smtmagazine.com

ENGINEERING SOLUTIONS FOR PCB MANUFACTURING

SMT®

MARCH 2014

AN I-CONNECT007 PUBLICATION

SMT ASSEMBLY, PART 2: Making the Connections

SHOW PREVIEW
APEX EXPO IPC 2014

Assembly Process Feasibility

of Low/No Silver Alloy Solder Paste Materials

by Jennifer Nguyen, et al. – pg. 18

thepcblist

***THE* best way to find a PCB fabricator, anywhere.**

Dragon Circuits (formerly North Texas Circuit Board - NTCB)

Grand Prairie, Texas, U.S.A.

Website | Contact Me | RFQ

Overview | Contact | Specs | About | Videos | Photos | Brochures | News

Formerly known as North Texas Circuit Board (NTCB), Dragon Circuits has been fabricating printed circuit boards for over 35 years. DCI is known for its high layer count multilayers, rigid flex and aerospace/military applications.

Markets:	Communication, Computers, Consumer, Industrial, Medical, Military/Aerospace, Other: Semiconductor Test Boards, RF Boards, Heavy Copper, High Aspect Ratio Holes
Board Types:	Single-sided, Double-sided, Multilayer, Flex, Rigid-Flex
Mfg Volumes:	Prototype, Small, Medium, Large
Other Services:	CAD, Consulting, Mass lamina[illegible]on, PCB layout, Quick turn-around, Turn-key
Speci[illegible]	Blind/buried vias, Bonded heat [illegible] [illegible]led Impedance, Filled/plugged vias, [illegible]
	[illegible]S-9100, ISO 9001, ITAR registere[illegible] [illegible]IL-PRF-55110

Click here to see a demo

Why YOU should Showcase:

- Capabilities listing for advanced search functionality
- Specialties and certifications listing
- Ability to upload brochures and videos
- Quick and easy "Contact" and "RFQ" buttons
- News, web and contact links

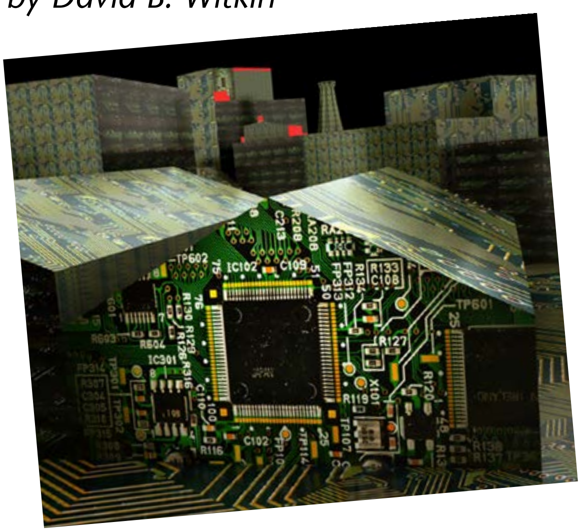
Click to see a partial list of registered OEMs!

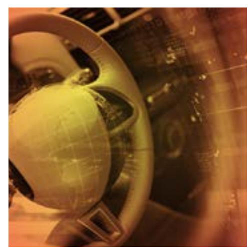
www.thepcblist.com

March 2014 Featured Content

SMT ASSEMBLY, PART 2

In Part 2 of our series, *SMT Magazine* helps you make all of your connections! This month, we dig deeper into the no-clean vs. water-soluble solder paste argument, the overstress of components during the soldering process, the feasibility of low/no-silver solder pastes, the influence of microstructure on bismuth lead-free solders, and high-temperature assembly materials.





The SMT Source™
Latest News About Manncorp SMT Assembly Equipment
March 2014

New Equipment for High-Mix Development & Production

Profilable Batch Reflow Oven

Android-controlled reflow system; preheat, soak, reflow, cooling; Wi-Fi data transfer

MC-301 **$4,995**

More Info

Dual-Head Pick and Place System

Place 01005 chips, BGAs, and 12 mil QFPs; up to 128 smart feeder ports; 14" x 17" PCB capacity

MC-385V2V **$59,995**

More Info

Vapor Phase Reflow System

Never overheat assemblies; compact, efficient, and oxidation-free; 20"x 20" capacity; profilable

VP500X **$43,900**

More Info

Fine-Pitch Stencil Printer

01005 through 12 mil QFP printing; 19" x 15.75" print area; programmable speed, stroke, snap-off

PB2300 **$24,995**

More Info

See Them All at APEX Booth #2070

Manncorp™

East Coast (Huntingdon Valley, PA) 800.PIK.MANN (745.6266) • West Coast (San Diego, CA) 888.PIK.MANN (745.6266)
Mexico: 52 1 656 217 8215

MARCH 2014
VOLUME 29
NUMBER 3
www.smtmagazine.com

SMT

ENGINEERING
SOLUTIONS
FOR PCB
MANUFACTURING

AN I-CONNECT007 PUBLICATION

CONTENTS


CLICK FOR VIDEO PRESENTATION
PCBnet.com
FREE PARTS
WE'RE NOT KIDDING!
LET US FABRICATE AND ASSEMBLE YOUR BOARDS, AND WE WILL PAY UP TO $500 FOR THE PARTS.
FIRST TIME CUSTOMERS ONLY
UP TO 10 PIECES
imagineering inc.
www.PCBnet.com
(847) 806-0003 · sales@pcbnet.com

THE WAY I SEE IT

Electric Cars Are the Future

by Ray Rasmussen
PUBLISHER, I-CONNECT007

Although I'm an environmentalist at heart (where would we be without the Clean Water and Clean Air acts?), this article isn't driven by that bent. I don't have solar panels powering my house because it doesn't make financial sense, and I won't buy an electric car until it does, either. I guess I'm a practical environmentalist. But the adoption of electric cars as the main source of personal transportation, worldwide, is a done deal and it's coming, fast.

Of course, I'm no expert, but when you see just about every car manufacturer on the planet introducing or developing electric cars, you have to believe they see the writing on the wall. From what I've read, there will be seven new electric cars (in addition to the 14 on the market in the U.S. today) entering the market in 2014 and lots more in 2015. Many of these will be pure electrics, not hybrids. For me, the tipping point is a 200-mile battery range. I don't mind paying more, initially, for an electric car since I'll be saving about $3 for every gas-equivalent gallon of electricity I buy, adding up to thousands in savings each year, but I've got to have more range.

But think of this: As the cost of these cars comes down, and as the cost of gas continues to rise, buying an electric car will basically be free, with the difference in the cost of fuel offsetting the monthly payment. That's when the market's going to explode. When the monthly cost of owning an electric vehicle, including electricity, is less than what it costs to fuel a gas powered car, people will be lining up to buy them. You'll see it in Europe, first, where gas is about $8 per gallon. Electrics will be an easy decision once the range issue is settled. And if you're paying attention at all, you've certainly noticed the billions of dollars flowing into battery R&D. Most major car companies see a 200-mile range battery for an average priced car hitting the market in the next few years. Tesla already does this if you're willing to pay $70k.

Another game-changer is that these cars perform better than their internal combustion engine (ICE) cousins. You get a lower cost for fuel, a safer vehicle for your family to ride around in, lower maintenance costs, higher reliability and a more powerful and better driving experience. That's why it's a game-changer.

Why fight it? The only thing holding back electric cars are the batteries' cost and range. That's it. Everything else is vastly superior to cars powered by ICEs.

Rimac's concept electric "supercar."

ELECTRIC CARS ARE THE FUTURE *continues*

Pundits of ICE-powered cars tout the improving efficiency as proof that there's a lot of life left in this 150-year-old technology. I disagree. ICEs are too complicated and costly (environmentally and geopolitically). By comparison, they're slow, noisy and smelly.

Here's what convinced me: I recently changed the spark plugs and spark plug wires on my 2005 Chevy Malibu, which had 100,000 miles on it. Three cylinders were upfront (really easy to get to) and three were up against the firewall with little room to get to the plugs. I got the job done, but it was a bear. Of course, shortly thereafter an engine warning light came on and after some Google searches I determined that I had to change the thermostat, which I did after draining all the radiator fluid. I had to dispose of the old fluid, buy more and refill the radiator. Sometime later, another warning light suggested I was low on oil. I guess my car was showing its age by requiring more oil than usual. In the past, I hadn't had to add any oil between oil changes. Then, another warning light indicated (after more Google searches) I needed a new gas cap since my original factory cap was causing the fuel system to lose pressure. That's when I knew the gasoline-powered car was finished. The ever-increasing complexity required by ICEs to meet the stringent government efficiency standards makes the ICEs a losing proposition. They can't compete.

Electric cars don't need oil; they don't need to be cooled and therefore have no radiators. They don't have a gas tank (a bomb, literally), either. Electric motors have worked reliably by the millions, day in and day out for years without any, or very little, maintenance. Electric cars are very powerful and will shame any ICE comparable car off the line. You see it more and more at local drag strips as electrics take on ICE muscle cars, crushing them in head-to-head duels. Global refueling stations (a plug) are already in place in every commercial building and in just about every home on the planet. Oh, and,

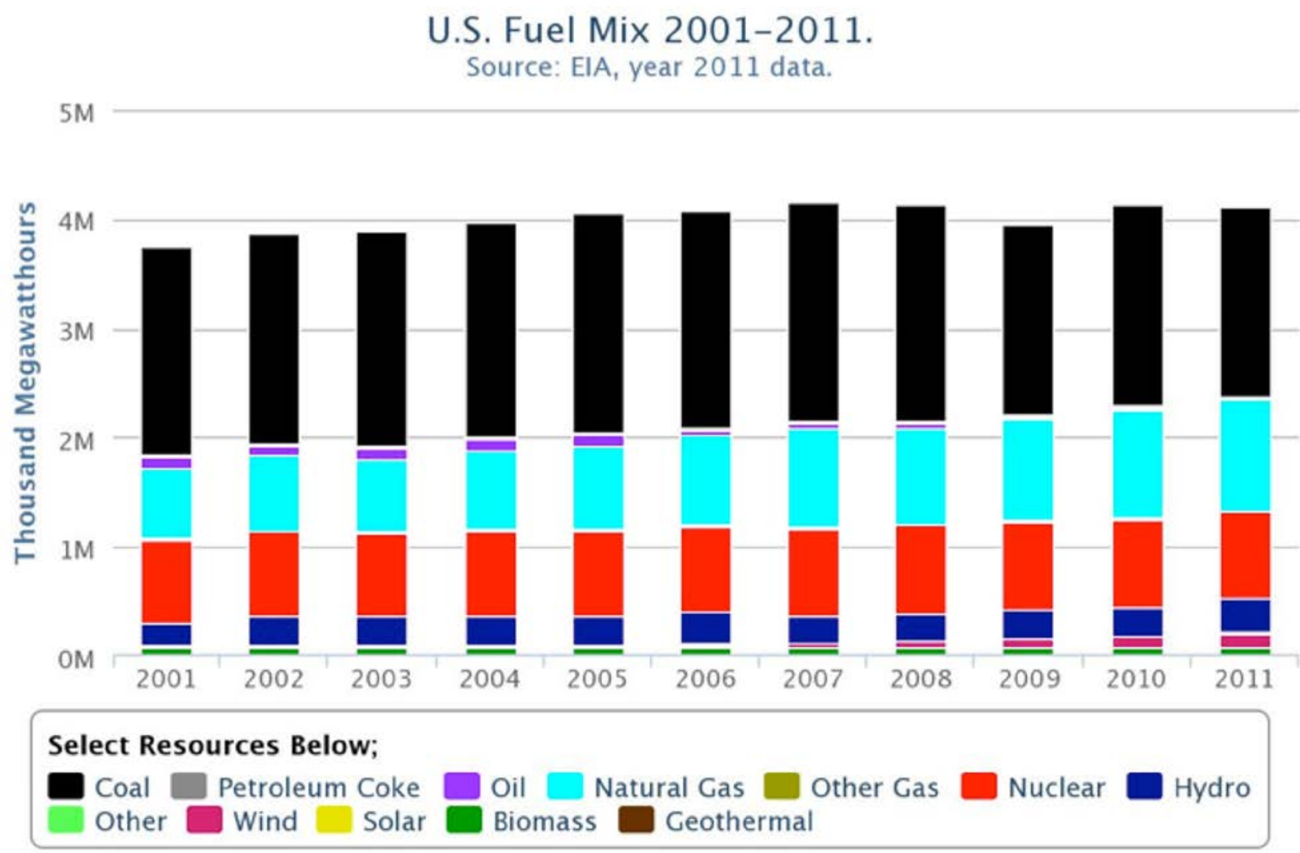


Figure 1.

they don't pollute, directly. Their sources do, mostly coal and natural gas, but the rest don't unless you consider nuclear and its very long term, long life to be pollution. But an electric car powered by mostly wind, hydro or solar doesn't pollute, and it doesn't contribute to the U.S.'s need to keep petroleum supply lines open in the Middle East. It actually does contribute to the stability of the long-term U.S. energy picture. It's a beautiful thing.

What does this mean to us in the PCB and EMS industries? Not too much since more and more electronics have been added to ICE power trains over the years. Instead of ICE controllers and sensors, electronics in electrics will control and monitor AC motors, the transmissions and the batteries. The brake controllers will be a bit more sophisticated because of the regenerative braking. Electronics for safety and entertainment will likely progress along the same path as ICE electronics. Adding solar into the roofs of electric cars, which Ford just announced it will be doing, will contribute a bit more electronics, as well. I think we just need to be aware of what's coming. Will companies like Tesla emerge as major automakers in the coming years? One company already in prime position with Tesla is Viasystems, which makes all of the PCBs, assemblies and battery buss bars for Tesla's cars.

What about Fisker and BYD? Warren Buffet made a large investment in BYD a few years ago. They plan a bunch of new electrics in the coming years. Fisker is building a high-end Tesla-like car. For our industry, it's more about the winners and losers. When the industry shifts to electrics, who will be left standing, and are they on your customer list?

Check out this concept car from Rimac. They're calling it a "supercar."

What we also see happening, as batteries improve, is a move away from gas-powered tools. Laptop batteries did a lot to advance this market. There are entire companies now building lines of outdoor power tools to replace gas-powered lawnmowers, trimmers, blowers, etc., and you'll see more and more electric motorcycles and bikes hitting the streets. They're working on electrics for planes (manned and unmanned). They're a lot quieter and more reliable. Dyson, the vacuum cleaner maker, believes that their new battery-powered vacuum cleaner, the DC59, could potentially replace corded vacuums—it cleans that well. All these products need electronic controls. That's where we come in.

There is another major impact of the electric car, which isn't being discussed too much: its impact on the fossil fuel industry. Combined with solar, the predictions are that within the next 10 to 15 years, many utilities will be out of the power generation business. That's the prediction in a new book from Stanford University lecturer Tony Seba. As the cost of solar drops, solar electricity will continue to be integrated into the energy mix. As consumers and businesses alike choose to lower their energy costs by installing solar panels, there will be a continual decline in the need for utilities to provide energy, relegating them to maintaining the grid as opposed to providing energy. Electric cars accelerate the consumer's move to residential solar systems since they help justify the system costs by offsetting the high price of gasoline. It's an interesting transition and we get a front-row seat in watching this transition from fossil fuels to an all-electric economy based on renewable energy.

Conclusion

Electric cars don't just offer an alternative form of fuel like diesel or hydrogen; the technology is *disruptive*. The dramatic reduction in fuel costs, the way the fuel (energy) is distributed and the simplification of the entire powerdrivetrain is a game-changer. That's why, once we get the batteries in place, the shift will happen almost overnight. Buying an electric car, for most, will be a no-brainer and in many cases "free." We certainly live in exciting times!

That's the way I see it. **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.

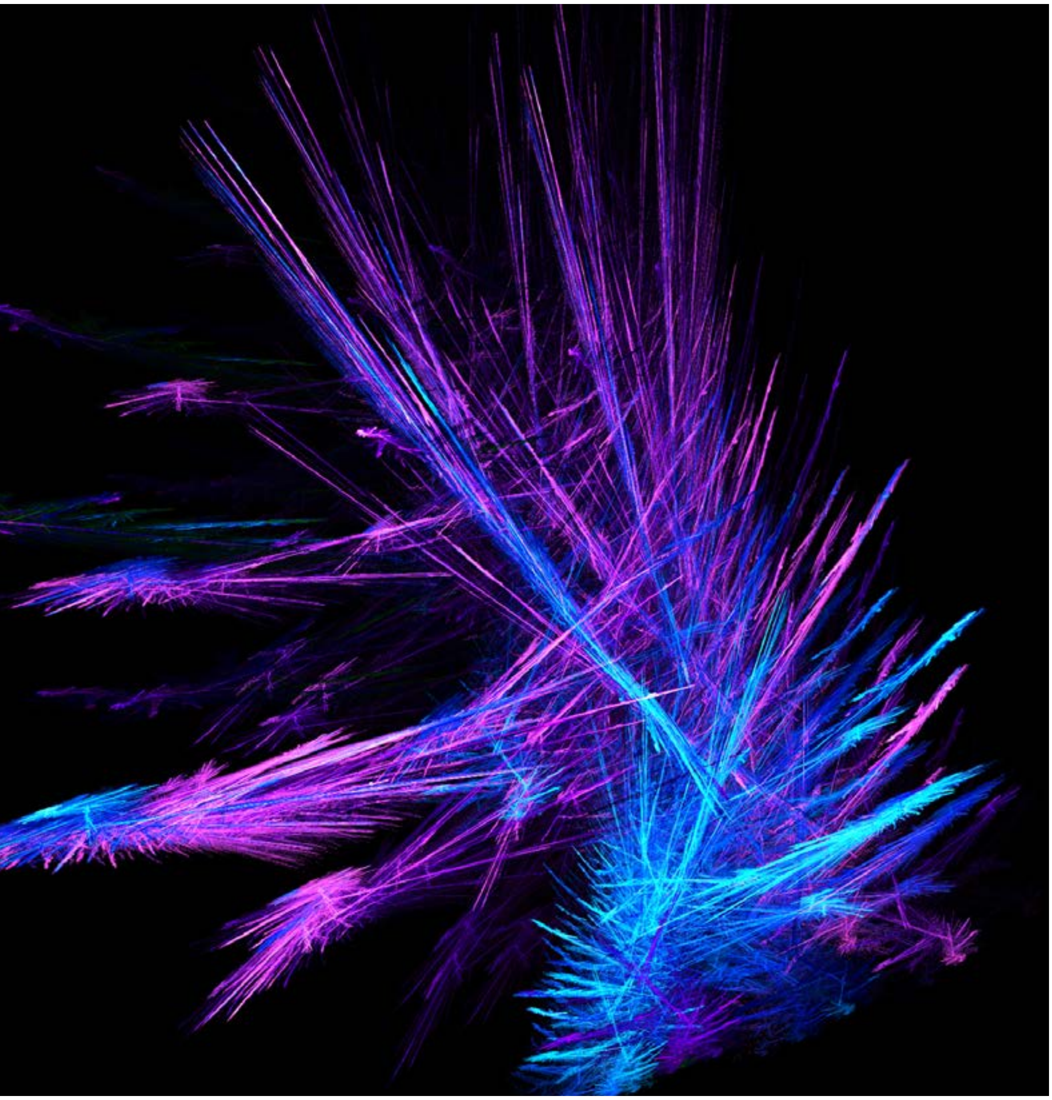
SMT PROSPECTS & PERSPECTIVES

Tin Whiskers, Part 4: Causes and Contributing Factors

by Dr. Jennie S. Hwang
H-TECHNOLOGIES GROUP

In this installment of the tin whisker series, we'll take a look at causes and factors that have been found or are considered to contribute to the appearance of tin whiskers. In the remaining installments, we will address *"Tin Whiskers—Plausible Theory," "Tin Whiskers—Impact of Testing Conditions,"* and *"Tin Whiskers—Preventive and Mitigating Measures."*

