exchange
  - Integrate all manufacturing processes into one line ('long line') to minimize WIP

- Improve process quality. Use pick and place machines with low DPM figures (best-in-class: < 1 DPM), where the first pass yield is considerably better than average pick-and-place machines (average: 30–50 DPM), resulting in much less rework and related rework operators.

- Automate assembly of 'very odd components' (large connectors, shields, cooling bodies, transformers, casings). The average cycle

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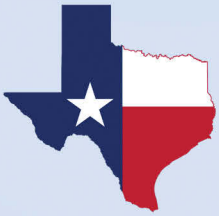

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MAKING SENSE OF BRINGING MANUFACTURING BACK HOME *continues*

time for most components placed by hand is three seconds. This doesn't sound like much until you have to do it 8,000 times a day—enough to drive the most psychologically sound worker to despair. An average robot can mount very odd parts at one second per part. This means one robot can do the work of three human workers over three production shifts. To state it another way, one robot can replace nine workers (three workers x three shifts) in odd component assembly. With the average cost of an operator in China being approximately $5,000 a year, one robot can save up to 9+ human worker costs, or $45,000 a year in hard dollar savings (soft dollar savings come from no longer having to absorb the social and overhead burden costs). A general rule of thumb in the capital equipment sector is that new equipment purchases must achieve a two-year payback, which here would be $90,000. And that is a very realistic figure given the cost of today's robots. Manufacturers of pick-and-place machines are already starting to offer equipment to automate (very) odd component and final assembly of consumer electronics products.

Of course, it is not possible to make a clear universal statement about the best place to manufacture your goods. This requires an in-depth analysis, taking all the specific influencing factors into account. However, there is a clear trend afoot to move back home. **SMT**

Sjef van Gastel is manager for advanced development at Assembléon Netherlands B.V., where he combines his experience as systems architect and machine designer to explore technical and business opportunities from emerging technologies. To read past columns, or to contact van Gastel, click here.

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SMTonline Market News Highlights

LED Lighting System Market to Reach $55B by 2020

The LED lighting system market is expected to kick into high gear in 2013 and begin to grow rapidly from 2015. In terms of revenue, the market is expected to reach $55 billion by 2020, up from $93 million (2012), with a high growth rate of 92.4% CAGR.

Health Care: New Tech Focused on Quality Improvement

Soaring healthcare costs, accompanied by growing demand from aging populations and emerging economies, are fueling technological and business innovation to address an emerging need in an industry worth trillions of dollars, according to Lux Research.

Apple Faces New Challenge After Latest iPhone Release

The new 5S has dazzled onlookers with its fingerprint reader, while adding a better camera and a faster processor, but Dr. Klingebiel, Assistant Professor of Strategy at Warwick Business School, believes that Apple should go beyond product innovation and develop its strategy further as well.

Power Semiconductors in Automotive Industry to Witness Significant Growth

Environmental regulations, the electrification of the powertrain, the need for efficient power management, and the availability of new safety features are driving the global power semiconductor market in the automotive industry. The popularity of electric vehicles, which have a larger content for power semiconductors, is fueling installations.

Solid State Lighting Market to Reach $56.79 Billion by 2018

The global solid state lighting market is expected to reach $56.79 billion by 2018, at an estimated CAGR of 18.7% from 2013 to 2018 with backlighting and general lighting applications contributing to the global SSL applications market with a share of 87% in 2012. It is expected to record high growth in coming years.

Printed Electronics Market Continues to Grow

The global printed electronics market has become a widely growing sector in recent years due to the many benefits it offers, including long switching times, simple fabrication, and low fabrication cost. The Asia Pacific market holds majority of the market share, followed closely by North America.

Wearable Electronics Market to Reach $8.3 Billion in 2018

The market was worth $2.7 billion in revenue in 2012. In terms of product, wrist-wear accounted for the largest market revenue at $876.70 million, while neck-wear enjoyed the least market share, all as of 2012.

IPC's Costlow: N.A. Economy Slow, But Steady

A couple national manufacturing studies out this week highlight the continuing resurgence of American manufacturing. The economy may not be roaring back with any real speed, but it's seeing steady growth.

Global Semiconductor Market to Grow 3% in 2013

The worldwide semiconductor market is expected to grow 3% from 2012 to 2013. There has been sequential market growth from 1Q13 to 2Q13 and the vast majority of the top 20 vendors are expecting 3Q13 to grow revenues again.

U.S. CFO Economic Optimism Improves Entering 2H13

Top financial decision makers in the U.S. share an optimistic outlook towards the sustained economic recovery and opportunities for their businesses, according to findings from the most recent survey of CFOs conducted by Financial Executives International (FEI) and Baruch College's Zicklin School of Business.

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A SHORT SCOOP

Stencils for QFNs

by Rachel Short
PHOTOSTENCIL LLC

QFNs (quad flatpacks, no leads) and DFNs (dual flatpacks, no leads) are becoming more popular component packages, in part because they are ideal for small, hand-held devices. As stencil manufacturers, our thoughts immediately turn to the question, how do we design and manufacture a stencil for these devices? What materials should be used? What types of coatings? How should the apertures be designed to get the best solder paste release? How can we accommodate the reduced footprint and keep-out areas? QFNs present many challenges to the assembly printing process, but the short scoop is that with proper stencil design, correct stencil technology selection (laser, electroform, and nano-coat), and consideration for the effects of PCB soldermask layout choices, these challenges can be overcome.

QFNs have a very small form factor—they are typically .85mm thick with a body size from 3mm up to 12mm. This allows for smaller and lighter packages. Most QFNs have a metal pad on the underside for grounding and heat conduction. The leads and ground plane conductor are flat and in the same plane on the bottom of the package. DFNs have a similar center metal pad, but have leads on only two sides. This ground plane provides excellent electrical conductivity and offers better heat sink thermal properties when compared to other SMT packages. All these advantages make QFNs a good choice for high density electronics. So let's discuss the problems that arise when using these components and what you can do to handle the printing challenges associated with fabrication.

QFNs, by their nature, create printing challenges. The package can float during reflow if there is too much solder. Aperture size is a problem because the apertures are short and narrow posing difficulties for paste transfer. Solder mask configurations chosen during the board design phase influence the stencil design. Board repair can also be difficult to accomplish.

The leadless QFN package sits almost flush against the board, but will float during reflow and can misregister if there is too much solder applied in critical areas of the component footprint. If the larger center thermal pad is printed 1:1, the reflowed solder can float the component due to the solder surface tension overcoming the weight of the package. The QFN/DFN stand-off height is a function of center and perimeter joint cohesion force balance. Surface tension during reflow causes the solder to dome up at the geometric center of the pad. The difference in the size of the larger center pad causes a large center dome to lift above the perimeter lead attachment pads. This height differential can cause the leads on the QFN and the pads on the PCB to misregister as the component floats on the dome formed by the center pad. Fortunately, QFN float can be controlled by reducing the amount of solder paste printed on the ground plane. Typically, a 50 to 60% reduction will

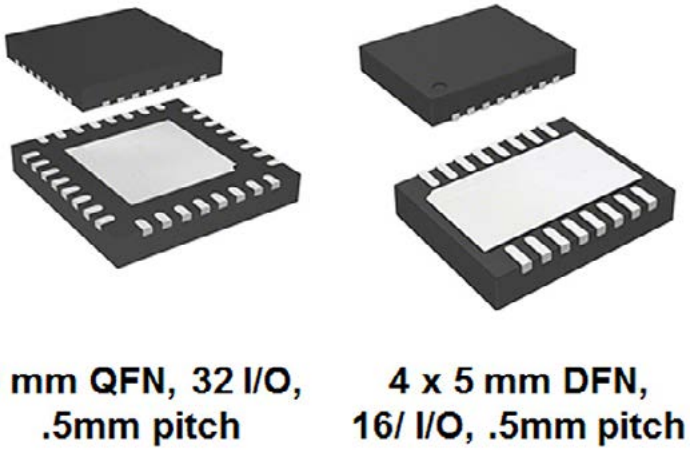

Figure 1: Examples of QFN/DFN.

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The Accelerating Technology Convergance in Medical Devices — Implications for the Future, Mark Kemp, President, Flextronics Medical

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STENCILS FOR QFNS *continues*

solve the QFN float problem, but the aperture reduction must be done judiciously. We recommend that a window pane aperture be used for most cases. This allows the solder paste volatiles to easily escape during reflow without moving the QFN device.

Why are area ratio and paste transfer critical issues? The side walls of the aperture hold the solder paste inside the aperture while the area under the aperture (pad on PCB) pulls the solder paste out of the aperture and away from the aperture walls. Compared to the pad area beneath the aperture, the larger the wall area, the more difficult it is for the paste to release from the aperture walls. For QFN and DFN packages, the required apertures have widths as low as 0.175mm and aperture lengths as low as 0.4mm so the area ratio is low, which can result in poor paste transfer.