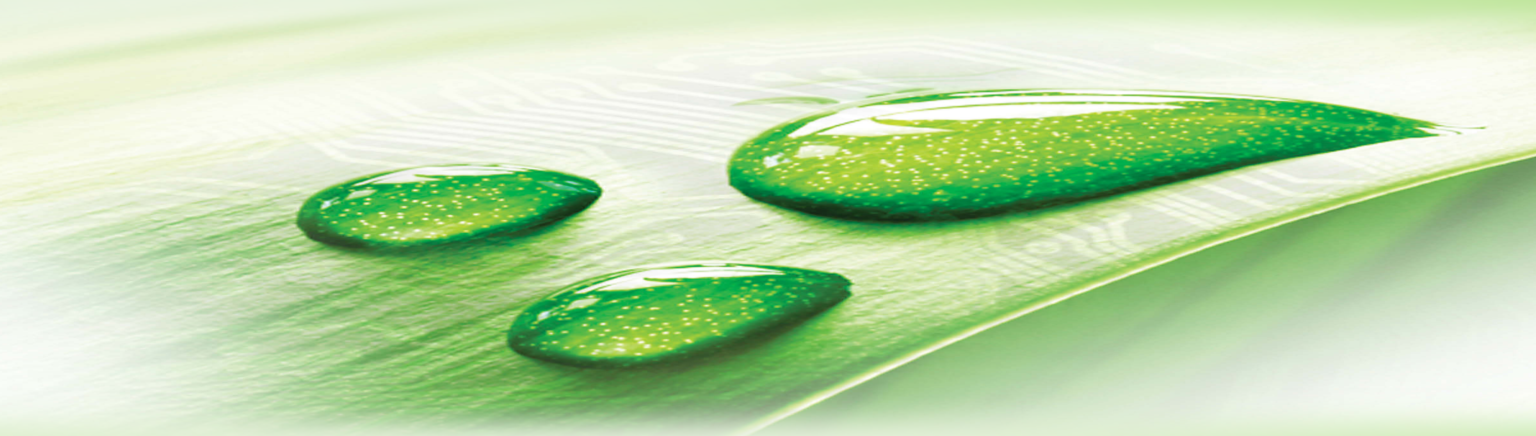
As all-encompassing tests to confirm or deny the culprits that cause tin whiskers are prohibitively costly and time-consuming, my thoughts focus on the logical causes and contributors. Fundamentally, the tin whisker follows the basic physical metallurgy in its principles on nucleation and crystal growth through the classic theories of dislocation dynamics and of other lattice defects in tin crystal structure. Thus, for whiskers to appear from the tin-plated (or tin-coated) surface, the causes and contributing factors should be intimately related to the nucleation sites creation and the subsequent growth paths after the coating process. However, for tin whisker due to tin's intrinsic characteristics, the actual processes of nucleation and grain growth are dauntingly complex.



Nucleation and growth can be encouraged by stresses introduced during and after the plating process. The sources of these stresses come from multi-fronts. This includes residual stresses caused by electroplating and/or additional stresses imposed after plating, and/or the induced stresses by foreign elements, and/or thermally-induced stresses. Specific causes and contributing factors are outlined below.

Organic Inclusions

Organic inclusions affect the tin crystal structure by distorting or crowd the crystal lattice,



Organic Impurity	No Mechanical Bend	Mechanical Bend
0.2%, 4 months	245 microns	312 microns
0.004%, 7 months	6 microns	6 microns

Table 1.

thus creating the internal stress. It is found that tin whisker growth is correlated to the organic inclusions as represented in carbon content in the coating. A test conducted at 50°C for four months on coatings with similar grain sizes generated the following results: For the coating containing 0.2% carbon, 235 µm whisker was formed while 12 µm whisker was formed for the coating containing 0.05% carbon content[1].

Surface Physical Condition

Surface conditions, such as notches and scratches in the coating surface, can be a source of atomic irregularity, which could contribute to the driving force of tin whisker formation.

Substrate Surface Morphology

Physically maneuvering the surface morphology of the substrate in the level of roughness was found to alter the tin whisker propensity—a rougher surface being less prone to tin whiskers[2]. It is believed that a relatively rougher surface facilitates the formation of an even interface between the tin coating and the substrate surface that contains a thinner and more uniform intermetallic layer.

Oxidation or Contamination Level

It is postulated that as the oxygen atoms diffuse into the tin crystal structure, oxygen can serve as nuclei and can also restrain grain boundary mobility and diffusion. When the lattice structure is oriented in such a way that is favorable to the protruding crystal growth, tin whiskers will occur. Some studies found that surface oxide (commonly tin oxide) promotes tin whiskers[1]. And studies also found that contamination contributes to tin whisker[3].

External Mechanical Stresses

Externally applied forces such as those introduced by the lead-forming, bending or torque after plating process may affect tin whisker formation. In studying the effect of external mechanical force that is imposed on the coating on tin whisker growth, the relative whisker growth under different levels of organic inclusions with and without an external mechanical force was performed. Under each level of organic inclusions, an external mechanical force (by means of bending) created an increased rate of whisker growth as shown in Table 1[4].

> “*In studying the effect of external mechanical force that is imposed on the coating on tin whisker growth, the relative whisker growth under different levels of organic inclusions with and without an external mechanical force was performed.*”

Substrate Base Material

It was found that there is a difference in tin whisker propensity between bronze and brass and between Cu-based and Alloy 42 leads, respectively. The differences are primarily attributed to relative inter-diffusion between the substrate material and the tin coating, as well as to the relative abundance of intermetallic compounds.

Metallic Impurities

As metallic particles enter into the tin lattice, they may or may not lead to the formation of intermetallic compounds, depending on the metallurgy of the elements involved. These metallic particles can change or distort the lattice spacing in the tin structure. It should be noted that the presence of intermetallic compounds in the tin coating layer or at the interface between tin layer and substrate is not a requirement for tin whisker formation.

Intermetallic Compounds

It should be emphasized that intermetallic compounds at the interface of the tin coating and the substrate or in the bulk of the tin coating is not a necessary condition for the occurrence of tin whisker. However, intermetallic compounds may exert additional effects in grain structure, as these compounds can form in various geometries and morphologies ranging from small, more-rounded particles to long needles. This formation creates either high localized stress or well-distributed stress or both in the tin lattice structure.

It should also be noted that the critical difference between SnPb and SnAgCu alloy is that SnPb does not (should not) form intermetallics in the bulk matrix, but SnAgCu alloys intrinsically contain intermetallics. The presence of intermetallics in SnAgCu and the absence of such in SnPb account for most of the phenomenal and property differences between SnAgCu and SnPb, including tin whisker.

CTE Mismatch Between Tin Coating and Substrate

The relative coefficient of thermal expansion between the tin plating and substrate can contribute to the occurrence of tin whisker as the result of additional global stress as well as localized stresses. In this regard, the lead material (e.g., Alloy 42 vs. Cu) is a factor. Although the larger mismatch between the tin layer and the substrate causes higher stress level, the diffusion rate of substrate atoms into the tin coating layer with or without the companion of the formation of intermetallics may skew the linear relationship between CTE mismatch and the whisker propensity.

Plating Process vs. Coating Surface Morphology

Tin plating process parameters control the lattice defects incorporated in the tin layer. They also determine the thickness of the coating layer. The organic content, grain size, and surface morphology highly depend on the coating chemistry and process parameters, including the type of electrolyte, additive/brighteners, current density, process temperature, and the process control. For instance, high current density allows faster rate of plating, and a faster rate may impede the tin atoms' ability to rearrange to a low-energy state, which contributes to subsequent whiskering conditions.

Take bright tin as an example, which is reportedly the most susceptible to tin whiskers. Its high susceptibility is largely attributable to the high residual stresses within the tin plating caused by the plating chemistry and process. The added brighteners in making tin bright may serve as nucleation sites and may prevent tin from settling into the low energy state to form large grains. The resulting small grains provide more grain boundaries that in turn offer diffusion paths for tin.

“Take bright tin as an example, which is reportedly the most susceptible to tin whiskers. Its high susceptibility is largely attributable to the high residual stresses within the tin plating caused by the plating chemistry and process.”

Plating Process vs. Coating Crystal Structure

The effect of microstructure in terms of grain size on whiskers has been observed. It is hypothesized that as grain size reduces below 1 micron, the internal stress and the driving force for recrystallization will be built up. This condition creates high whisker propensity.

Thickness of Tin Coating

It is postulated that it takes a proper thickness for whisker to grow. To make a statement on the correlation between the thickness of tin layer and the whisker propensity is indeed oversimplistic. Yet, some results do support that a too-thick coating can bury whiskering tendency and a too-thin coating can shortchange the materials needed to grow whiskers. The proper thickness also is related to stress distribution ability.

Temperature Effect

Temperature drives the kinetics of defect dynamics in the tin layer by affecting stress relaxation and atomic mobility-related phenomena. A high temperature relative to tin's recrystalization temperature is expected to impede the continued growth along the protruding direction, resulting short whiskers.

Conclusion

Overall, from the atomic lattice structure standpoint, most of the above sources do not play out by themselves in the tin coating layer, rather they are intricately interplayed. This is the very challenge imposed to the evaluation of tin whisker propensity based on a set of testing conditions. **SMT**

References

1. (ISBN: 9780901150400) *"Environment-Friendly Electronics—Lead Free Technology,"* Electrochemical Publications, LTD, Great Britain, 2001, Chapter 26.

2. BAE Systems/Celestica study.

3. George Milad, Uyemura International.

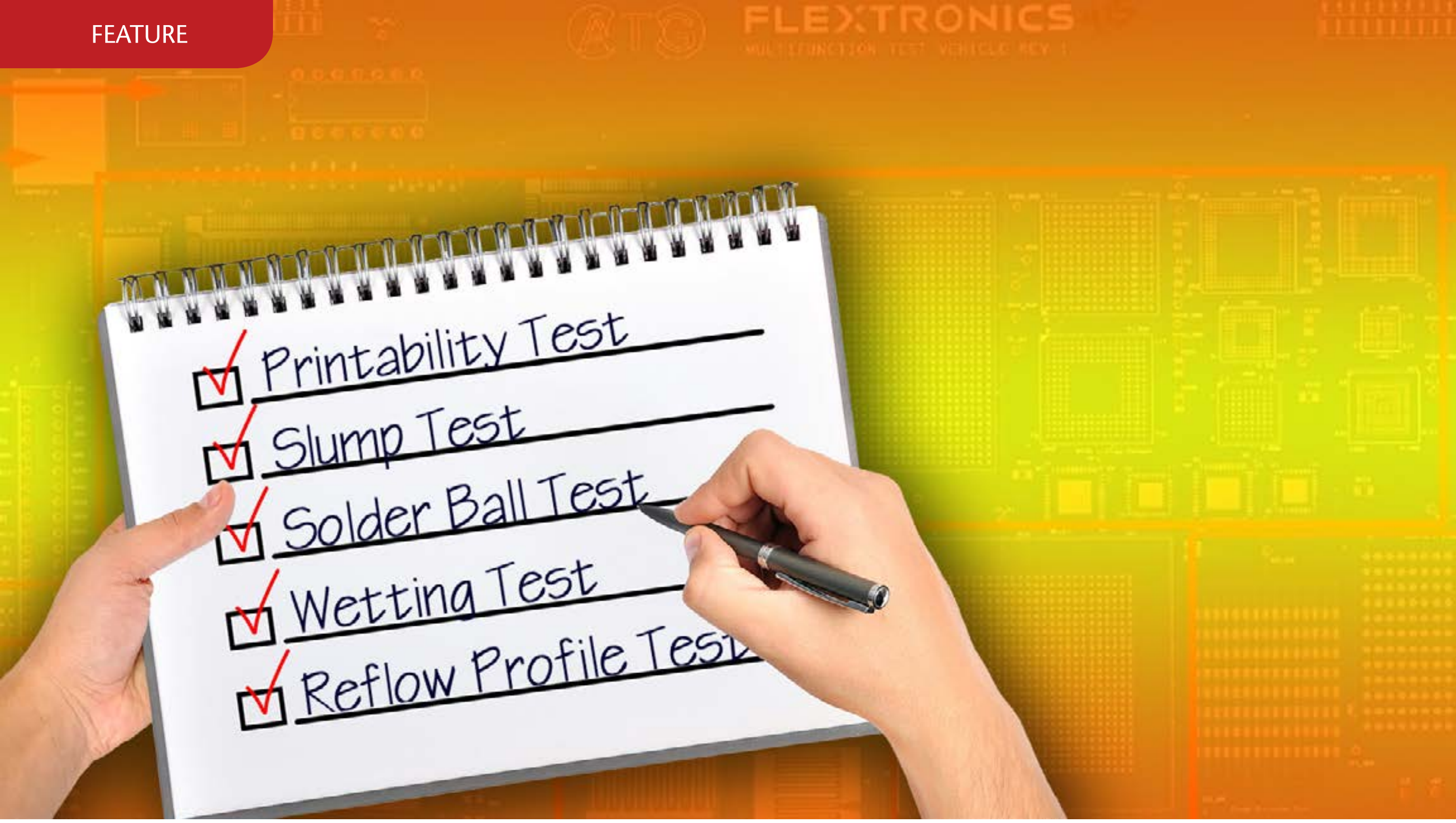
4. (ISBN: 9780901150400) *"Environment-Friendly Electronics—Lead Free Technology,"* Electrochemical Publications, LTD, Great Britain, 2001, Page 697.

Dr. Hwang will present an SMTA webtorial, *Tin Whisker—All You Should Know* on March 11 and 13, and deliver a lecture, "Preventing Manufacturing Defects and Product Failures" at IPC APEX EXPO in Las Vegas, Nevada, on March 24.

Dr. Hwang, a pioneer and long-standing contributor to SMT manufacturing since its inception, as well as to the lead-free development and implementation, has helped improve production yield and solved challenging reliability issues. Among her many awards and honors, she is inducted to the WIT International Hall of Fame, elected to the National Academy of Engineering, and named an R&D-Stars-to-Watch. Having held senior executive positions with Lockheed Martin Corp., Sherwin Williams Co., SCM Corp, and IEM Corp., she is currently CEO of H-Technologies Group, providing business, technology and manufacturing solutions. She has served on the U.S. Commerce Department's Export Council, various national panels/committees, and the board of Fortune 500 NYSE companies and civic and university boards. She is the author of 400+ publications and several textbooks, and an international speaker and author on trade, business, education, and social issues. Her formal education includes four academic degrees (Ph.D., M.S., M.A., B.S.) as well as Harvard Business School Executive Program and Columbia University Corporate Governance Program. To contact the author, or to read past columns, click here.

Breakthrough in Rechargeable Battery Technology

Researchers at the Materials and Surface Science Institute (MSSI), University of Limerick, Ireland, have made a significant breakthrough in rechargeable battery technology. An ever-increasing demand for portable electronic devices and improved technology for battery life and stability is a vital factor in device performance. The combined value of the rechargeable battery technology market is set to grow from $11.8 billion in 2010 to $53.7 billion in 2020. A research team at UL has developed a technology that more than doubles and retains the capacity of lithium-ion battery anodes even after being charged and discharged over 1,000 times.



Feasibility of Low/No Silver Alloy Solder Paste Materials

by Jennifer Nguyen, Ranilo Aranda, David Geiger, and Murad Kurwa
FLEXTRONICS INTERNATIONAL

SUMMARY: Many alternative low/no silver solder pastes are available today. This article will present the performance and process capability of various low/no silver alloy solder pastes, along with a variety of benefits and concerns.

Abstract

Sn3.0Ag0.5Cu (SAC305) is the most popular near-eutectic lead-free alloy used in the manufacturing processes. Over the last several years, the price of silver has dramatically increased, driving a desire for lower-silver alloy alternatives.

As a result, there is a significant increase in the number of alternative low/no silver lead-free solder alloys available in the industry recently. In this paper, we'll present the performance and process capability of various low/no silver alloy solder pastes. Data from printability, wetting test, slump test, solder ball test, voiding, etc., will be discussed and compared with the control SAC305 solder paste. Benefits and concerns of using low/no silver alloy solder paste materials will also be addressed.

Introduction

Sn3.0Ag0.5 solder paste is currently the common alloy for lead-free solder paste in the PCB assembly industry. However, the price of silver has kept increasing over the last several years. The silver price chart within the last five years is shown in Figure 1. This drives the desire for alternative low/no silver alloy materials and leads to the development of many alternative alloys. Today, many alternative low/no silver alloy solder pastes are available in the market. There are publications on the alternative lead-free alloys[1–3]. However, most of the studies focus on the alternative alloys of the BGA solder balls and their reliability. There is very limited published information on the performance of

Figure 1: Five-year silver history chart.

Item #	Alternative Material	Alloy Composition	Liquidus Temp. (°C)	Type
1	Material A	SAC0307	227	3
2	Material B	SACX0307	228	3
3	Material C	SAC0307	227	3
4	Material D	Sn99.2/Bi3/Cu0.5/Co	228	3
5	Material E	SAC0307	227	3
6	Material F	Sn0.1Ag0.7Cu0.03Co	227	3
7	Material G	Sn100C	227	3
8	Material H	SAC0307	227	3
9	Material I	Sn-0.3Ag-0.7Cu-Bi,In	225	3
10	Material J (Control)	SAC305	217	3
11	Material K	SN100C	227	3
12	Material L	Sn100C	227	3

Table 1: Alternative low/no silver alloy solder pastes.

low/no silver alloy solder pastes. In this article, we will discuss the process feasibility and challenges of low/no silver alloy solder pastes.

Alternative Low/No Silver Alloy Solder Pastes

In the study, we evaluated 11 different alternatives alloys and compared their performance with the control SAC305 solder paste (Table 1). Type 3 was used in the evaluation. Sn3.0Ag0.5Cu alloy typically melts at ~217°C. Alternative low/no alloys have about 10°C higher melting temperature than SAC305 solder paste. Its liquidus temperature ranges from 225°C to 228°C.