IPC 7525B Stencil Design Guidelines for Area Ratio Standards recommends the following types of stencils for specific area ratios (AR):

AR> .90:	Laser-cut, high precision Chem-etch, Chem-etch
AR .66 to .90:	Laser-cut, high precision Chem-etch
AR .5 to .66:	Electroform stencils

Roughness of the aperture wall only makes matters worse giving the paste something to bite onto and preventing good paste release. Aperture wall smoothness is a key issue for proper paste transfer, particularly when the area ratio is small. For area ratios below .66 electroform stencils or nano-coated stencils are normally recommended.

Nano-coating on the aperture walls as well as on the bottom side (PCB side) of the stencil is a good solution for single level stencils without a step. Nano-coatings have a property called fluxophobicity. It is the stencil's ability to resist the spread of flux on its surface and is measured in the form of the flux contact angle. This is the angle that the flux forms when a drop is placed on the surface of the stencil. Nano-coating not only increases the paste's ability to release from the apertures, but also to resist spreading on the bottom side of the stencil when the paste is extruded into a cavity created by the NSMD-Window. Nano-coating eliminates the need for frequent under board wiping and reduces the occurrence of pad to pad bridging.

> ***Nano-coatings have a property called fluxophobicity. It is the stencil's ability to resist the spread of flux on its surface and is measured in the form of the flux contact angle.***

The solder mask windowing technique employed on the PCB can be a substantial determining factor for achieving the best result. There are three types of solder mask designs used for QFN and DFN packages:

a) SMD, where the pad opening on the board is defined by the solder mask

b) NSMD, where the pad itself defines the boundary of the pad and the solder mask is pulled back off the pad (typically .05 to .075mm per side)

c) NSMD-Window. In this last case there is no solder mask between pads so bridging between pads is more likely than with solder mask between pads.

Table 1 (a, b, and c) shows stencil design guidelines for these three solder mask cases. It shows package size, lead pitch, the number of I/Os, package lead dimensions, the recommended PCB pad dimensions, stencil aperture dimension, stencil thickness, and the resulting area ratio. For NSMD the stencil aperture for the pin connections should be 1:1 with the PCB pad dimension.

The last problem to be considered for the QFN and DFN package is unit repair. The first step to repair a defective QFN device is to remove the defective device from the PCB and clean the excess solder from the PCB pads. Solder paste is then printed either on the PCB or on

Stencil Aperture Design for SMD Mask										
Package	Pitch	I/O	Pkg Lead Width	Pkg Lead Length	PCB	PCB	Aperture	Aperture	Stencil Thickness	Area Ratio
3mm	.5mm	12	.23mm	.55mm	.23mm	.75mm	.18mm	.70mm	.125mm	0.57
4mm	.5mm	20	.25mm	.40mm	.25mm	.60mm	.20mm	.55mm	.125mm	0.59
7mm	.5mm	44	.25mm	.55mm	.25mm	.75mm	.20mm	.70mm	.125mm	0.62
10mm	.5mm	72	.23mm	.40mm	.23mm	.60mm	.18mm	.55mm	.125mm	0.54
12mm	.5mm	80	.25mm	.55mm	.25mm	.75mm	.20mm	.70mm	.125mm	0.62

Table 1a: Typically there is a reduction to the pad layout on the PCB. Area ratios are usually <.66, thus paste transfer is an issue. An electroformed stencil is normally recommended.

Stencil Aperture Design for NSMD Window Mask										
Package	Pitch	I/O	Pkg Lead Width	Pkg Lead Length	PCB	PCB	Aperture	Aperture	Stencil Thickness	Area Ratio
4mm	.4mm	32	.175mm	.45mm	.175mm	.610mm	.175mm	.560mm	.125mm	0.53
4mm	.4mm	32	.175mm	.45mm	.175mm	.610mm	.175mm	.560mm	.100mm	0.67

Table 1b: Typically 1-1 with the pad width layout on the PCB. Most .4 mm QFNs are NSMD window and even though the apertures are 1-1 with the pad width, area ratios are <.66. Stencils with smooth aperture walls such as electroformed stencils are recommended.

Stencil Aperture Design for NSMD Mask										
Package	Pitch	I/O	Pkg Lead Width	Pkg Lead Length	PCB	PCB	Aperture	Aperture	Stencil Thickness	Area Ratio
3mm	.5mm	12	.23mm	.55mm	.23mm	.75mm	.23mm	.75mm	.125mm	0.7
4mm	.5mm	20	.25mm	.40mm	.25mm	.60mm	.25mm	.60mm	.125mm	0.71
7mm	.5mm	44	.25mm	.55mm	.25mm	.75mm	.25mm	.75mm	.125mm	0.75
10mm	.5mm	72	.23mm	.40mm	.23mm	.60mm	.23mm	.60mm	.125mm	0.71
12mm	.5mm	80	.25mm	.55mm	.25mm	.75mm	.25mm	.75mm	.125mm	0.75

Table 1c: Typically 1-1 with the pad layout on the PCB. Area ratios are typically >.70, thus paste transfer is not an issue.

the bottom of the QFN prior to placing the QFN on the PCB and locally heating to reflow the solder paste and solder the device in place. Mini stencils are normally used to print paste on the PCB. This can be a difficult and tedious task for very small QFN devices. Printing solder paste directly onto the QFN device is a more popular approach to solving the rework problem.

While the basic challenges of continually denser package attachments are not new, the specifics of how to effectively deal with the new component types requires subtle tailoring. You can see that when it comes to optimizing your design for QFN and DFN packages there are a lot of things to consider, from the initial design of the solder mask opening to your selection of the proper stencil type and finish. As component packages continue to evolve and push the envelope, fabricating with new attachment patterns will pose challenges to the manufacturer for continued production of high quality, high yield assemblies. At Photo Stencil, we are always available to provide the assistance and experience needed to optimize a stencil for your unique design requirements. **SMT**

Rachel Short is vice president of sales and marketing at PhotoStencil LLC. She may be reached via e-mail, or by phone at 719-304-4224.

Mil/Aero007 News Highlights

Sparton Secures DARPA Contract for UFP Program

The company was awarded a Phase 1 contract for the Defense Advanced Research Projects Agency (DARPA) Upward Falling Payload (UFP) program. Sparton will design a system intended to live on the sea floor and release payloads. This enablement would represent a game-changing capability for mission commanders.

Positive Q4 Results Position OSI Systems for Growth

Deepak Chopra, OSI Systems president and CEO, stated, "During the fourth quarter, our Security Division achieved record operating profits as the higher margin turnkey screening solution business was a key factor in increasing our operating margins from 7% in fiscal 2012 to 16% in fiscal 2013."

OnCore's Tijuana Mexico Facility Earns ISO14001:2004

"This marks the third of the OnCore locations to achieve this important environmental compliance certification," stated Tony Batalha, vice president of quality. "We are continuing to expand the ISO14001 certification activity to all of our locations in our effort to deliver common processes across all of the OnCore sites worldwide."

Plexus Expands Operations in Guadalajara, Mexico

Todd Kelsey, executive vice president and chief operating officer commented, "As part of our strategic planning process, we carefully evaluate the Plexus value proposition and service offerings of each of our regions to ensure we meet our customers' current and future needs."

Unmanned Surface Vessels Set to Conquer the Seas

Unmanned surface vessels still lag far behind their aerial equivalents in terms of technical capabilities, technology, and deployment. However, new threats, cost-benefit calculations, operational experiences in the past decade, and new technological developments are driving rapid growth in the market.

Sparton, USSI JV Nets $10.8M Sonobuoy Contract

Sparton Corporation and Ultra Electronics—USSI, a subsidiary of Ultra Electronics Holdings plc, announce the award of subcontracts valued at $10.8 million to their ERAPSCO joint venture, for the manufacture of sonobuoys for the United States Navy.

Russia to Overtake West in Defence, Growth, Electronics

Steen Lomholt-Thomsen, IHS senior vice president, EMEA, said, "Russia is an exceptional opportunity. While leaders globally are concerned and cautious about geopolitical instability and economic volatility, business sentiment is rising in Russia."

OSI Electronics Acquires Briton EMS

Paul Morben, OSI Electronics' president, commented, "This acquisition adds a very valuable UK manufacturing operation to our organization. The Bedford team has considerable experience in managing the complete manufacturing operation from initial design ideas to the finished, tested, and delivered product."

Zero Defects International Earns ITAR Registration

Zero Defects International (ZDI) has received notice of ITAR registration. ITAR is a U.S. State Department program which regulates the export and import of military and defense related equipment and information.

China's Aero & Defense Industry Seeing Rapid Growth

With a rapidly growing government budget for the defense sector, the Chinese aerospace and defense industry is witnessing the growth of many multinational companies who are setting up in the country and also actively indulging in joint ventures with Chinese companies.