Test Vehicle

Flextronics multi-function test vehicle is used in the evaluations (Figure 1). The board dimensions are 225 mm x 150 mm x 1.67 mm. The board surface finish is OSP. The test vehicle

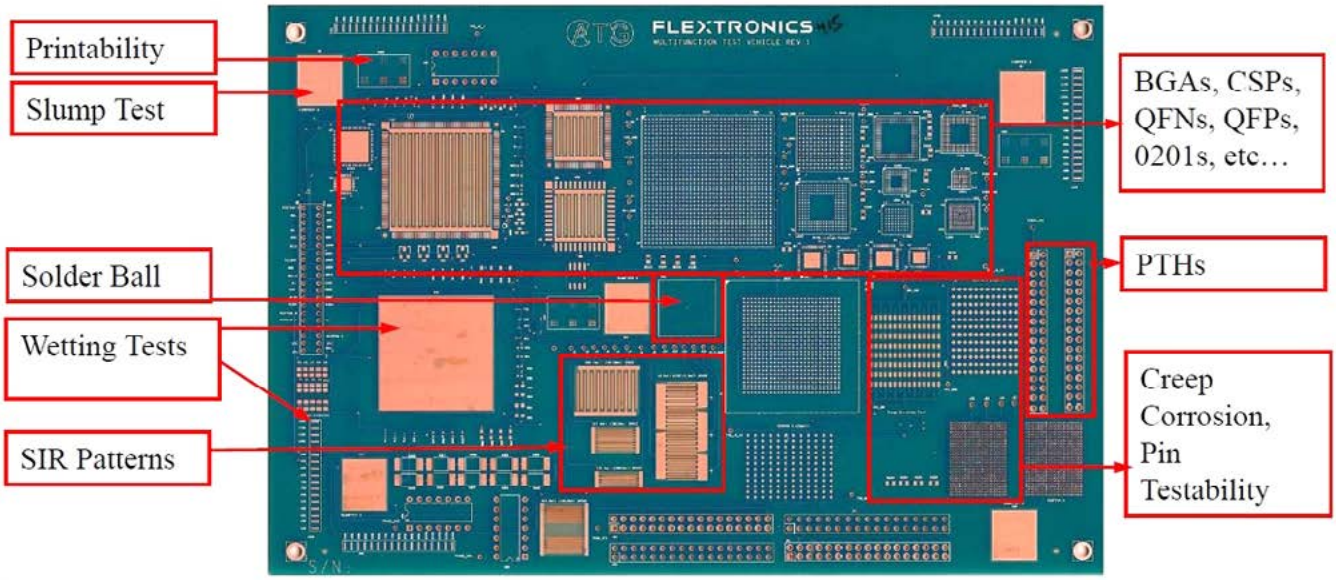


Figure 2: Flextronics multi-function test vehicle, Rev 1.0.

has many different SMD component types such as BGAs (0.8 mm and 1.0 mm pitch), CSP (0.5 mm pitch, 0.4 mm, 0.3 mm), QFN component (0.5 mm pitch and 0.4 mm pitch), leaded components (SOIC, QFN100, QFN208, etc.), chip components (0201,0402, 0603, 0805), through-hole components, etc. In addition, the test vehicle has different areas designed for printability test, slump test, wettability test, solder ball test, pin testability, etc. The test vehicle is shown in Figure 2.

Evaluation Methodology and Procedure

Printability Tests

For printability tests, the solder pastes were printed using the optimized printing parameters at 0-hour and 4-hour stencil life. Solder paste volume and its standard deviation were then recorded and analyzed. Besides the solder paste volume and standard deviation, we also considered other aspects of printability such as printing speed and missing solder. Typically, a slower printing speed tends to provide a better paste volume and small standard deviation. For volume manufacturing a good solder paste material should perform well not only at slow printing speeds but also at high printing speeds. While the printing speed varies based on the complexity of the product, a good solder paste should be able to print well at a speed of 50–70 mm/s or higher.

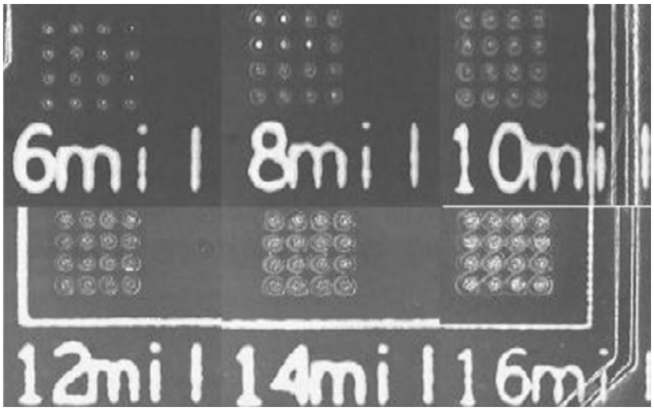


Figure 3: Printability area for missing print.

Different area ratios ranging from 0.3–0.8 were used for the missing solder evaluation (Figure 3). The insufficient or missing prints were analyzed. The missing solder was defined as less than five solder particles on a pad.

Slump Test

Cold and hot slump tests were performed at 0-hour and 4-hour using the IPC-A-20 stencil pattern. The number of solder bridges at different spacings was analyzed. For the cold

Figure 4: Solder ball test.

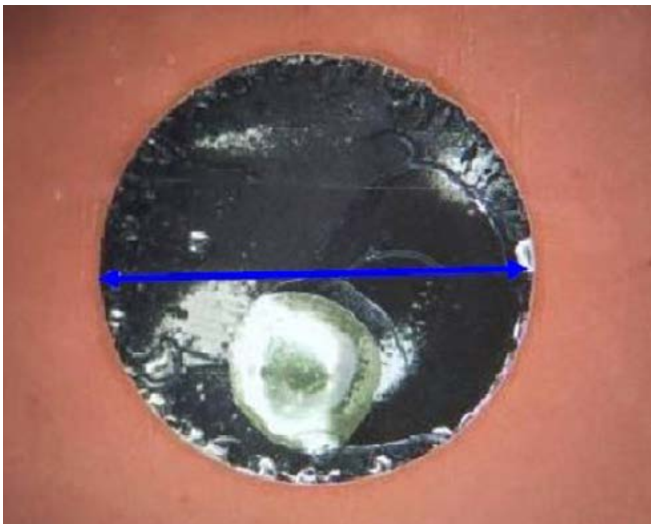


Figure 5: Wetting test 1.

slump test, the solder bridges were counted at the room temperature. For the hot slump test, the test vehicles were baked at 125°C–150°C for about 20 minutes. The solder bridges were then recorded and compared.

Solder Ball Test

Solder paste was printed on solder mask and reflowed (Figure 4). The solder balls, appearance and flux residues were analyzed. A quantified test for solder balling can be done by counting the number of solder balls at a designed location.

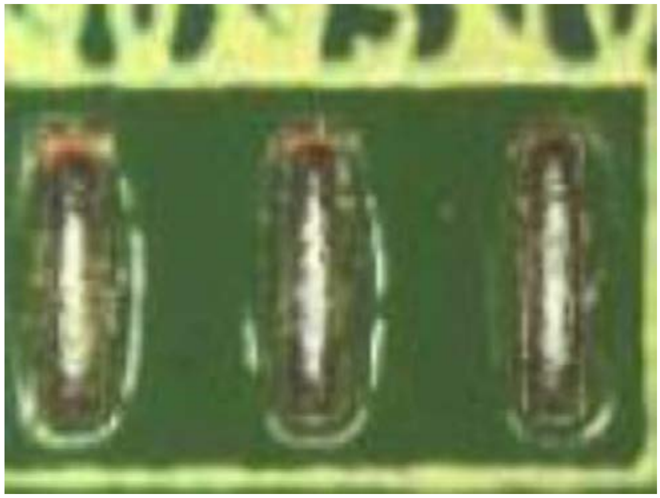


Figure 6: Wetting test 2.

Wetting Tests

Solder wetting test was done by reflowing the solder paste printed at time zero and at 4-hours of stencil waiting time. Two wetting tests were used in the initial evaluation. In Wetting Test 1, the solder spreading (diameter) was measured and compared (Figure 5). In Wetting Test 2, the solder paste was printed at different aperture openings and reflowed. Lead-free solder paste usually does not wet as well as tin lead and thus requires an over pad print to achieve full pad coverage. For Wetting Test 2, the minimum print area to achieve 100% solder coverage of the pad was observed and analyzed (Figure 6).

Reflow and Process Robustness Tests

To verify the process robustness of the solder paste materials, further tests were performed on the top performing solder pastes from the screening tests. Real components were used to simulate the production environment. Three different reflow profiles (low, medium, hot) were used in the low/no silver solder paste evaluation. Table 2 summarizes the difference between the profiles. All the boards were reflowed in air environment. Print quality (volume and standard deviation), solder balls, wetting, voiding, flux residues and appearance were then evaluated. A good solder paste should have good performance across all the tests, and its quality should be consistent within a wide process window.

Profile Name	Peak Temperature (°C)	Reflow Time (s) (>217°C)	Soak Time (s)
Low	231-240	52-69	75-82
Medium	240-245	57-77	102-110
Hot	250-255	79-89	100-110

Table 2: Reflow profiles summary.

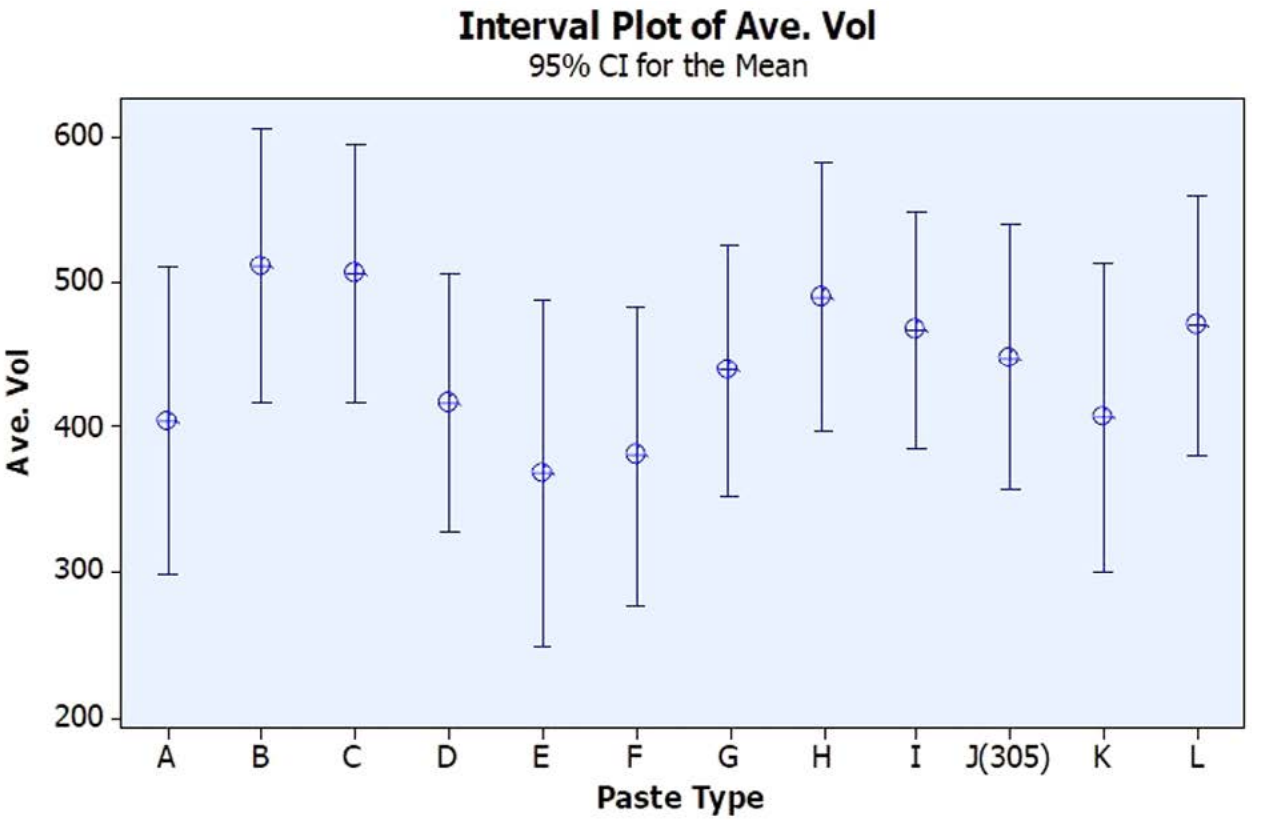


Figure 7: Printability of low/no silver alloy solder pastes at t=0.

Results and Discussions

Printability

Alternative low/no silver alloy solder pastes can print as well as SAC305 solder paste at t=0 (Figure 7). However, some low/no silver alloy solder paste materials (such as A, D, E, F, K) didn't perform well after four hours waiting time as compared to SAC305 solder paste. It is believed that the flux chemistry in the solder paste played an important role in the material printing performance.

Wettability

In term of wettability, many low/no silver alloy solder performed well in this category. Figure 8 shows the images of Wetting Test 1 for a SAC305, SAC0307 and SN100C alloy solder paste. These three solder pastes averagely had a similar spreading diameter.

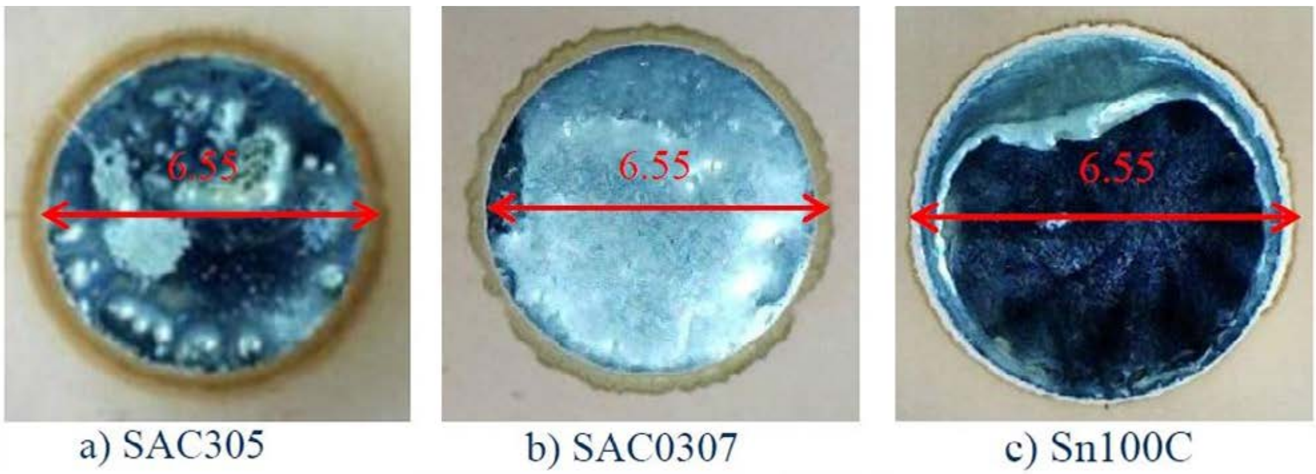


Figure 8: Wetting test results of various lead-free alloy solder pastes.

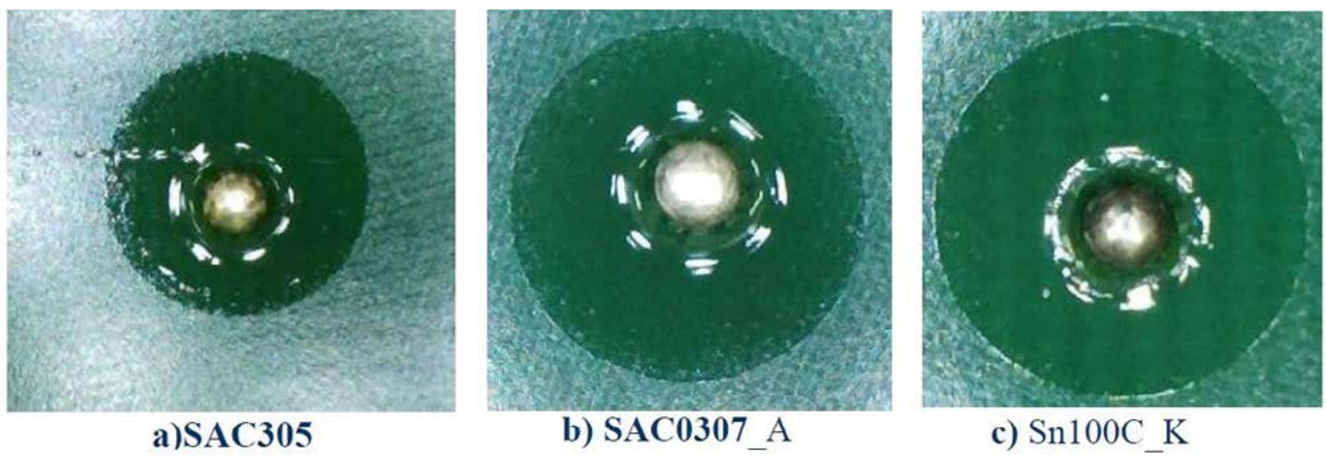


Figure 9: Solder ball test results: good solder paste materials.

Figure 10: Solder ball test results: Many alternative alloy solder pastes resulted in excessive solder balls.

Again, flux chemistry has a greater impact on the material performance than the alloy composition.

Solder Balling Test

Some alternative alloy solder pastes performed good in the solder balling test (Figure 9). However, many alternative low/no silver alloy solder pastes had excessive solder balls (Figure 10). During the previous lead-free (SAC305) solder pate evaluations, almost all materials performed well in this solder balling test, and excessive solder balls weren't seen.

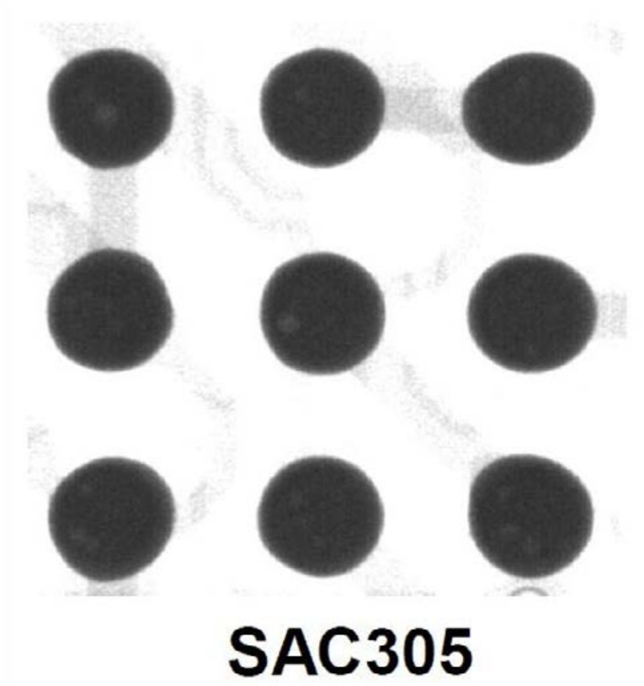


Figure 11: X-ray image of BGA solder joint reflowed with SAC305 solder paste. Little voids were seen.