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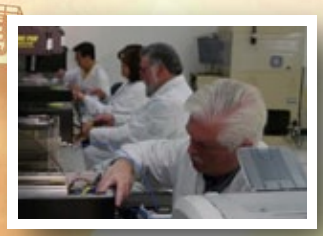
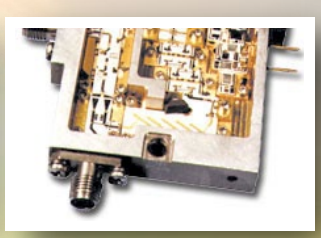
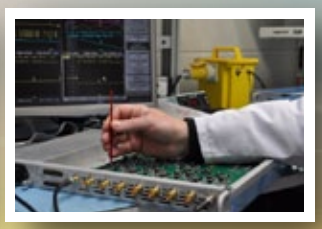


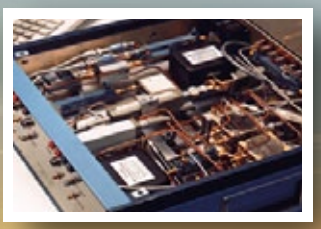
AS-9100C ELECTRONIC MANUFACTURING SERVICES



COMPLEX RF ASSEMBLIES



FUNCTIONAL RF TESTING TO 77 GHz



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ZULKI'S PCB NUGGETS

Get Another Look Into AOI

by Zulki Khan
NEXLOGIC TECHNOLOGIES INC.

PCB inspection is taking on greater significance as boards and packaging become increasingly smaller, with greater functionality. Automated optical inspection (AOI) and its backup associate, X-ray, team up to catch a variety of board assembly problems. But it's AOI that's at the forefront of this process.

AOI takes on a variety of key assignments, such as checking out the numbers labeled on passive and active devices and matching them with the database to assure they're legitimate components, as specified in the BOM. Also, if alternate parts are used, the AOI machine is trained to verify them, regardless of manufacturer, as long as the device has the same footprint, value, tolerance, voltage, package type, etc.

That's only the beginning. AOI is excellent at detecting missing or wrong components and misalignments. If a component is misaligned, say at 30° or 45°, AOI catches it. It also catches opens and bridging, and it can check for skewed parts and tombstoning (Figure 1). AOI can detect anything as long as it's written on the component.

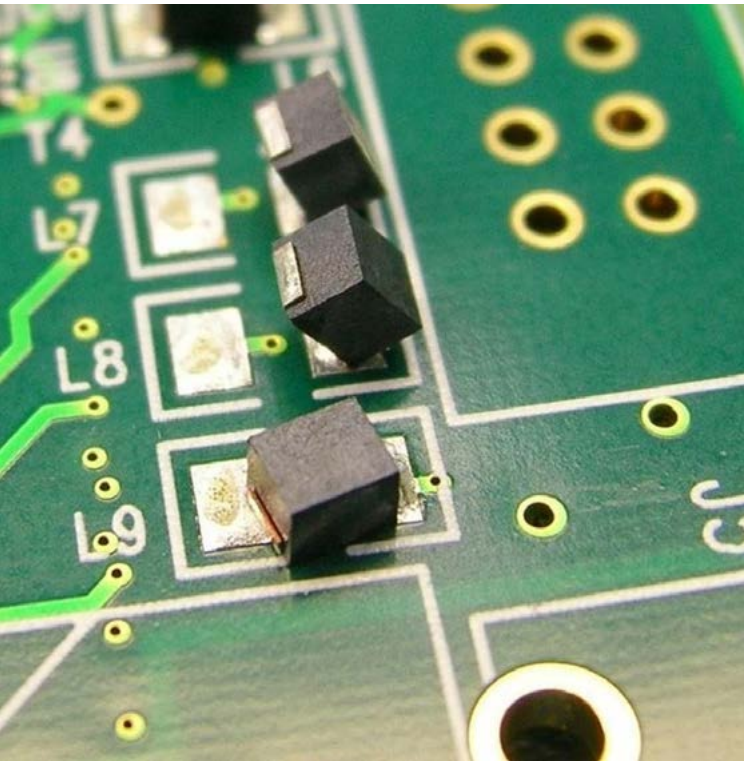

Figure 1: An example of tombstoning.

Detecting date codes on active components is especially important for medical and mil/aero products. These industries do not want to use components that are four or five years old, so a date code of 9/2007 would be out of the question, but a date code of 9/2012 would be fine.

Normally, this is a kit audit function when the audit is performed in the stock room. There, personnel check for the value of the components, their types, and tolerances and match it with the BOM. AOI then supplements date code detection and rejects boards that are out of the date code the customer authorizes.

Unfortunately, there is one particular detection area where AOI falls short, and that is at detecting a marginal connection between a component lead and the PCB's surface. X-ray can help somewhat, but it's the trained eye of the QC technician that can detect these types of marginal connections and resolve them on the spot.

AOI is adept at catching problems associated with passive devices like capacitors, resistors, and inductors and problems related to active devices, especially those with leads extending from the package, like gull-wing and J-leads. AOI can easily see and catch solder defects.