Voiding

The X-ray image of BGA solder joints reflowed with SAC305 solder paste is shown in Figure 11. The X-ray images of BGA solder joints reflowed with SAC0307 and SN100C solder paste are shown in Figure 12 and Figure 14, respectively. In general, many alternative low/no silver alloy solder pastes resulted in more voiding than SAC305 solder paste. Some alternative alloy solder pastes had similar voiding level as SAC305 solder paste for the BGA solder joint (Figure 13a and 14a). For the QFN components, the voiding level was significantly increased for the samples reflowed with low/no silver solder pastes, as shown in Figure 15.

Process Window

Alternative low/no silver alloy solder pastes had a narrower process window than SAC305 solder paste. Many alternative alloys hadn't completely reflowed at the low lead-free profile (Figure 15). Medium or hot profile may be needed when alternative low/no silver alloy solder paste is used. This raises the concern about the

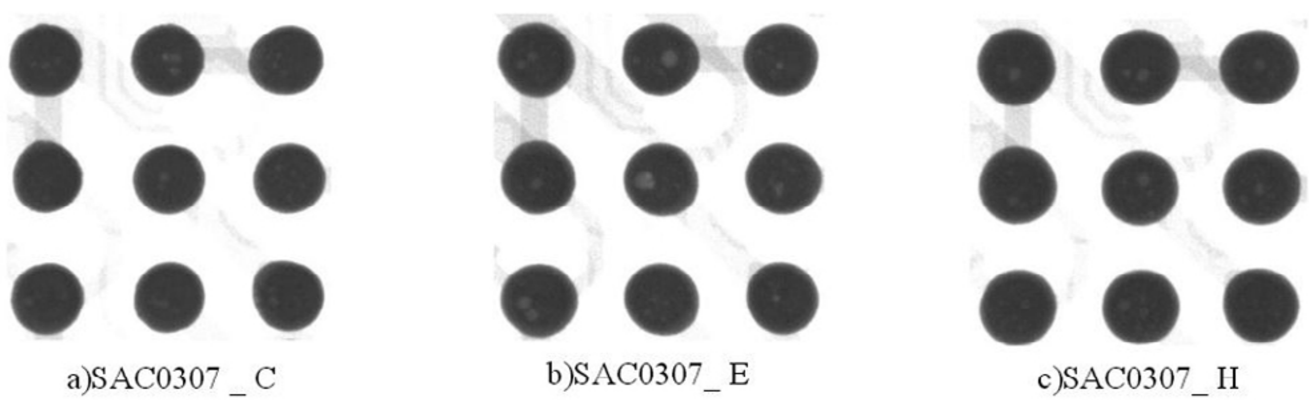


Figure 12: X-ray images of BGA solder joints reflowed with SAC0307 solder pastes. Good SAC0307 solder paste (12a) had similar voiding level as SAC305 solder paste. Many evaluated SAC0307 solder pastes (12b,c) had slightly more voids than the control SAC305 solder paste.

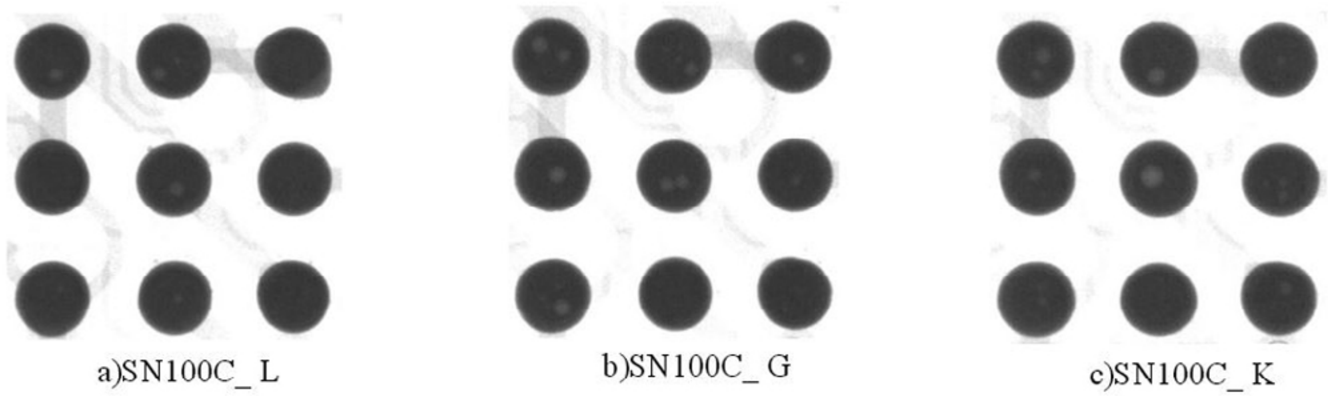


Figure 13: X-ray images of BGA solder joints reflowed with Sn100C solder pastes. Good SN100C solder paste had similar voiding level as SAC305 solder paste (Figure 13a). Many evaluated SN100C solder pastes had slightly more voids than the control SAC305 solder paste (Figure 13b 13c).

Figure 14: X-ray images of QFN88 components assembled with different lead-free alloy solder pastes. Low/no silver alloy solder pastes resulted in more voids and larger voids than SAC305 solder paste.

profile temperature impact on the component's process temperature limitation.

Conclusions

There are many alternative low/no silver solder pastes in the market today. In general, alternative low/no silver solder pastes have higher liquidus temperature and require a higher reflow profile than SAC305 solder pastes. Thus, the process window of low/no silver solder paste is much narrower than the process window of SAC305 solder. Many alternative lead-free solder paste materials have good printing and wetting performance. However, low/no silver alloy solder pastes may result in more defects such as solder balling, voiding (especially on QFN components) and solder bridging. Flux chemistry and supplier play a critical role in the performance of alternative lead-free solder paste materials. A good selected low/no silver solder can have similar performance as SAC305 solder pastes in many aspects when the process conditions are optimized. The higher reflow profile associated with alternative low/no silver alloy solder paste creates some concerns about the component's process temperature and its limitation. When alternative low/no silver solder paste is used, it is recommended to review the component's temperature limitation to make sure that they can survive the reflow profile. Further work on the reliability of lead-free solder joints assem-

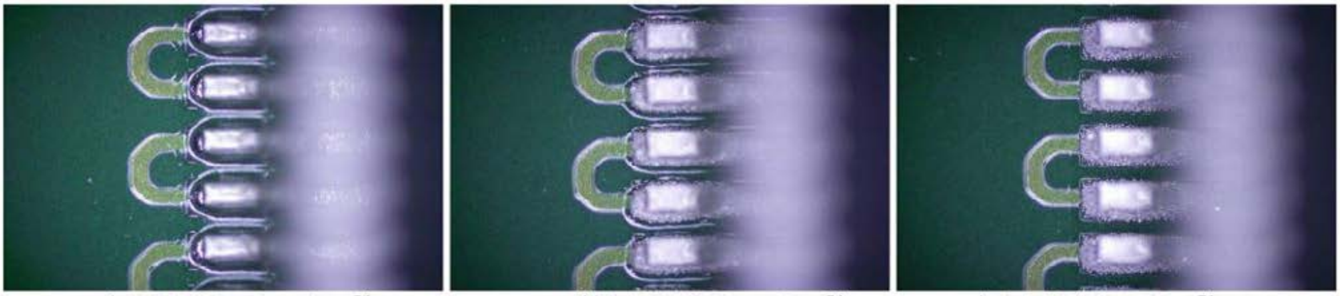


Figure 15: Visual images of solder joints reflowed with different lead-free alloys using low lead-free profile. 15a) Solder paste was melted for SAC305 alloy. 15b and 15c) Cold solder was observed for SAC0307 and SN100C using a low lead-free profile.

bled with alternative low/no silver solder paste is recommended. **SMT**

References

1. J. Smetana, R. Coyle, P. Read, T. Koshmeider, D. Love, M. Kolenik and J. Nguyen, "Thermal Cycling Reliability Screening of Multiple Pb-Free Solder Ball Alloys," Proceedings of IPC APEX EXPO conference, 2010.

2. G. Henshall, et al., "INEMI Pb-Free Alloy Characterization Project Report: Part I-Program Goals, Experimental Structure, Alloy Characterization and Test Protocols for Accelerated Thermal Cycling," Proceedings of SMTAI, 2012.

3. K. Sweatman, et al., "iNEMI Pb-Free Alloy Characterization Project Report: Part III—Thermal Fatigue Results for Low Ag Alloys," Proceedings of SMTAI, 2012.

4. Jennifer Nguyen, David Geiger and Dongkai Shangguan, "Evaluation of Lead-Free Solder Paste Materials for PCBA," Proceedings of IPC APEX EXPO conference, 2011.

NOTE: This article was published in the 2013 IPC APEX EXPO technical conference proceedings.

Jennifer Nguyen is manager of worldwide assembly and test technology at Flextronics.

Ranilo Aranda is a process engineering manager at Flextronics.

David Geiger is director of assembly and test technology at Flextronics.

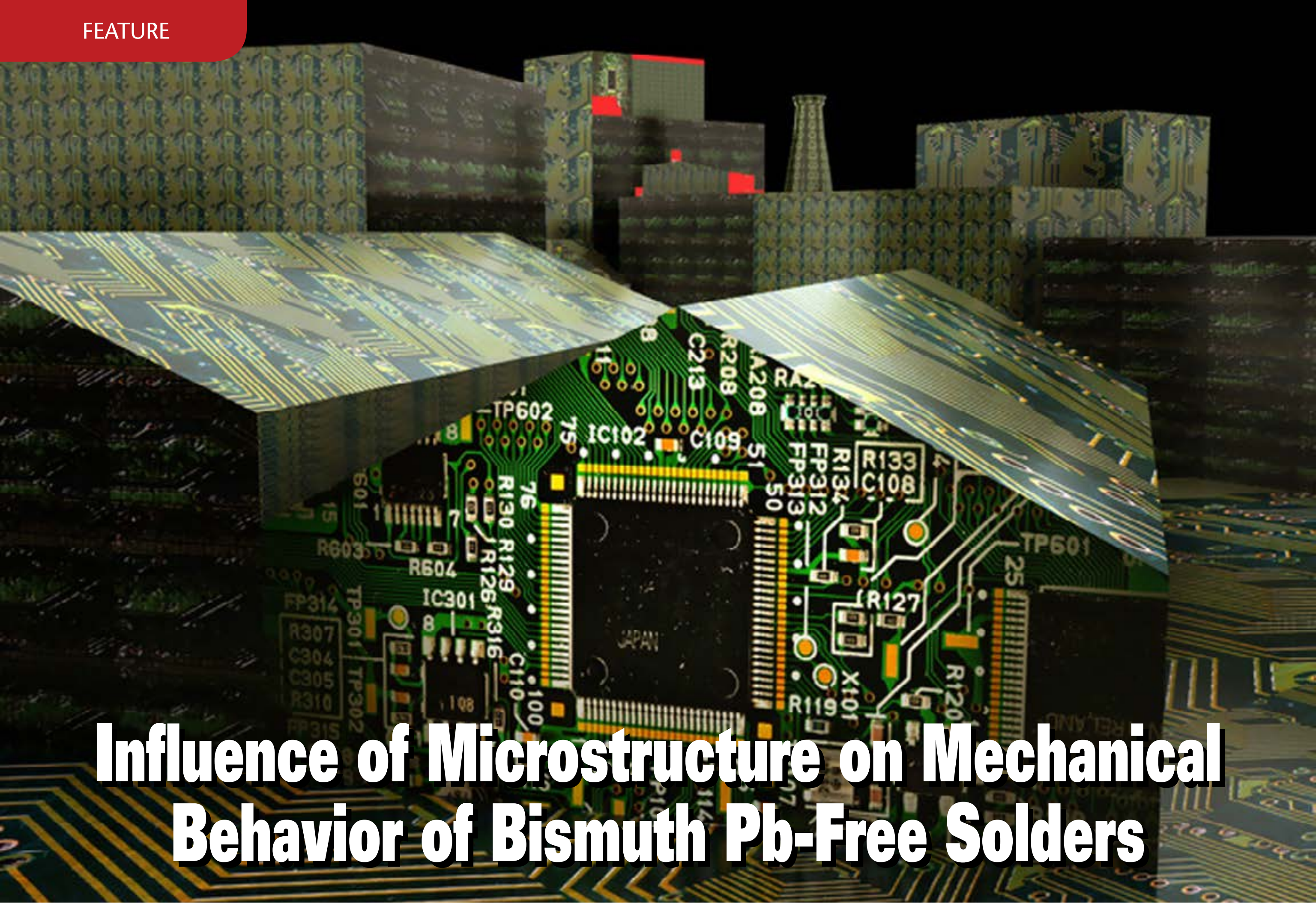
Murad Kurwa is vice president of engineering for the Advanced Engineering Group at Flextronics.

Circuits with Stretchable Optical Interconnections

Wearable body sensors and robotic skin must ferry information along flexible routes. Electronics that bend and stretch have become possible, but similar work in the field of optics has lagged behind. Particularly difficult to engineer have been optics that stretch when someone wearing body sensors bends or twists.

Belgian researchers report progress with an optical circuit that uses both bendable and stretchable interconnections made of a rubbery material called poly-dimethylsiloxane.

"To our knowledge, this is the first truly bendable, stretchable optical link with these miniature dimensions," said lead author Jeroen Missinne of Ghent University and imec, a nanoelectronics research center in Belgium.



Influence of Microstructure on Mechanical Behavior of Bismuth Pb-Free Solders

by David B. Witkin
THE AEROSPACE CORPORATION

SUMMARY: Certain alloys that contain bismuth have shown superior reliability in PCB testing, but they have not been widely used in electronics manufacturing due to their Bi content. This article focuses on the microstructure and behaviour of Bi-containing alloys, and compares this data with that of SAC305.

Introduction

SAC-Bi and Sn-Ag-Bi alloys have demonstrated superior performance in thermal cycling reliability tests of PCBs, such as the National Center for Manufacturing Sciences (NCMS) programs in the 1990s[1, 2] and the Joint Group on Pollution Prevention-Joint Committee on Aging Aircraft program of the early 2000s[3]. Despite these promising results, they have not been widely used in electronics manufacturing due to their Bi content, which has raised concerns for the potential of forming the low-melting point Sn-Pb-Bi eutectic phase (Tm 96°C) in mixed SnPb/Pb-free soldering. The recently concluded (December 2011) NASA-DoD program Phase II follow-on to JCAA-JGPP revived the possible use of Bi-containing alloys with the recommendation that lower reflow temperatures for ternary Sn-Ag-Bi and quaternary SAC-Bi could reduce potential for pad cratering, as well as possess greater resistance to the growth of tin whiskers[4].

At the same time, an explanation for the performance of Bi-containing alloys documented in thermal cycling has not been provided, and basic aspects of the metallurgy of these alloys have not been explored to the same extent as more common SAC alloys. The original NCMS project on Pb-free solder[1] elected not to pursue this type of characterization of the alloys on the presumption that mechanical property data for the solders did not necessarily correlate with or provide insight into the reliability of the circuit board, which was the project's motivation.

In the present work, the relationship between microstructure, aging and mechanical behavior was studied for Sn-3.4Ag-4.8Bi (SnAg-

Bi) and Sn-3.4Ag-1.0Cu-3.3Bi (SAC-Bi) and compared to SAC305. Tensile properties, creep behavior and damping capacity of these alloys were evaluated. The results show significant differences in these properties between the as-cast and aged conditions. In particular, the properties of SAC305 respond to aging differently from the Bi-containing alloys. For example, while aging at 150°C for 336 hours (two weeks) decreases the yield and tensile strength of SAC305 by nearly a factor of two, the same aging treatment leads to a much smaller relative change in the strength of SAC-Bi. The relationship between aging, microstructure and mechanical properties do not necessarily explain performance in board-level thermal cycling tests but the metallurgical differences observed between the alloys due to Bi addition could contribute to fundamental basis for improved reliability.

"The alloys that were selected for this study had shown good performance in circuit board reliability testing but had not been extensively characterized and had not been adopted for use by the consumer electronics industry for Pb-free assembly."

Experimental

Alloy Selection

The alloys that were selected for this study had shown good performance in circuit board reliability testing but had not been extensively characterized and had not been adopted for use by the consumer electronics industry for Pb-free assembly. The alloy selection strategy was based on three suppositions. First, the selection criteria for Pb-free solders in consumer electronics assembly would emphasize cost considerations and regulatory compliance deadlines in product design and manufacturing. Second, the reliability and product lifetime expectations for Pb-free consumer products are entirely different from high-reliability systems, especially space flight hardware where repair and replacement on orbit are not possible. Consequently, the performance and reliability requirements for industries whose products were initially exempt from RoHS would not be considered in alloy selection and development of best assembly practices. The third supposition in alloy selection was that the consumer electronics industry would extensively characterize the Pb-free solder alloys for their systems. Therefore, alloys chosen for this study were those which had shown early promise in circuit-board reliability testing but were subsequently abandoned by the electronics assembly business.

The main sources used for the selection process were the two published by the National NCMS [1, 2, 5] and the U.S. Department of Defense-sponsored JGPP-JCAA[3]. Two Bi-containing alloys were selected based on review of these sources:

1. Sn-3.4Ag-4.8Bi (wt. %): This alloy performed well in studies reported by NCMS in 1997[1], and was the best performer in the initial screening in the 2001 NCMS report[2]. It was dropped from consideration at this point because of its high Bi content. Bi forms a low melting ternary eutectic with Sn and Pb (melting point 96°C), so this alloy was potentially problematic in a mixed-alloy environment. The actual composition of the alloy reflects the largest amount of Bi that could be added to the Sn-Ag eutectic without showing evidence of Sn-Bi eutectic (melting point 138°C) during thermal analysis[6].

2. Sn-3.3Ag-1.0Cu-3.4Bi: This alloy was the highly rated in the NCMS 2001 study and was one of the alloys selected for extensive characterization in the JCAA-JGPP study[3]. The alloy outperformed SAC and SnPb in manufactured circuit boards (high Tg board materials) in the latter effort, but did not do as well in reworked boards, in which hand soldering of eutectic SnPb was used to simulate repair of low-temperature circuit boards that had been originally soldered with Pb-free alloys. This specific parameter was intended to duplicate actual practices for aircraft circuit board repair, and it is not certain wheth-

er the results for this alloy in these test articles are due to the low-melting Sn-Pb-Bi eutectic or other factors. Subsequent analysis of the test results[7] showed that test alloys were a less important factor in reliability testing than component type for both thermal and vibration testing.

Sample Preparation and Testing

Solder alloys were purchased as bars in pre-alloyed form from commercial vendors. In addition to the two Bi-containing alloys, SAC305 was included as a reference alloy, as were SnPb and commercially pure Sn for selected testing. Specimens for various tests were prepared in bulk form in graphite molds by heating to 270°C and holding for 20 minutes, followed by rapid quenching to room temperature or 0°C, resulting in as-solidified microstructures similar to that observed in actual solder joints. Samples were tested in as-cast condition or aged condition, which consisted of 336 hours in an inert environment at 150°C. After casting or aging, specimens were stored in a freezer at -10°C except during machining or testing.

Tensile specimens were machined from cylindrical blanks as round dogbones with threaded grips to conform to requirements in ASTM E8 standard for tensile testing of metallic materials. The cylindrical castings had a diameter of 9.5 mm, and the tensile specimens were machined with a gauge diameter of 4.1 mm and a gauge length of 16.3 mm. Tensile tests were performed on an Instron (Instron Corp., Norwood, MA) 8800 series test frame at a strain rate of $8.3 \cdot 10^{-4}$ sec^{-1} at temperatures of 24, 75 and 125°C. Three or four specimens were run at each temperature for both as-cast and aged conditions of each alloy. Testing conditions were ambient air and samples were allowed to equilibrate for 15–20 minutes prior to beginning the test. Strain measurements were made using a video extensometer.

"Solder alloys were purchased as bars in pre-alloyed form from commercial vendors. In addition to the two Bi-containing alloys, SAC305 was included as a reference alloy, as were SnPb and commercially pure Sn for selected testing."

Creep specimens were of a double shear geometry inspired by earlier work on the creep of pure Sn and pure Pb[8]. The specimen features three grip sections of identical diameter and two reduced gauge sections. The specimen is held at each end and pulled in the middle by a fixed load, and approximates a constant stress condition to high strains. Specimens were machined from cylindrical castings with a diameter of 12.5 mm to dimensions of approximately 23 mm in length and an overall diameter of 11.5 mm. The reduced gauge sections were each 2 mm long and 5.7 mm diameter. The specimen geometry is intended to keep the specimen at constant shear stress during the test, although pure shear is not strictly attained. Tests were performed at 42, 75, 100 and 125°C by submersing the sample and fixturing into a heating silicone oil bath. Room temperature tests were performed under ambient laboratory conditions. Temperature fluctuations in both cases were less than ±1 K over the duration of the tests. Creep tests were performed at ranges in applied stress equivalent to approximately 20–90% of the yield strength in tension, which worked out to a range of applied shear stress from 3.5 MPa to 60 MPa, depending on the alloy and condition. The higher-strength Bi-containing alloys required higher creep test stresses and accounted for the higher test loads.

Displacement of the samples was measured with an accuracy of 5×10^{-4} mm, or a strain of approximately 9×10^{-5}. Tests were concluded no sooner than having met one of two conditions: a) rupture or clear evidence of the onset of tertiary creep, or b) extended period of apparent steady-state creep through a minimum test duration of 2.5×10^{5} seconds (approximately three days). Several tests were run in excess of 5×10^{5} seconds. The nature of the alloys was that true steady-state secondary creep was not

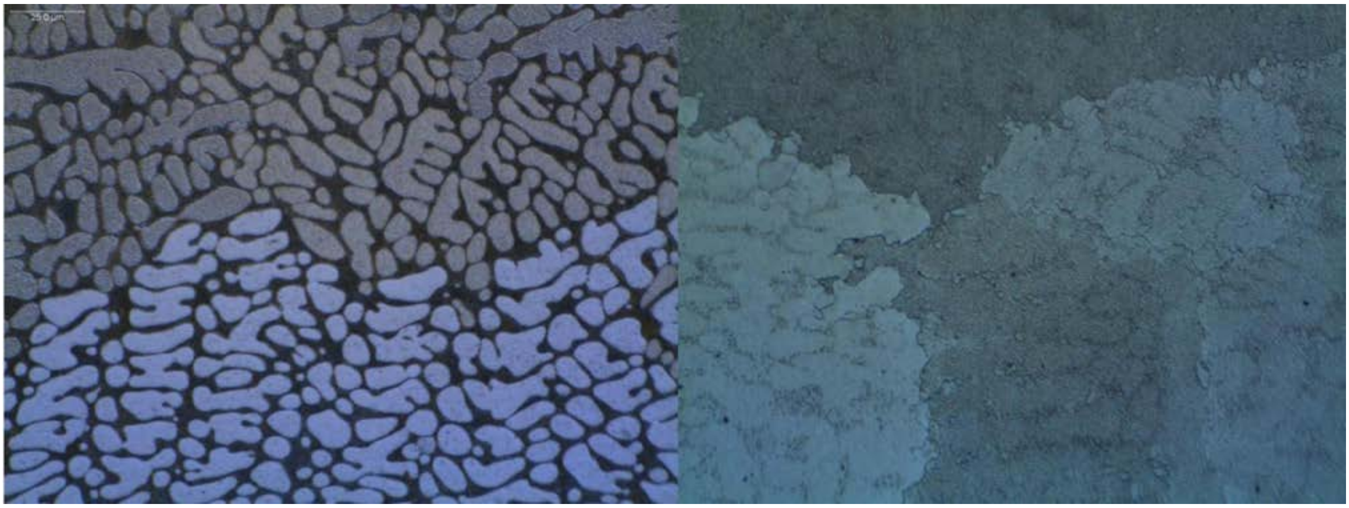


Figure 1: Optical micrographs of as-cast (left) and aged (right) SAC305.

attained so a minimum creep rate was substituted for steady-state creep rate where necessary.

Specimens for dynamic mechanical analysis (DMA) were prepared from rectangular graphite molds that yielded bars measuring approximately 60 x 6.4 x 3.2 mm. These rectangular bars were reduced to a thickness of approximately 1.7 mm by manually grinding and lapping roughly equal amounts of material from each face. DMA was performed using a TA Instruments Q800 DMA in dual cantilever mode, in which the rectangular beam sample was fixed at its ends and the middle. Tests were run in both isothermal and temperature sweeping modes. For the former, measurements at frequencies from 0.1 to 200 Hz were collected at 0 and 24°C and displacements of 5, 10 and 20 µm. A complete set of alloys and aging conditions were run in duplicate only at 5 µm, which for a nominal beam thickness of 1.7 mm was equivalent to a strain of approximately $7.5 \cdot 10^{-5}$. Measurements above 50 Hz were discarded due to instrumental factors. Comparison of alloys in isothermal mode is made here most extensively for tests run at 0°C because at the lower temperature there was less dependence of measured tan δ on strain. Additional tests were run as temperature sweeps using a displacement of 5 µm at fixed frequencies from temperatures of -100 to +100°C.

Results

Microstructures

Details of as-cast and aged microstructures, including micrographs, of SAC-Bi, SnAg-Bi and SAC305 for the tests discussed herein have been previously published[9, 10] and are only summarized here. As reference, previously unpublished metallographic images of SAC305 at 400X magnification are provided in Figure 1, and SAC-Bi and SnAg-Bi in Figure 2. All three alloys share similarities in their microstructures and response to aging. In the as-cast condition the microstructure is dominated by the dendritic structure exemplified in Figure 1. Individual intermetallic particles that formed upon solidification ($SnAg_3$ and Sn_5Cu_6) were too small to be resolved even at 10,000x magnification in a scanning electron microscope. Aging at 150°C for 336 hours leads to ripening of these particles and loss of dendritic structure. Intermetallic particles are typically found stabilizing irregular grain boundaries.

The story for the two Bi-containing alloys is similar with respect to grain boundaries and Sn-Ag and Sn-Cu compounds. Bi does not form compounds with Sn, Cu or Ag, so it is present either in solid solution or as a separate elemental phase. In as-cast SAC-Bi, Bi particles solidify at the edges of individual Sn dendrites. Given the undercooling of the primary β-Sn phase that oc-

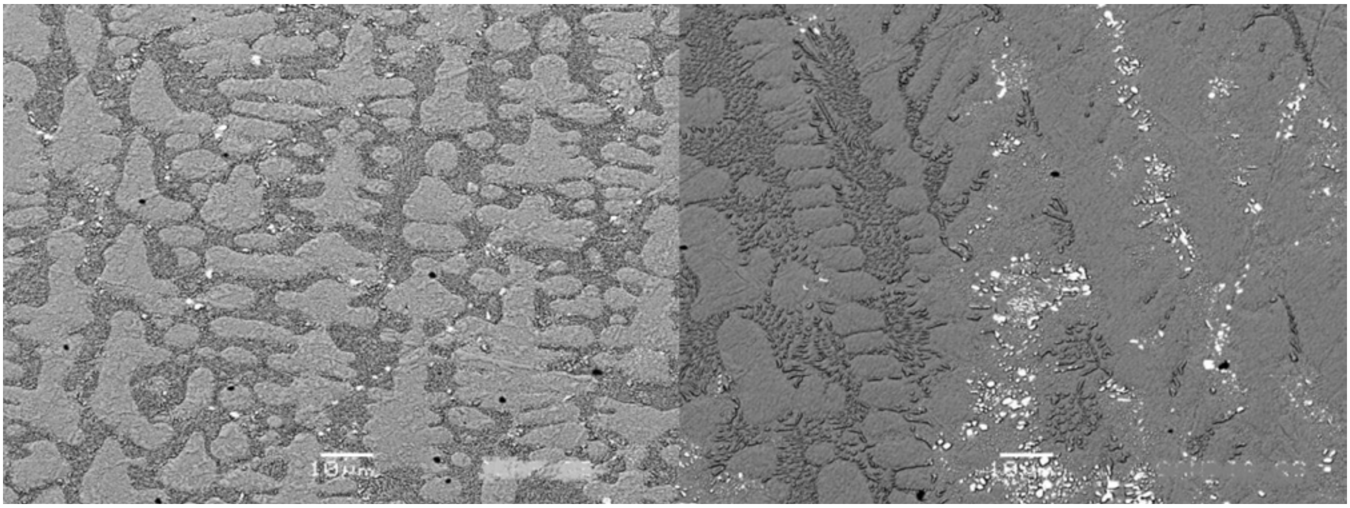


Figure 2: SEM BSE micrographs (1000x) of as-cast microstructure of SAC-Bi (left) and SnAg-Bi (right).

curs during solidification of Pb-free solders and the relatively low temperature of the binary Sn-Bi eutectic, the location of Bi particles is interpreted as evidence that the boundary between primary tin dendrites and eutectic regions is the last part of the melt to solidify. After aging, Bi precipitates are found predominantly found at grain boundaries. The solubility of Bi in Sn at the 423 K aging temperature exceeds the Bi content of the alloy, so the preferential nucleation and growth of Bi at heterogeneous nucleation sites due to aging suggests either that the Bi diffused rapidly at room temperature after aging or was retained at grain boundaries even during extended aging.

The trends observed in SAC-3.4Bi are also true for SnAg-4.8Bi, but the distribution of Bi through the alloy is different due to differing Bi content. In the as-cast SnAg-Bi the Bi particles are found in the interior of the Sn dendrites (Figure 2), not at the dendrite-eutectic interface as in SAC-Bi. The logic for the SAC-Bi leads to the conclusion that the solidification of the Sn phase proceeds from the eutectic region to the interior of the dendrites. After aging the Bi distribution consists of 1–5 µm equiaxed particles along grain boundaries and a fine dispersion of sub-micrometer particles throughout grain interiors. The room-temperature solubility of Bi in Sn is approximately 1.8 wt %, so the SnAg-Bi alloy contains approximately twice the Bi beyond the solubility limit as the SAC-Bi alloy. This difference accounts for the different microstructures in the aged condition of the two alloys.

The anisotropy of the tetragonal β-Sn unit cell has been noted for its influence on both mechanical behavior of Pb-free solder[11] and solder joint reliability[12]. The crystallographic orientation of various samples was not assessed in the current work but there is no indication that results were unduly influenced by preferred orientation or very large grain sizes. The influence of preferred orientation of the Sn unit cell with respect to applied loads in the various tests should thus be considered part of the systematic error in the reported results.

Tensile Properties

Tensile properties (yield strength and ultimate tensile strength) for tensile tests performed at three temperatures are summarized in Table 1. The Castin™ (AIM Solder) alloy was also tested and is included in the table. The change in yield or ultimate strength due to aging is shown as a percentage.

There are two primary trends in Table 1. The first is the large difference in strength imparted to the SAC-Bi and SnAg-Bi alloys by the addition of Bi, and the second is the differences among the alloys in response of strength to aging. In SAC305, the considerable drop off in strength after aging is attributed to the loss of intact eu-

	SAC305						SAC-Bi					
	Yield			UTS			Yield			UTS		
Test Temperature (°C)	As Cast	Aged	Change (%)	As Cast	Aged	Change (%)	As Cast	Aged	Change (%)	As Cast	Aged	Change (%)
25	39.0	23.0	-41.1	43.1	27.0	-37.4	65.4	57.1	-12.7	79.5	78.2	-1.6
75	31.4	14.2	-54.8	33.1	15.5	-53.2	57.1	46.9	-17.8	60.7	52.1	-14.1
125	24.1	13.9	-42.6	24.6	14.3	-41.7	39.3	35.6	-9.5	40.4	37.0	-8.3
	SnAg-Bi						Sn-2.5Ag-0.8Cu-0.5Sb (Castin)					
	Yield			UTS			Yield			UTS		
	As Cast	Aged	Change (%)	As Cast	Aged	Change (%)	As Cast	Aged	Change (%)	As Cast	Aged	Change (%)
25	58.3	55.4	-4.9	81.4	83.6	2.7	39.8	26.3	-33.9	45.3	30.5	-32.8
75	46.1	46.3	0.3	53.1	57.8	8.7	30.9	19.2	-38.0	33.5	20.2	-39.8
125	38.4	38.2	-0.5	40.6	39.8	-1.8	20.4	14.0	-31.6	21.8	14.6	-32.9

Table 1: Tensile Properties of Solders (all values in MPa; average of three or four specimens per condition).

tectic regions which constrain the deformation of the relatively softer primary β-Sn. The aged microstructure contains relatively less abundant and much larger intermetallic particles that are primarily found at grain boundaries. In uniaxial tension it is expected that these grain boundary particles do not strengthen SAC305 and the drop in strength due to aging is dramatic, a result consistent with other investigations[13, 14].

The influence of Bi on Pb-free solder mechanical properties have been attributed to a combination of solid solution and particle strengthening for both SAC-Bi and SnAg-Bi[9]. The results in Table 1 show that the while the strengths of SAC-Bi and SnAg-Bi respectively are not too different from each other in the as-cast condition, the alloys respond to aging differently. The strength of SAC-Bi decreases after aging, although less in absolute and much less in relative terms than was observed for SAC305. In contrast, the strength of SnAg-Bi remains nearly constant. The microstructural changes that occur in aging of SAC-Bi are similar to those observed in SAC305, with the additional feature of precipitation of grain boundary Bi particles. Therefore, the strength is diminished in a similar way by the loss of particle-reinforced eutectic regions, an effect which is countered by the presence of Bi in solid solution. Aging of SnAg-Bi leads to a ripening of Ag3Sn particles and erosion of the eutectic region but it is accompanied by a redistribution of Bi particles that results in a fine dispersion of Bi throughout grain interiors, not only at grain boundaries. The small changes in tensile properties for this alloy are somewhat surprising in light of the dramatic differences between the as-cast and aged microstructure. This too is understood as the dual contribution to strengthening by Bi as particles and in solid solution, although the relative contributions of the two types of strengthening cannot be determined based on this data.

Creep

Creep data for Pb-free solder alloys and multiple sample scales (e.g., bulk, lap shear and solder-joint scale) have been analyzed using both hyperbolic sine models and power law models[15, 16]:

Hyperbolic Sine Model:

$$\dot{\gamma} = A\sinh^{n}(B\tau)\exp\left[\frac{-Q}{RT}\right]$$

Power Law Model:

$$\dot{\gamma} = A\frac{G}{T}\left(\frac{\tau}{G}\right)^{n}\exp\left[\frac{-Q}{RT}\right]$$

Creep data were analyzed in detail using both models in a previous publication[10], but it

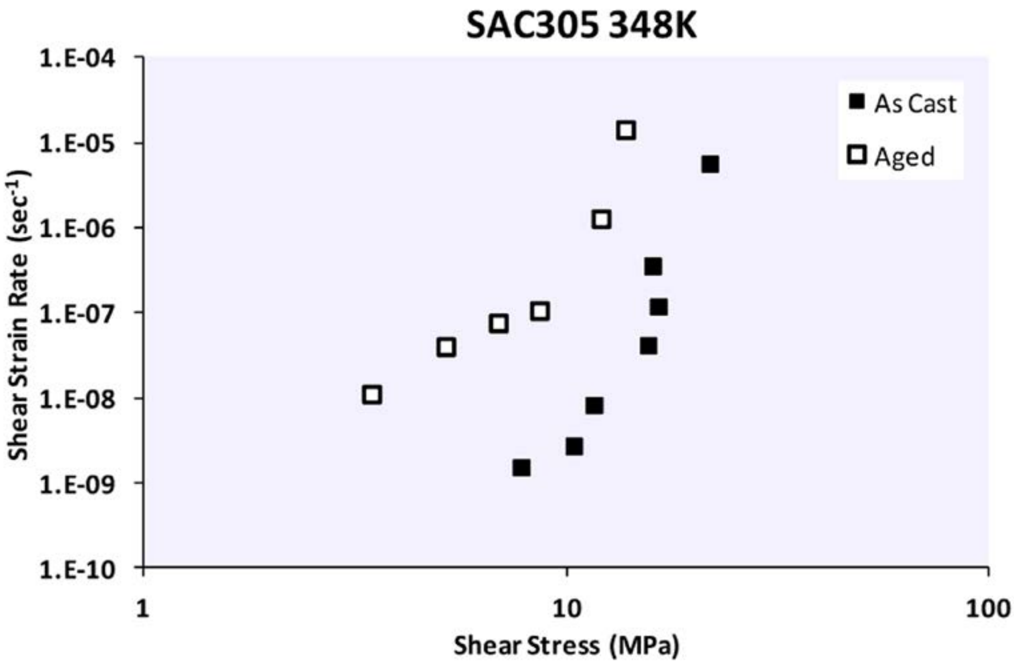


Figure 3: Creep data for as-cast and aged SAC305 tested at 75°C.

should be noted that in that publication the use of hyperbolic sine model was used to compare the data for SAC-Bi and SnAg-Bi alloys to published data for dilute Sn-Bi alloys[17] and to compare as-cast and aged SAC305 to published data for as-cast[18] and aged[19] bulk SAC396. The hyperbolic sine model may have merit as a modeling tool for solder joint deformation calculations, but when confronted with a change in creep behavior as a function of applied stress, it can obscure the actual operative creep mechanisms by rolling all data into a single expression with one stress exponent and activation energy. For example, comparing creep data for SAC305 at 75°C reveals key differences between the as-cast and aged condition, as shown in Figure 3.