The AOI process works by viewing a component and matching it with the components on the golden board. Fitted with solder pattern matching, it can look at ICs; with the edge locator functionality, AOI can detect the edge of the component. This process can look at the component on the board and recognize through its video processing capabilities where the component starts and what it looks like.

AOI does have a tough time, however, inspecting LGAs, BGAs, micro BGAs, CSPs, micro CSPs, flip chips, and similar packaging. This type

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GET ANOTHER LOOK INTO AOI *continues*

of device packaging has its leads, balls, or bumps under the package, so that AOI cannot see them. It can only view top surfaces of the components and recognize components and see the sides of these bodies to include the leads and assure the viewing of solder patterns.

But even when AOI is not able to catch a defect, X-ray is able to. In other words, between the two, with AOI leading the charge, defects are captured to maintain high board integrity and reliability.

Getting a Handle on AOI

But what's truly important for OEMs is having a good handle on what's good and not so good when it comes to AOI technology. All AOI machines are not created equal. The internal algorithms play an important role in catching most of the defects and differentiate the most effective AOI machines from the least effective. The more powerful the algorithms, the more precise the AOI search is for zeroing in on defects.

Additionally, for viewing purposes, some AOI machines use two cameras, while others have four. Some have an array of cameras for top, bottom, and angle viewing at 45°. Obviously, the more cameras and viewing angles, the better the AOI machine can catch defects. In certain cases, there may be some marking or laser cut on a component's top side, and it can only be read if the AOI machine has a side angle camera.

Even with those advances, AOI still needs improvement, especially when it comes to ever-shrinking PCB real estate and smaller packaging. Here, I'm talking about the camera's image-processing capabilities, the pixel size of the camera lens and the camera's magnification or zoom level. Pixel size is of utmost importance when PCB real estate is scarce. So you need powerful devices with high pixel count to assure the tiny numbers and characters written on a0201 are correctly read, are either good or bad, and are placed on the PCB according to the BOM.

Also, you've got to look carefully at whether an AOI's lighting system is based on conventional light sources or LEDs. An LED dome system is the best, with excellent brightness with sharp focus on components that can uniformly view the inspection area and detect flaws and defects. The uniformity and angle of the light source must