The as-cast SAC305 can be fit using a single power-law model, while the aged alloy could be fit using either a single hyperbolic sine function or a combination of a low-stress and high-stress power law function. In the case of aged SAC305, the change from a lower stress exponent at lower stress ($n = 2.5$) to a higher stress exponent ($n = 7.8$) at applied shear stress above roughly 10 MPa at 75°C may mean that a different deformation mechanism needs to be considered at different loads, and that the transition between the two regimes is not likely to occur at the same shear stress in aged SAC305 as it does in as-cast SAC305. In general for all three alloys the transition between low and high stress occurs at a temperature-compensated shear stress τ/G (where G is shear modulus) of approximately 4 x 10-4.

While the previous publication provides details of the creep model parameters n and Q for each equation, a rough summary of the observations for all three alloys can be made using a single figure showing the measured steady-state or minimum shear strain rate as a function of temperature under a constant stress of 8.7 MPa, as shown in Figure 4.

While higher applied loads were necessary during testing to complete tests in a reasonable amount of time, lower stresses such as 8.7 MPa (~1250 psi) are more representative of the types of thermomechanical loads that might be expected in solder joints in actual applications. In this case, the data show that SAC305 is most creep resistant in the as-cast condition, but in the aged condition it deforms more rapidly than any other alloy. The 8.7 MPa stress in Figure 4

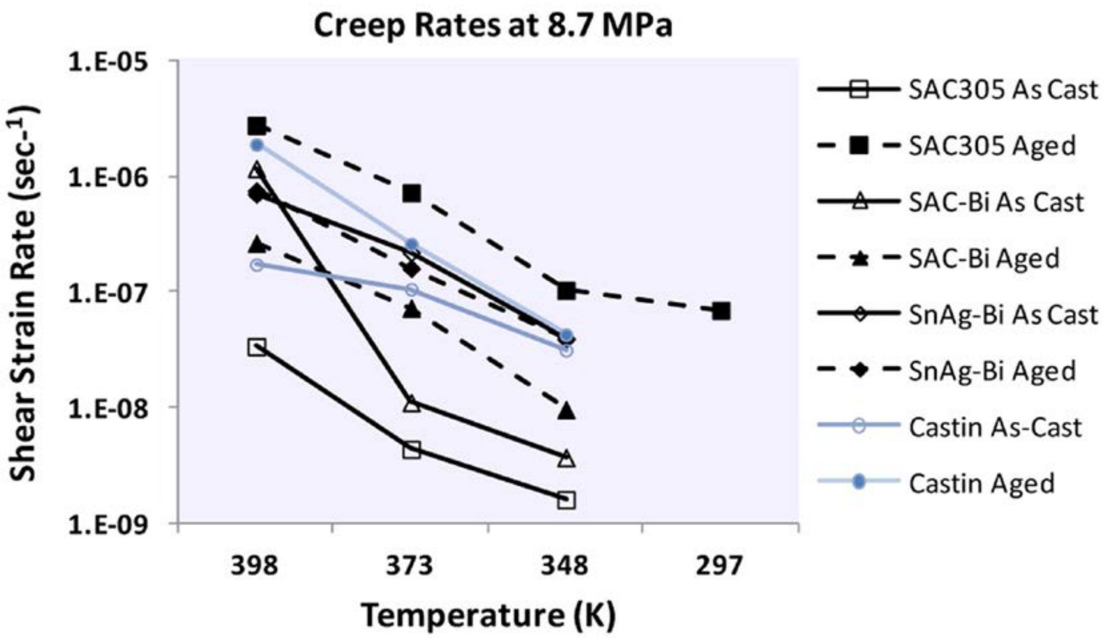


Figure 4: Comparison of shear strain rates of alloys in aged and as-cast condition. Previously unpublished results for Castin (SAC-Sb) are also shown.

is a larger fraction of the yield strength in as-cast SAC305 than for SAC-Bi or SnAg-Bi, so the change in creep strain rates in SAC305 with aging is due to the shift to the high stress regime with higher stress exponent n for the aged alloy even though at the same applied load. At the other extreme, the measured creep strain rates for SnAg-Bi do not change due to aging.

While the details of creep analysis are important, the quantitative results of creep testing can be summarized as follows[10]:

- Aging decreases the apparent activation energy of creep for SAC305 and SAC-Bi;
- Aging has minimal effect on the activation energy of SnAg-Bi; and
- The activation energy of creep in SAC305 is lower than SAC-Bi and SnAg-Bi in either as-cast or aged conditions.

In practical terms, the implications of the first two of these three statements are captured to a great extent in Figure 4: The creep rates of SAC305 and SAC-Bi will change with the microstructural changes that occur during aging, but the creep rate of SnAg-Bi will remain nearly constant. It has been found that extended aging of SnPb at 125°C had minimal effect on room-temperature creep rates of Sn-37Pb[13], so the behavior of SnAg-Bi is similar to SnPb in that respect.

Damping Capacity

Damping capacity is reported as loss tangent (tanδ), where the loss angle δ represents the phase angle between stress and strain. The loss angle is related to the engineering quantity specific damping capacity Ψ by the relationship:

$$\Psi = 2\varpi \tan\delta$$

The specific damping capacity refers to the ratio of the energy dissipated to maximum elastic energy stored[20]; in the DMA testing the source of the elastic energy is the cantilever bending imposed by the test frame. Presumably higher damping capacity could lead to better dynamic performance, with less elastic energy from impacts available to cause failures in intermetallics or pad cratering. For SAC solders the energy stored during the input of elastic energy may provide a similar driving force for micro-

structural evolution as observed during isothermal aging, although by a different route than particle coarsening. For example, decrease in hardness was measured as a function of shear fatigue cycles even though the typical intermetallic particle size did not change as a result of the applied elastic/plastic loads[21].

The testing temperature is sufficiently high relative to the melting points of the alloys that at 0°C, the damping behavior is attributed to thermally activated dislocation movement that is sensitive to microstructural factors such as grain size and dislocation density[22]. Literature data for high purity tin[23] are seen to be consistent with the present data, including the small absorption peak that occurs in several alloys but not Sn-37Pb. The general behavior of all of the Pb-free alloys appears to be consistent with the response of the β-Sn matrix to the elastic input, while the differences between them are attributed to individual characteristics of the microstructures.

"The coarsening of lamellae in Sn-37Pb leads to reduction in the number of phase boundaries which is presumably responsible for the decrease in damping."

While the log-log nature of the tanδ vs. frequency plots obscures the magnitude of the change between as-cast and aged Sn-37Pb, there is a roughly 0.011 decrease in tanδ due to aging, which is the largest measured change of all the alloys. The coarsening of lamellae in Sn-37Pb leads to reduction in the number of phase boundaries which is presumably responsible for the decrease in damping. In the Pb-free alloys, the behavior of SAC305 with respect to aging is the opposite of SAC-Bi and SnAg-Bi, as aging SAC305 leads to an increase in damping capacity while it is decreased in the Bi-containing alloys. For SAC305, the positive change is attributed to the formation of a continuous Sn matrix. For SAC-Bi and SnAg-Bi the decrease is consistent with the general notion that a coarsening of the microstructure and annealing reduces damping capacity.

The plot of tanδ vs. temperature at a single frequency (in this case 10 Hz) in the presentation charts shows that considering the data at only 0°C does not provide a complete picture of the behavior of these alloys. As the test temperature reaches room temperature and above, tanδ of the Bi-containing alloys increases dramatically relative to SAC305, so that above 50°C damping capacity of SnAg-Bi actually exceeds SAC305 while SAC-Bi exceeds SAC305 in the as-cast condition. The trends in damping capacity as a function of temperature can be compared to results for commercially pure Sn and Sn-37Pb. This comparison shows that SAC305 behaves like Sn, exhibiting a gradual and relatively small change over the 200-degree change from –100 to + 100°C. SAC-Bi and SnAg-Bi are more like SnPb, in which a relatively large increase in tanδ occurs as temperature increases past room temperature. Given the similarities between the binary phase diagrams of Sn-Pb and Sn-Bi, the results for damping capacity indicate that the Sn-Bi interfaces are more important in determining the behavior of SAC-Bi and SnAg-Bi than the intermetallic particle-Sn matrix interfaces in SAC305.

Conclusions

The objective of this research was to characterize the mechanical metallurgy of alternative solder alloys for high-reliability applications. Key differences in use of high-reliability electronic systems compared to mass-produced consumer electronic devices include harsh deployment environments and length of service life. Electronic systems installed in a satellite, for example, may be built years before the spacecraft is launched and then must survive many years in orbit with no opportunity for repair or replacement. The system life cycle, sustainability requirements and usage environments for space vehicles differ from airborne systems and there is no reason to expect that the optimal solder alloy for space is the same for aircraft. Characterizing behavior and performance of solder joints over long time scales may not be a high priority for consumer electronics manufacturers, although the documented changes in SAC alloy microstructures due to isothermal aging and their impact on reliability have been documented[24, 25].

The selection of Bi-containing alloys was

based on their performance in early circuit-board reliability testing programs. The mechanical behavior of these alloys shows that the addition of Bi to SnAg or SAC leads to a different response to isothermal aging than is seen in SAC305. These results do not necessarily explain the performance of Bi-containing alloys in reliability testing, but they do show the extent to which the mechanical behavior of different alloys can vary. The results of this research demonstrates the need for microstructure-based material properties for modeling of solder joint behavior in long-lifetime high-reliability systems but they also suggest that the additions of small amounts of Bi could decrease changes in solder alloy properties over time and result in more readily predictable solder joint deformation.

Acknowledgements

The research described here was supported by The Aerospace Corporation's Independent Research and Development program, and was undertaken with the enthusiastic support of Dr. L. Parker Temple III. I thank numerous colleagues for their contributions: Dhruv Patel, Ben Nelson, Byron Zeigler, Jay Yamasaki, Robert Castaneda, and Brian Gable, as well as student interns Kareem Hammoud, Jonathan Salfity and Swati Bhanderi. All trademarks, service marks and trade names are the property of their respective owners. SMT

References

1. NCMS, Lead-Free Solder Project: Final Report, National Center for Manufacturing Sciences, Ann Arbor, Mich., 1997.

2. NCMS, Lead-free, High-temperature, Fatigue-resistant solder: Final Report, National Center for Manufacturing Sciences, Ann Arbor, Mich., 2001.

3. JCAA-JGPP, JCAA-JGPP Lead Free Solder Project Joint Test Report, Executive Summary, International Trade Bridge, Dayton, Ohio, 2006.

4. NASA TEERM, NASA-DoD Lead-Free Electronics Project Joint Test Report, December 2011.

5. F.W. Gayle, G. Becka, J. Badgett, G. Whitten, T.Y. Pan, A. Grusd, B. Bauer, R. Lathrop, J. Slattery, I. Andersen, J. Foley, A. Gickler, D. Napp, J. Mather, C. Olson, JOM, 53 (2001) 17-21.

6. P.T. Vianco, J.A. Rejent, J. Elec. Mat., 28 (1999) 1127-1137.

7. D. Fritz, B. Russell, G. Latta, in: 7th IPC International Conference on Reliability, Rework and Repair of Lead-Free Electronics, IPC, Raleigh, NC, 2008.

8. F.A. Mohamed, K.L. Murty, J.W. Morris, Met. Trans. A, 4 (1973) 935-940.

9. D.B. Witkin, Mat. Sci. Eng. A, 532 (2012) 212-220.

10. D.B. Witkin, J. Elec. Mat., 41 (2012) 190-203.

11. A.U. Telang, T.R. Bieler, A. Zamiri, F. Pourboghrat, Acta Mat., 55 (2007) 2265-2277.

12. T.K. Lee, B. Zhou, L. Blair, K.C. Liu, T.R. Bieler, J. Elec. Mat., 39 (2010) 2588-2597.

13. H. Ma, J.C. Suhling, Y. Zhang, P. Lall, M.P. Bozack, 57th IEEE ECTC (2007), 653-668.

14. Y. Zhang, Z. Cai, J.C. Suhling, P. Lall, M.P. Bozack, 58th IEEE ECTC (2008), 99-112.

15. J.-P. Clech, SMTAI04, Proceedings, SMTA (2004).

16. H. Ma, J. Mat. Sci., 44 (2009) 3841-3851.

17. D. Mittlin, C.H. Raeder, R.W. Messler, Met. Mat. Trans. A, 30 (1999) 115-122.

18. P.T. Vianco, J.A. Rejent, A.C. Kilgo, J. Elec. Mat., 33 (2004) 1389-1400.

19. P.T. Vianco, J.A. Rejent, A.C. Kilgo, J. Elec. Mat., 33 (2004) 1473-1484.

20. R.S. Lakes, Rev. Sci. Inst., 75 (2004) 797-810.

21. L. Yang, L. Yin, B. Roggeman, P. Borgesen, 60th IEEE ECTC (2010) 1518-1523.

22. A.S. Nowick, B.S. Berry, Anelastic Relaxation in Crystalline Solids, Academic Press, New York, 1972.

23. L.S. Cook, R.S. Lakes, Scripta Met. Mat., 32 (1995) 773-777.

24. V. Venkatadri, L. Yin, Y. Xing, E. Cotts, K. Srihari, P. Borgesen, 59th IEEE ECTC (2009) 398-405.

25. T.K. Lee, W. Xie, B. Zhou, T.R. Bieler, K.C. Liu, J. Elec. Mat., 40 (2011) 1967-1976.

NOTE: This article was presented at the IPC APEX EXPO Technical Proceedings.

David B. Witkin is an engineer with The Aerospace Corporation.

EOS Exposure of Components in Soldering Process

by Vladimir Kraz
ONFILTER INC.

SUMMARY: This article examines the nature, consequences and mitigation of electrical overstress (EOS) caused by electromagnetic interference (EMI), or electrical noise, on power lines and ground in a manufacturing environment.

Introduction

Soldering irons, solder extractors and other equipment that comes in direct electrical contact with sensitive components can inject significant energy into these devices. Specifically, metal-to-metal contact between the tip of the soldering iron and pins of the components can be a gateway for high current that can cause significant device damage.

Where would a soldering iron tip get voltage? After all, it is supposed to be grounded, just like the PCB to which the components are being soldered, so theoretically there should be no difference in voltage and thus no harmful currents between the tip of the iron and the devices. This, however, may only be true for DC or for very low frequencies such as power mains (50/60Hz). For high-frequency signals it may be very different.

Transient Signals: A Source of Electrical Overstress

Assuming the tip of the iron is properly grounded, the voltage on it can arrive mainly via ground connection and to some degree via capacitive coupling between the heating element and the tip.

Ground by itself is not a generator of any signal. However, grounding wires connect the entire factory and once some stray electrical signal enters grounding network, this signal can reach quite far.

Main source of voltage on ground is transient signals leaked from power lines. Transient signals can come from a number of sources, such as switched power supplies, thyristor control, servo motors, equipment commutation and so on[1]. These signals can reach significant magnitude. Figure 1 shows a transient signal on a power line caused by turning on ubiquitous heat gun. As seen, the peak signal reaches 8.7V and this is not the highest magnitude found in manufacturing environment where plenty of high-current equipment is operating.

By virtue of neutral and ground being eventually connected together at some point, and because of leakage currents (parasitic currents between power lines and ground) present in almost all equipment and, to a much higher degree, in manufacturing equipment, these transient signals are also present on ground. Current leakage at high frequencies is significantly higher than often-specified leakage at power line frequencies.

This is due to much-reduced impedance of parasitic capacitance coupling at higher frequencies. With the complexity of grounding network and increased leakage at high frequencies in the soldering iron itself, there is a strong possibility of current spikes between grounded iron tip and grounded PC board with components.

What is Acceptable and Safe?

There are a number of standards and recommendations limiting signal on the tip of a soldering iron. The ESD Association's STM13.1-2000[2] sets current limit at 10mA and voltage limit at 20mV. While the test set-up in this document implies mains (50/60Hz) signal, there is no stated limit of properties of the signal. It should be noted that the current limit in this document is about 15 years old (it takes at least three years to finalize and to release a document within the standards organizations); the current limits now should be substantially lower to reflect higher sensitivity of today's components.

Now-obsolete MIL-STD-2000[3] and its associated military standards specify no more than 2mV RMS voltage on the tip. RMS values may be very misleading for transient signals. 2mV RMS may translate into quite high peak-voltage of transient signal; the voltage spikes can be very narrow (i.e., have very short duty cycle). Figure 2 shows the difference between peak and RMS values of a transient signal, and from turning on the same heat gun on a workbench where the time base was spread to the degree where typical multimeter can measure it. 761mV peak translates into only a 15.8mV RMS signal, a 48x ratio in this case. For this type of waveform, a 2mV RMS signal would translate into 96mV peak signal. Obviously, RMS value is not the

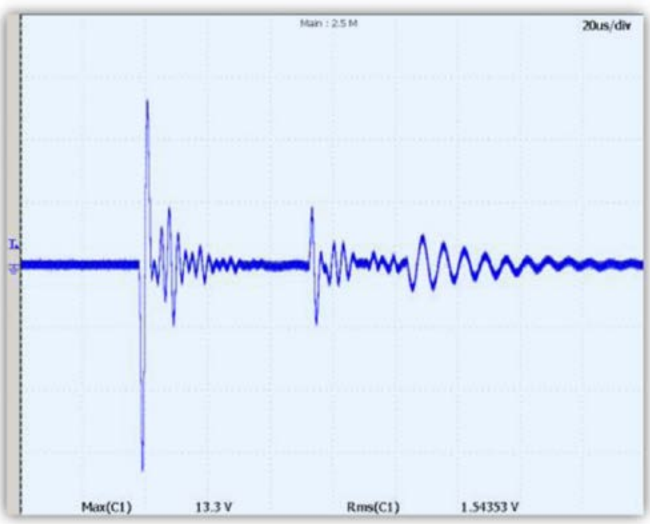


Figure 1: Transient signal on power line caused by turning on heat gun.

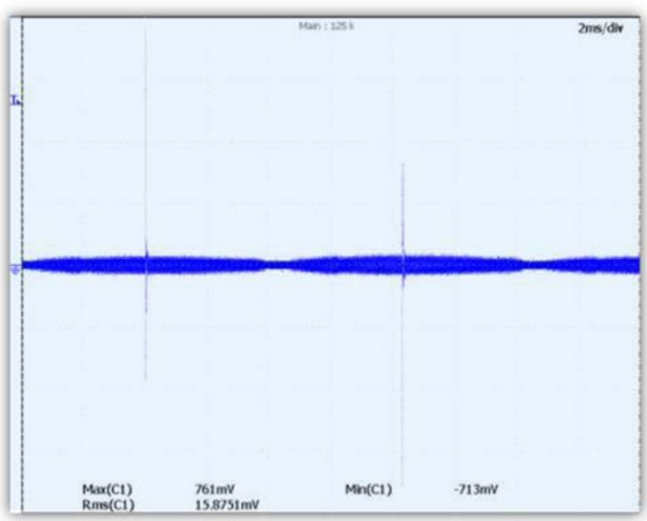


Figure 2: RMS and peak values of a transient signal typical on power lines.

best way to specify signal on the tip of the iron. A common multimeter often used for this purpose provides measurements of either RMS value or close to average—good for 50/60Hz, but unusable for transient high-frequency signals.

IPC-TM-650 section 2.5.33.2 allows for 2V peak voltage on the tip of the soldering iron, which is extremely high; section 2.5.33.3 of the same document allows maximum of 1μA of current measurable with a multimeter, not a scope thus providing RMS or average value.

In dissent with the above IPC standards, IPC-A-610-E[4], the most fundamental document controlling quality of PCB assembly, provides the following instructions:

3.1.1 EOS/ESD Prevention—Electrical Overstress (EOS)

...Before handling or processing sensitive components, tools and equipment need to be carefully tested to ensure that they do not generate damaging energy, including spike voltages. Current research indicates that voltages and spikes less than 0.5 volt are acceptable. However, an increasing number of extremely sensitive components require that soldering irons, solder extractors, test instruments and other equipment must never generate spikes greater than 0.3 volt.

IPC-77115, which provides directions for rework of the electronic circuits, mimics IPC-A-610-E.

Which Measurements are Important

Let's examine the properties of the EOS signal caused by conducted EMI. As a rule, conducted emission signals are high-energy signals(i.e., having low output impedance and capable of delivering high currents). The reason for this is that creation of disturbances on low-impedance power line requires power and only truly low-impedance sources of noise can

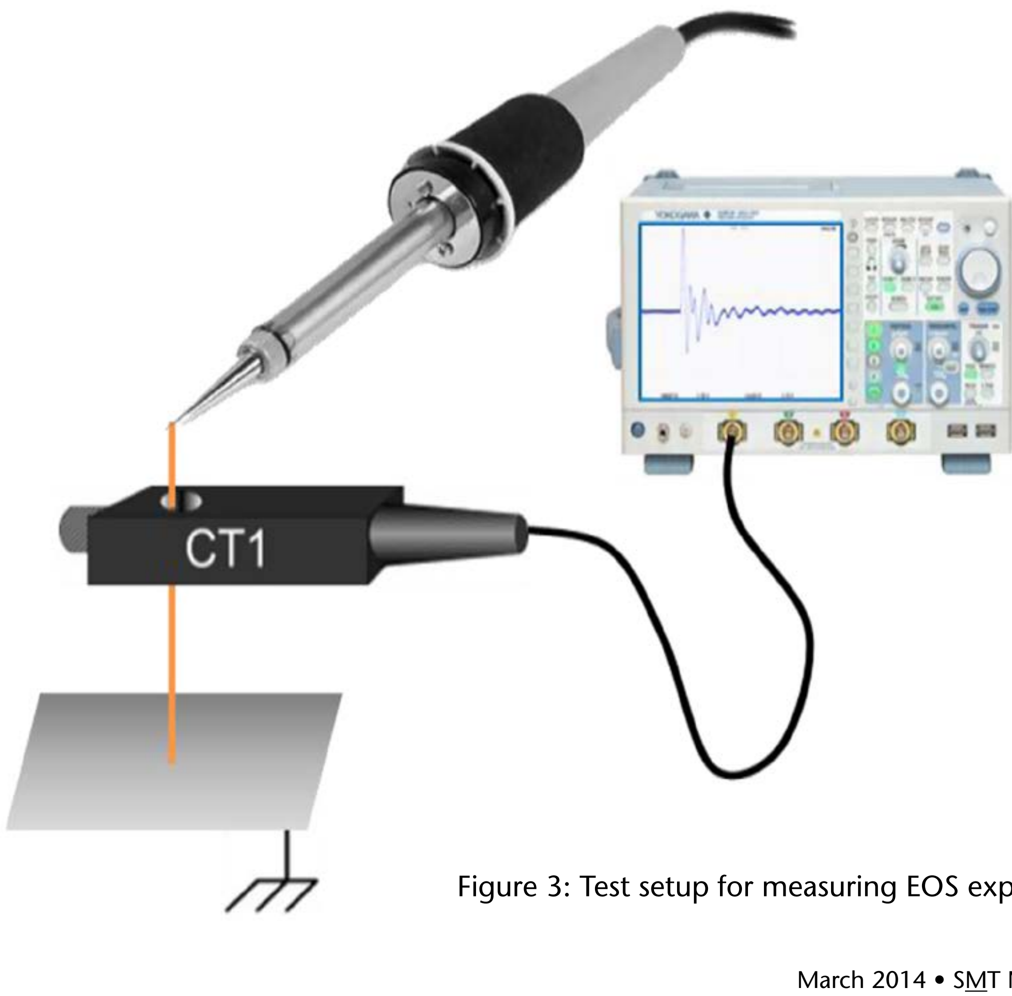


Figure 3: Test setup for measuring EOS exposure.

deliver. Even fairly low voltage transient signals on power lines can be quite dangerous because of their current capability.

Current is a better measure of EOS safety of sensitive devices since it is the current that causes actual damage (with very few exceptions). In addition, due to complex impedances the current capability of some devices and boards may be limited at high frequencies; therefore, voltage measurements alone may not be a definitive indication of current injection into the circuit.

Another factor in favor of current measurements vs. voltage is that strong transient signals on power lines and ground can easily inject corresponding signals into oscilloscope probe cables via radiated emission thus distorting voltage measurement results. Injection of radiated signal into current probe is significantly less than into a voltage probe due to a number of factors, including lower impedance of the current probe arrangement. We will focus on measurements of current.

A typical setup of a workbench is seen in Figure 3. A grounded metal plate is used in lieu of a PCB as the worst-case scenario. Current is measured using a Tektronix CT1 current probe[6] with bandwidth of 1GHz. This probe has conversion factor of 5mV/ma, meaning that 1mA of current would be seen as 5mV on the oscilloscope.

There are many sources of noise in manufacturing environment. Some of them are random, such as transients from turning on and off a typical heat gun or other piece of equipment. Others are periodic, synchronized with the waveform of voltage on the mains (50 or 60 Hz). Periodic transient signals are caused by a variety of equipment, including heaters, brightness control for vision systems and countless more. For the purposes of repeatability of the data we will focus on periodic signals. An easily-reproducible noise from a common light dimmer connected to a 60W light bulb was used in tests described below.

Figure 4 depicts such transient signal on power lines and corresponding current between the tip of the soldering iron and the component in the setup of Figure 3. As seen, the peak current from the tip (19.12mA) is significantly higher than allowed by ESDA STM13.1-2000. It should be noted that typical transient signals on power lines in the industrial settings are often significantly higher than the ones shown in Figure 4; see earlier Figure 1.

Data from previously-published sources corroborate the above data. Raytheon, in its paper[7] presented at the ESD Symposium in 2005, show transient currents at the tip of soldering iron reaching 1000mA.

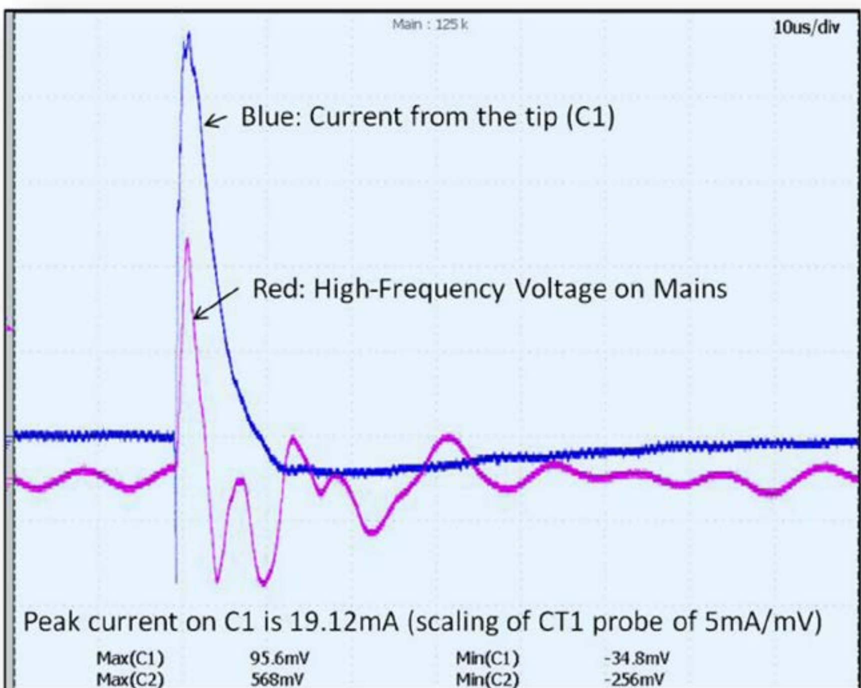
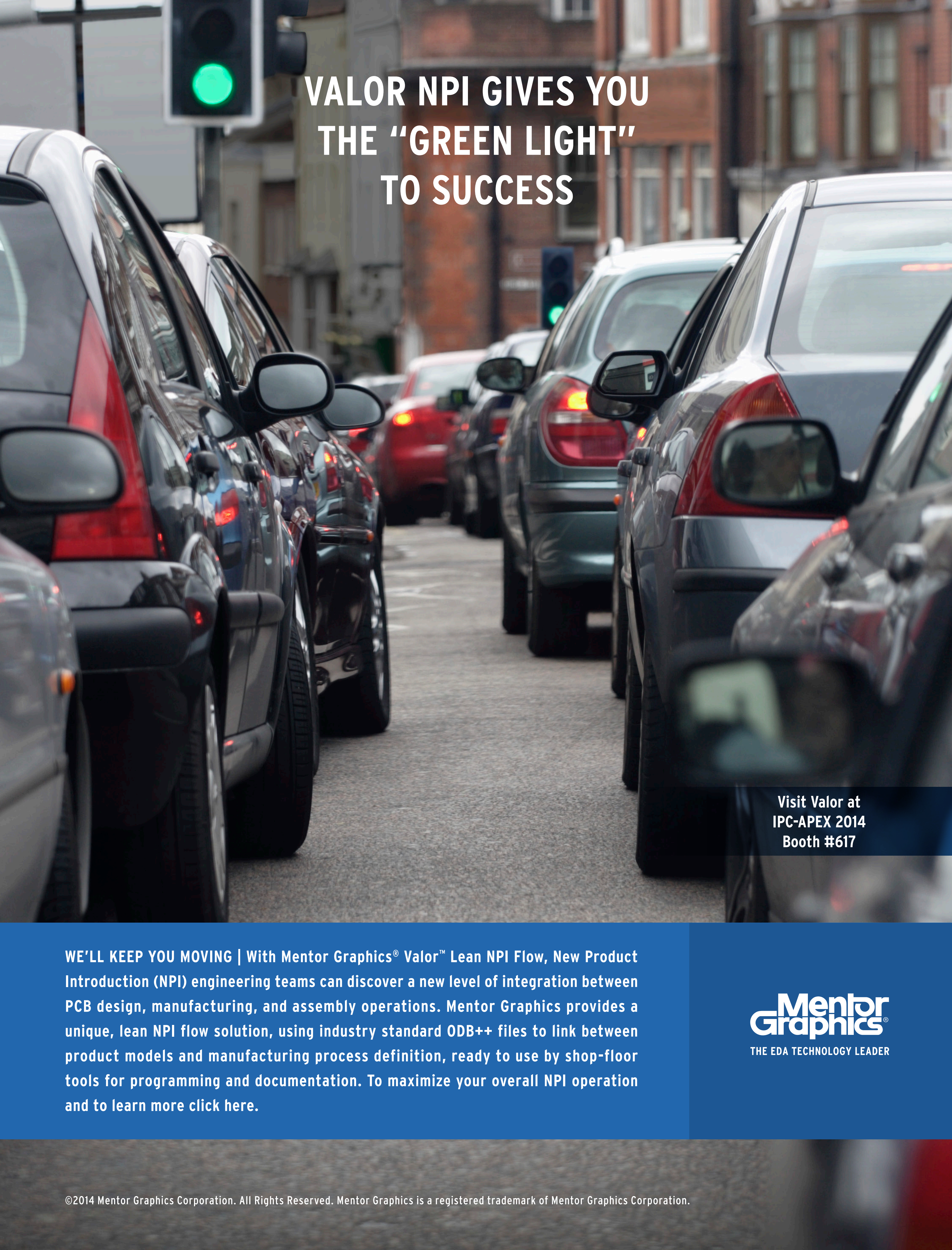


Figure 4: Transient on power line from periodic signal and resulting current from the tip.

How Does the Noise Get on the Tip of the Soldering Iron?

Although the tip of most professional-grade soldering irons is grounded quite sufficiently for DC and very low frequencies, at high frequencies the situation is quite different. Figure 5 shows how the solder-


VALOR NPI GIVES YOU THE "GREEN LIGHT" TO SUCCESS
Visit Valor at IPC-APEX 2014 Booth #617
WE'LL KEEP YOU MOVING | With Mentor Graphics® Valor™ Lean NPI Flow, New Product Introduction (NPI) engineering teams can discover a new level of integration between PCB design, manufacturing, and assembly operations. Mentor Graphics provides a unique, lean NPI flow solution, using industry standard ODB++ files to link between product models and manufacturing process definition, ready to use by shop-floor tools for programming and documentation. To maximize your overall NPI operation and to learn more click here.
Mentor Graphics®
THE EDA TECHNOLOGY LEADER
©2014 Mentor Graphics Corporation. All Rights Reserved. Mentor Graphics is a registered trademark of Mentor Graphics Corporation.

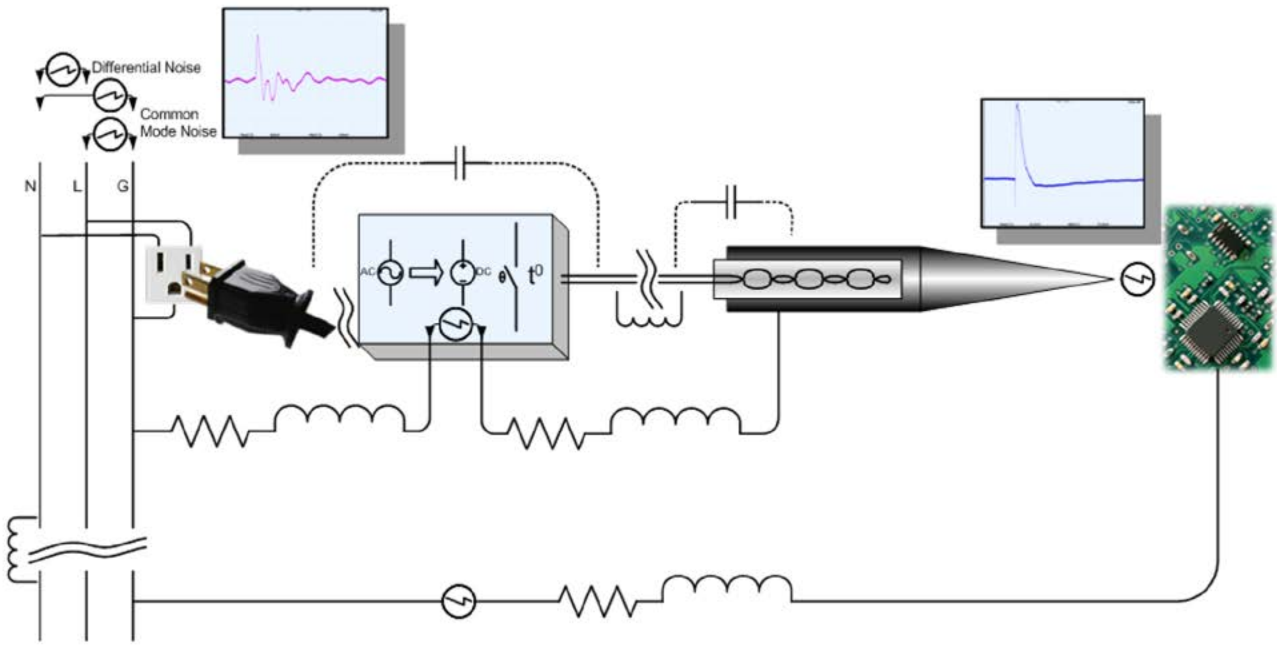


Figure 5: Noise propagation in the soldering iron.

ing iron and a workbench look like at high frequencies.

Several factors are at play (in no particular order of significance):

- Noise on power lines induces corresponding noise on ground via capacitive and inductive coupling, as well as via leakage currents
- Switched power supplies (the ones that are used in soldering irons to convert 120/250V down to a typical 24V) can be transparent for high-frequency signals due to a number of factors, parasitic capacitance being the dominant one. The noise from the mains thus can propagate to the low-voltage line of the iron's heating element
- Switched power supply inside the soldering iron can be a source of noise by itself
- Iron's heating element is capacitively coupled with the tip allowing propagation of high-frequency signals
- Ground wires—from mains to the iron's supply, from the iron's supply to the iron itself and from the soldered object to the facility ground—have complex impedance, including resistance and inductance

If the voltage on the tip is the same as the voltage on the PCB or on the soldered components, then there won't be any current. At DC and 50/60Hz the grounding scheme of professional soldering irons typically works well.

At high frequencies the voltage between the tip and the components is nearly impossible to equalize due the complex impedance of overall grounding wiring. This impedance causes, among other things, ground bounce[8] and phase shift, as well as resonance and ringing[9]. What sometimes aggravates the situation is that some factories opt for a separate "ESD Ground," a different grounding network which is eventually connected to a facility ground. The long wires in these two grounding networks leading to the soldering iron and to the workbenches greatly contribute to a voltage differential at high frequencies. Figure 6 shows the current from the tip of the iron in several situations with different distances between where the soldering iron is plugged in and grounding of the workbench/PCB. As seen, the difference in current reaches ~80%.

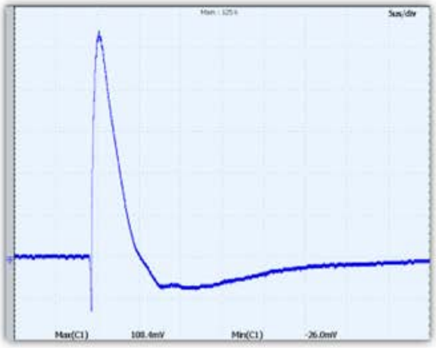


Figure 6a: PCB is grounded ~1.5 m from the iron.