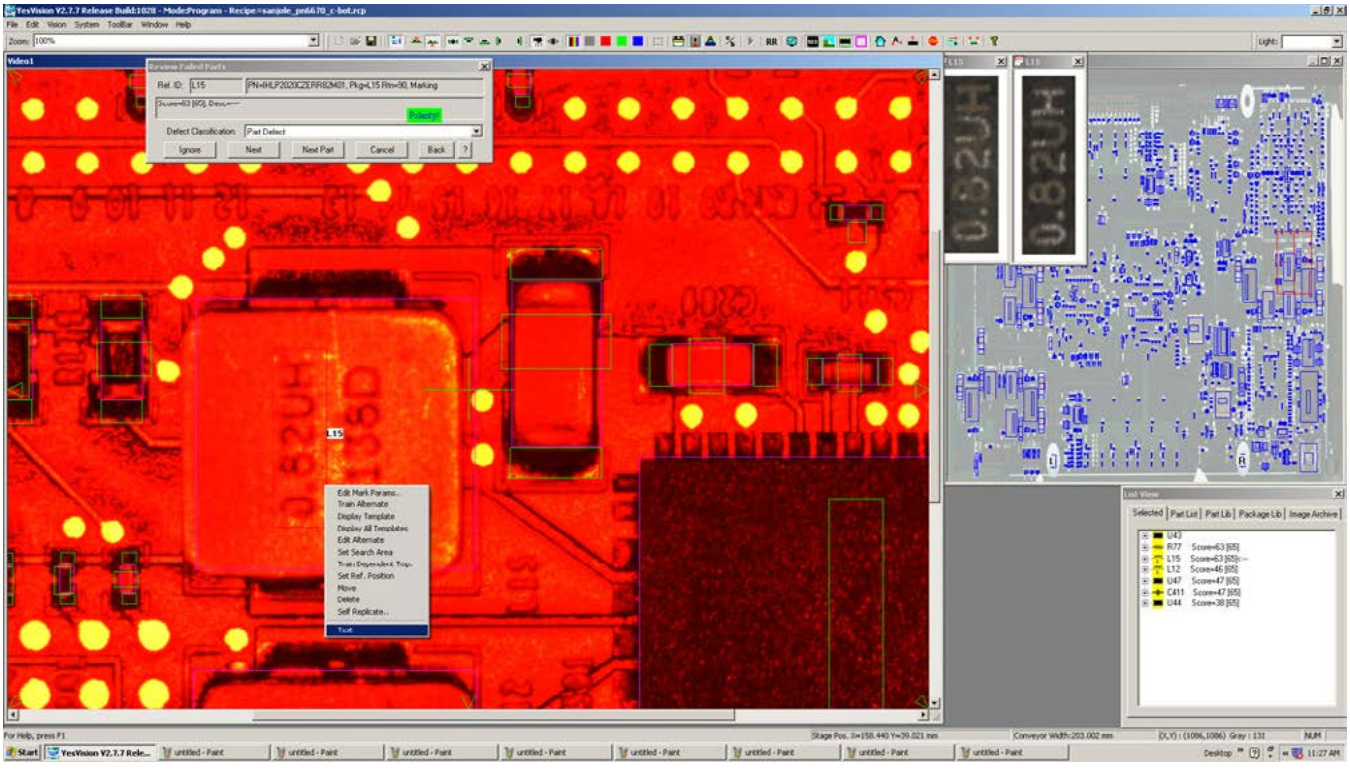

Figure 2: Inspection under orange light.

be uniform throughout the subject target, also known as "region of interest."

A good AOI machine also tests colors. This is where color inspection and pattern matching come in. This involves shining light with different intensity, brightness, and colors. At times, a component's numbering is white; if it's exposed to white light, a blank is shown, and AOI cannot read it. Instead, AOI changes light brightness and color and sends a blue or orange light, allowing it to read numbers written on top of both active and passive components (Figure 2).

As for through-hole assembly, AOI can read a device's bands to assure that the right components are used, and that the tolerances are correct. There may be a 50-ohm resistor, but the OEM is looking for a 1% tolerance. It's the right component of 50 ohms value, but it's only 10% and not 1%. Earlier-generation AOI might not have been able to catch this component tolerance or other finer details. But the more advanced AOI methodologies can detect, catch, and flag it.

When it comes to tall devices like vertical heat sinks, there's a special caution because they might hinder AOI, which works most efficiently at an optimal distance from a high-magnification camera in relation to the target size. AOI's light may also cast a shadow on adjoining components, causing them to go dark, and preventing inspection. The resolution to the tall components issue is to not install these hindrance-imposing components prior to the AOI process. Then, they can be manually installed as a secondary operation and visually checked after AOI is finished.

Programmer and Operator Expertise

Let's segue into the importance of operator expertise. Knowing how to expertly deal with PCBs fitted with tall components and a variety of vertical heat sinks is especially important today, as boards have greater functionality and an increasing need for thermal dissipation. But even beyond this area, the AOI operator must fully understand the strengths of AOI and how best to perform the inspection process. For example, solder fillets or below par solder joints pose one particular issue that demands considerable time, patience, and a well-trained eye.

Additionally, AOI presents questionable components connections, and it's up to the operator to make sure these defects are either accurate or false. One thing they must be mindful of is defining the tolerance of inspection window in the region of interest to be as tight as possible so that the window can accurately read components on the board.

Look Out For Poorly Trained AOI

As mentioned previously, AOI must be trained to verify alternate components. There's considerably more to this than meets the eye, but there are some key points to know.

AOI scans the PCB and looks at the components and matches them according to the BOM. A picture of each component is captured and that component is trained as part of the overall process. In short, training means telling the AOI machine's algorithm that the component is acceptable. Also, this defines a certain window that profiles the size of the inspection area to include size, length, and width.

Regardless of the component's manufacturer, a component and its alternates must undergo this AOI training. If this step is overlooked or miscalculated, the AOI machine will spit out so many false values that it will stop after a few seconds.

Consequently, it will take an inordinate amount of time to inspect one board because the technician has to resort to manual inspection using a microscope or magnifying glass. For example, AOI takes anywhere from 30–45 seconds per board, but a QC inspector might take 15–20 minutes. Plus, manual inspection is prone to human errors and poor reliability.

The takeaway in this column is that the OEM should be wary of using AOI for its products. Given the fact that board technologies are constantly changing and getting smaller, like the 01005 resistor, an OEM's PCB order today demands state-of-the-art AOI to avoid costly and time-consuming mistakes and worse, latent field failures. **SMT**

Zulki Khan is the founder and president of NexLogic Technologies, Inc. To read past columns, or to contact the author, click here.

TOP TEN

News Highlights from SMTonline this Month

1 Sparton Enjoys 42% Sales Growth in Q4

Cary Wood, president and CEO, commented, "We are extremely pleased with our fiscal year financial results that include sales increasing 19% to $266 million and adjusted EBITDA expansion of 33% to $22.1 million, as well as $1.17 adjusted earnings per share, which was 29% higher than the previous year's $0.91 adjusted earnings per share diluted."

2 Flextronics to Acquire RIWISA; Expands Medical Solutions

"The addition of RIWISA's precision plastics and automation capabilities to Flextronics Medical is a tremendous complement to the broad range of healthcare solutions we can offer our customers globally and underscores the strategic commitment we have made to expand our services in this market," said Mark Kemp, president of Flextronics Medical.

3 Asian Circuits Now Offers Free DFM Service

"The DFM Service is one of the features of our PCB Assembly service that our clients highly value," says Qin Mei Kuan, technical support specialist. "By having our engineers verify a client's files, errors can be prevented prior to production, which in turn can significantly reduce the total cost of manufacturing."

4 Flextronics Ireland Now Certified to ISO 13485 Standards

The company has received an ISO 13485 certification for its Raheen site in Limerick, Ireland. The certification demonstrates the existence of a highly-effective quality management system that meets international regulatory, safety, and quality concerns specific to the medical device industry.

5 Absolute EMS, Ionics EMS Collaborate; Boost Capacity

"We have partnered with Ionics EMS, the premier EMS provider in the Philippines, to increase our production capabilities and capacity to align with the needs of our most successful customers and their need to scale volumes quickly and easily to handle growth on demand," said President Dave Kichar at Absolute.

6 ESCATEC Supplies Temp Monitors to Berlinger & Co.

The company is building nearly a third of a million temperature monitors a year for Berlinger & Co, of Switzerland. The monitors, which cost a few dollars each, monitor the temperature of goods in transit and storage.

7 Microtronix Boosts Productivity; Adds New Universal Line

Microtronix Manufacturing recently added two Universal Advantis® AC-90T Platforms, one Genesis GX-11S Platform with a Direct Tray Feeder, and a Line Manager software module to its production facility in Johannesburg, Gauteng, South Africa.

8 Elecsys EMS Sales Soar 69% in Q1

Sales for the company's EMS business segment increased approximately 69% to $4,308,000 for the quarter ended July 31, 2013. The increase of approximately $1,754,000 in EMS revenues resulted from increased orders from certain existing customers combined with the addition of several new customers during the period.

9 Neways Reports 6% Revenue Increase in Q2

Neways recorded an increase of 6% in turnover and an improved profit in the second quarter compared to the first quarter of 2013. Net turnover for the first half of 2013 came in at EUR 131.4 million, down 9% compared with the same period of last year.

10 Bittele Electronics Reports Double-digit Growth in 2012

"Throughout this past year, we experienced strong demand for our PCB assembly which emphasizes high quality with fast turnaround," stated Ben Yang, president and CEO. "Our customer list expanded to hundreds of new corporations and we deepened our business activity with existing Fortune 500 customers."

EVENTS

For the IPC's Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar, click here.

For a complete listing, check out *SMT Magazine's* full events calendar here.

2013 SMART Group European Conference
October 2–3, 2013
Oxfordshire, UK

RFID in the High-Tech
October 2–3, 2013
San Francisco, California, USA

Long Island SMTA Expo and Technical Forum
October 9, 2013
Islandia, New York, USA

IEEE SMC 2013
October 13–16, 2013
Manchester, UK

electronicAsia
October 13–16, 2013
Hong Kong

SMTA International
October 13–17, 2013
Fort Worth, Texas, USA

SMTA Harsh Environments Symposium
October 14–15, 2013
Fort Worth, Texas, USA

SMC 2013
October 16–17, 2013
Santa Clara, California USA

2013 CEA Industry Forum
October 20–23, 2013
Los Angeles, California, USA

IMPACT-IAAC 2013
October 22–25, 2013
Taipei, Taiwan

TPCA Show 2013
October 23–25, 2013
Taipei, Taiwan

IEEE-SA Symposium on EDA Interoperability
October 24, 2013
Santa Clara, California, USA

Conformal Coating Reliability Seminar
October 24, 2013
Greater London, UK

MRO ASIA
October 29–31, 2013
Singapore

International Wafer-Level Packaging Conference
November 4–7, 2013
San Jose, California, USA

LA/Orange County Expo & Tech Forum
November 5, 2013
Long Beach, California, USA

productronica 2013
November 12–15
Munich, Germany

SMTA/iNEMI Medical Electronics Symposium—Tabletop Exhibition
November 12, 2013
Milipitas, California,USA

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Next Month in *SMT Magazine:*

Rework, Modification & Repair

No one likes to repair packages. And the rework and repair of advanced packages is becoming increasingly complex, not to mention expensive. Next month, our veteran contributors explore the ins and outs of repairing packages such as large area arrays and column grid array assemblies.

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