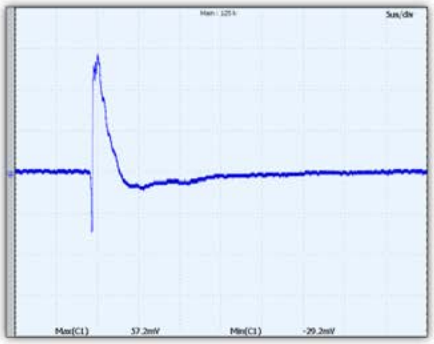


Figure 6b: PCB is grounded ~18" from the iron.

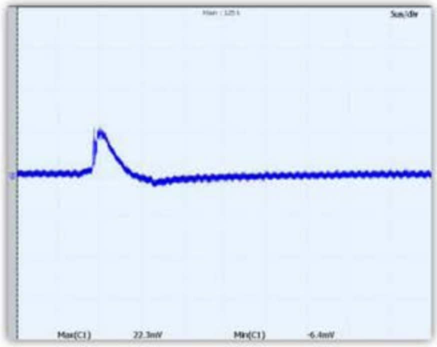


Figure 6c: PCB is grounded next to the iron.

Soldering Iron Properties

Are all soldering irons alike in generating and/or passing the noise down the tip? What about top-of-the line soldering irons? If there is a current from the tip of the soldering iron, does it mean that the iron itself is defective or unsuitable for work with sensitive components?

High-frequency currents from the tip of the professional-grade properly-installed iron are caused not by the iron itself, but by the reality of complex facility topology, wiring and operation of equipment. Soldering iron is just one component in soldering process and no matter how good it is it cannot fundamentally solve the issues of facility by itself. In short, if you have a quality soldering iron, it is doing its job. It is a user's task to provide safe EOS environment for the entire bench where the iron is only one of components.

Mitigating Effects of Transient Signals on Power Lines and Ground

If the sources of transient signals on power lines is known and can be removed without affecting production process, then the reduction of current from the tip of the soldering iron is relatively simple. However, too often the source is either unknown or cannot be removed. The only remaining options are grounding management and filtering out the transient signals on power lines and ground.

Grounding Management

Re-routing of ground connection and separation of "noisy" ground from a clean one can help to reduce harmful currents. Techniques recommended and explained in this paper[4] help to alleviate some of the noise issues. Specifically, low impedance to facility ground and separation between noisy and quiet grounds and connecting soldering iron and the workbench to the quiet ground often result in lower level of transient signals.

As shown in Figure 6, grounding of the workbench and of the soldering iron as close as possible to each other can significantly reduce current exposure during soldering.

Grounding management alone, however, cannot satisfactory resolve noise issues since the source of EMI is not removed and the problematic signal still present in the soldering iron.

Filtering Out the Noise

Unless noise on power lines and ground is greatly reduces, there always will be a possibility of EOS exposure during soldering. Intel recommends[10] power line filters as the first line of defense against EOS.

These filters suppress noise on power lines and provide soldering iron with relatively clean power. Some EMI filters also suppress noise in ground line.

Figure 7 shows recommended application of power line EMI filter with the soldering iron. It is important to connect ground of your workbench or tool to the ground terminal of the filter, not to the facility ground—the filter creates a quiet "EMI ecosystem" at its output. Figure 8 shows the current from the tip of the iron used

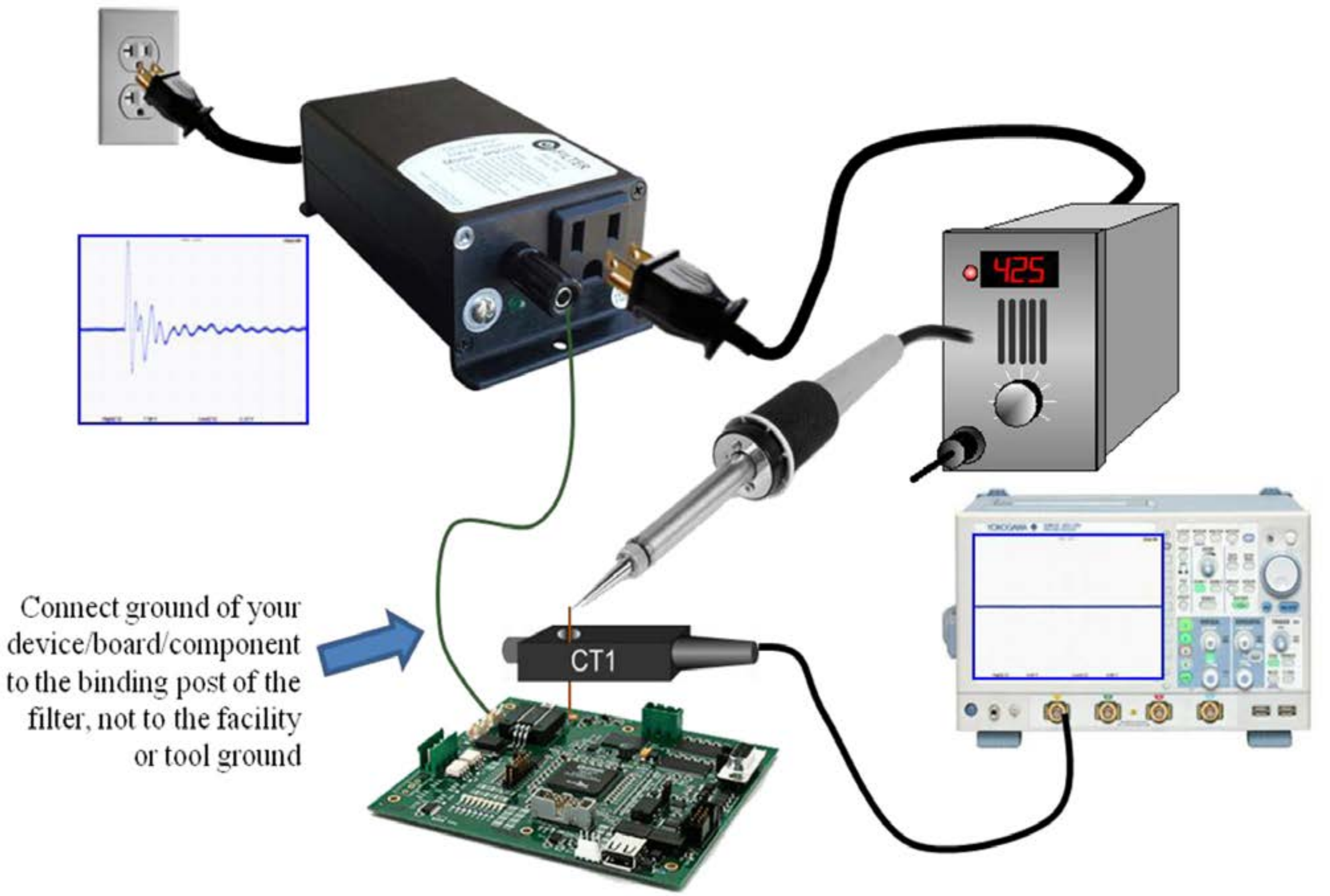


Figure 7: Soldering Iron with power line EMI filter (OnFILTER model APN515LG).

with OnFILTER's APN515LG filter under the same noise on power lines as in Figure 4. As seen, the current from the tip becomes negligibly low.

This requires specially-designed filter optimized for soldering process properties. Some soldering irons that include a "generic" type of filter can actually add noise[7]. This paper[9] provides explanation of this phenomenon.

Conclusion

High-frequency signals on power lines and ground can drive high currents into sensitive devices during soldering, resulting in electrical overstress and device damage. Proper analysis of the soldering environment, as well as any environment where conductive objects come

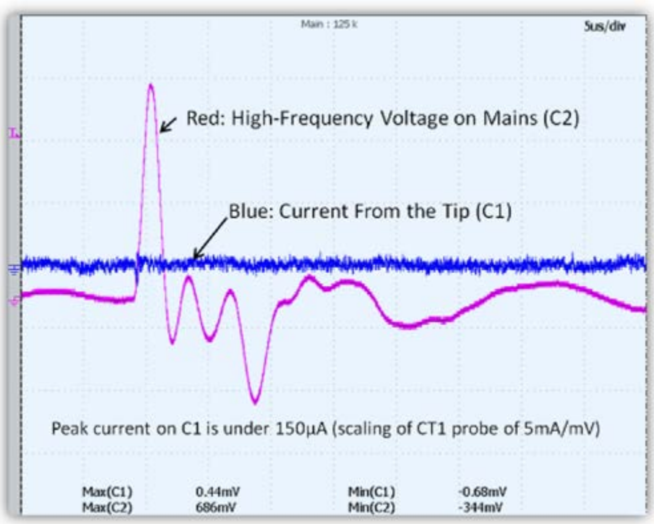


Figure 8: Soldering tip current after power line EMI filter (OnFILTER model APN515LG).

in contact with the sensitive devices and implementation of preventive and corrective measures improves yield and reduces EOS-caused failures. **SMT**

References

1. Electrical Overstress (EOS) and Its Effects on Today's Manufacturing, V. Kraz, Pulse Magazine, April 17, 2012.

2. ESDA STM13.1-2000 www.esda.org.

3. MIL-STD-2000 Military Standard: Standard Requirements for Soldered Electrical and Electronic Assemblies.

4. IPC-A-610-E-2010, Acceptability of Electronic Assemblies, IPC.

5. IPC-7711B Rework, Modification and Repair of Electronic Assemblies, IPC.

6. AC Current Probes, Tektronix.

7. EOS from Soldering Irons Connected to Faulty 120VAC Receptacles, Raytheon, W. Farrel, et.al. ESD Symposium Proceeds, 2005.

8. How Good is Your Ground? V. Kraz and P. Gagnon, Evaluation Engineering, 2001.

9. EOS Damage by Electrical Fast Transients on AC Power, A. Wallash, V. Kraz, Proceeds of ESD Symposium, 2010.

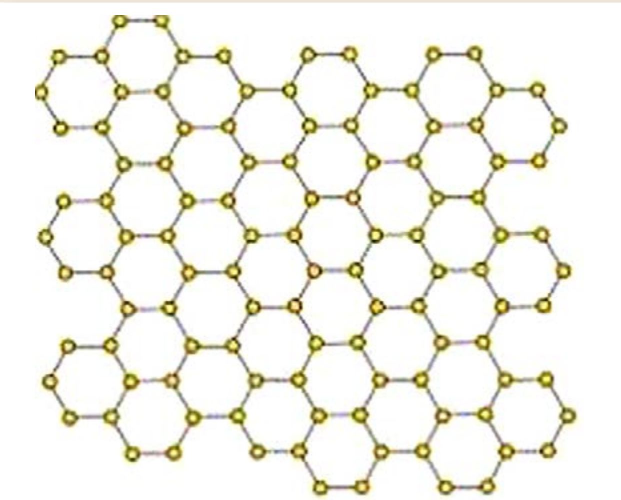
10. Intel Manufacturing Enabling Guide, May 2010, Ch. 3.

Vladimir Kraz is president of OnFILTER Inc.

Artificial Graphene a New Breed of Ultra-thin Super-material

A new breed of ultra thin super-material has the potential to cause a technological revolution. Artificial graphene should lead to faster, smaller, and lighter electronic and optical devices of all kinds, including higher performance photovoltaic cells, lasers, or LED lighting.

For the first time, scientists have been able to produce and analyse artificial graphene from traditional semiconductor materials. Such is the scientific importance of this breakthrough, in findings published recently in one of the world's leading physics journals, Physical Review X. A researcher from the University of Luxembourg played an important role in this highly innovative work.



Graphene

Graphene (derived from graphite) is a one atom thick honeycomb lattice of carbon atoms. This strong, flexible, conducting, and transparent material has huge scientific and technological potential. Just recently discovered in 2004, there is a major global push to understand its potential uses. Artificial graphene has the same honeycomb structure, but in this case, instead of carbon atoms, nanometer-thick semiconductor crystals are used. Changing the size, shape and chemical nature of the nano-crystals makes it possible to tailor the material to each specific task.

The University of Luxembourg is heavily involved in cross-border, multidisciplinary research projects. In this case it partnered with the Institute for Electronics, Microelectronics, and Nanotechnology (IEMN) in Lille, France, the Debye Institute for Nanomaterials Science and the Institute for Theoretical Physics of the University of Utrecht, Netherlands and the Max Planck Institute for the Physics of Complex Systems in Dresden, Germany.

Welcome to the 2014 IPC APEX EXPO Show Guide

This year, the Mandalay Bay Hotel and Convention Center is the site for the industry's premier event, with 430 exhibitors from more than 50 countries. Featuring advanced and emerging technologies in printed board design and manufacturing, electronics assembly, test and printed electronics, APEX is a great place to find new suppliers with new solutions and connect with colleagues from around the world. Plenty of free offerings are on hand—follow these links for a complete online show brochure or event schedule.

Here are a few highlights of what attendees may expect include:

- 430 exhibitors showing equipment, materials and services for printed boards and electronics manufacturing—plus printed electronics! There›s no better place to see and compare.
- The largest technical conference for our industry in the world. Highly selective, the conference presents new research and innovations from experts in the fields of electronics assembly, test and board fabrication and design.
- FREE! Industry poster sessions—Catch up on the latest research and meet the authors.
- Professional development courses provide comprehensive updates on pressing industry concerns.
- Standards development meetings that help shape the future of our industry.
- IPC International Hand Soldering Grand Championship—Compete in or watch the excitement on the show floor.
- Other happenings on the show floor include the Show Floor Welcome Reception on Tuesday and a display of cutting-edge products and services in the New Product Corridor. There are also plenty of informational resources at the IPC Bookstore.
- Networking opportunities including an International Reception, First-Timers' Welcome, IPC Tech Talk, Women in Electronics Networking Meeting, and IPC Government Relations Committee Open Forum allow attendees to meet colleagues, get updates on key issues and share ideas.

To register to attend IPC APEX EXPO 2014, click here.

For an inside look at the show and in-depth interviews with industry insiders directly from the show floor, be sure to visit I-Connect007's Real Time With... site during the show. We're the only publication posting interviews and events in real time!

Opening Keynote Address:
Tuesday, March 25, 2014
8:30–9:30 a.m.

Peter Diamandis, M.D.
Creating a World of Abundance

Peter Diamandis, M.D., is a dynamic inspirational speaker and tech entrepreneur who will share his insights about how breakthroughs in exponentially growing technologies like artificial intelligence, nanomaterials, 3D printing, robotics and digital medicine will re-engineer products, companies, industries—and even society—over the next 20 years. Diamandis will explain how human society has evolved from "local and linear" to "global and exponential," and how this change has not only spawned the creation of new billion dollar start-ups out of nowhere, but also led to the demise of 50-year-old billion-dollar companies overnight.

Through his work as chairman and co-founder of Singularity University and chairman/CEO of X PRIZE, Diamandis has proven the transformational power that exponentially growing technology has on companies, governments and humanity—and on "do-it-yourself" technologists and small companies who can now achieve what only governments or large corporations could do before.

Day Two Keynote Address:
Wednesday, March 26, 2014
9–10:00 a.m.

James McLurkin
Swarm Robotics and the Toys, Movies and Insects that Made it all Possible

They will flock. They will swarm. And they will tackle the dangerous, dirty and dull jobs for which humans are inherently ill-suited. They're multirobot systems—and one day they will become the norm, according to roboticist, inventor, researcher and teacher, James McLurkin. Inspired by the complex group behaviors found in ants, bees, wasps and termites, McLurkin's work focuses on developing software and programming techniques for groups of autonomous robots with populations ranging from 10 to 10,000.

As a child, McLurkin was constantly playing with Star Wars® toys and building with LEGO® bricks, cardboard boxes and any other materials he could access. Today, armed with degrees in electrical engineering and computer science from M.I.T. and University of California, Berkeley, McLurkin continues to harness his inventiveness to develop the robot swarms that will one day perform jobs ranging from warehouse operations to search-and-rescue missions to Mars exploration. Don't miss this fascinating look at the future of robotics and the technology that is making it happen.

Day Three Keynote Address:
Thursday, March 27, 2014
9–10:00 a.m.

Diandra Leslie-Pelecky, Ph.D.
The Physics of NASCAR

How do you design and manufacture a car that will move at speeds in the neighborhood of 200 mph (321 km/h), yet handle with precision and, most important, keep the driver alive? What technology makes a NASCAR car different from the vehicles you see on the highway?

In a presentation based on her book, "The Physics of NASCAR," physicist and researcher Diandra Leslie-Pelecky, Ph.D., will take you behind the scenes of America's most popular spectator sport—and explain the feats of engineering that make NASCAR work. Drawing on her extensive access to NASCAR race shops, drivers, crew chiefs, engine builders and pit crews, Dr. Leslie-Pelecky will trace the lifecycle of a racecar, from its creation at leading race shops to competing in the action of the NASCAR series.

Free IPC APEX EXPO BUZZ sessions

Eight free BUZZ sessions will be offered at IPC APEX EXPO this year. The industry's top technical experts on subjects ranging from automotive and new technologies to conflict minerals, export controls and technology roadmaps will provide insights into timely issues. Admission to the BUZZ sessions and the exhibit hall is free to pre-registrants, a savings of $25 on-site. Click the link above for BUZZ session times and a complete schedule.

This year's BUZZ session topics:

- Underwriters Laboratories: Updates
- Advanced Fabrication Instruction Exchange Between Design and Manufacturing: The IPC-2581B Model
- Promoting Excellence: New IPC Standards for Reliability and Quality, and IPC Validation Services Program
- Forbidden by the Government: Electronics' Materials Restrictions
- INEMI Sustainability Forum
- Counterfeit Components
- What's Coming in 2015 in Electronic Technology Roadmaps

IPC EMS Management Council Meeting

Monday, March 24
8:00 a.m.–5:00 p.m. (includes networking breakfast, lunch and dinner)

With a unique high-level focus, this event will provide information on current trends and strategies so you can make the best choices for your company's future. Network with your peers and learn how other EMS executives are resolving problems that you are also facing. For a complete meeting agenda, including topics to be covered, click here. Note: Must be a representative of an EMS company to attend.

IPC APEX EXPO 2014 Technical Conference

The IPC APEX EXPO technical conference is known worldwide as one of the finest and most selective in the world. Learn about new research and innovations from key industry players in the areas of board fabrication and design and electronics assembly.

Sign up for one day, the full conference or an All-Access Pass. Click here for complete registration information and forms.

Professional Development Courses

Sunday and Monday, March 23–24
Thursday, March 27

This year, 29 professional development courses are being offered, with each three-hour course focusing on a critical issue within nine specialized areas, including: assembly processes for lead free and tin-lead soldering; cleaning, coating and contamination; design; emerging technologies; environmental issues and compliance; PCB fabrication and materials; printed electronics; quality, reliability and test; and supply chain/business issues. Course attendees will receive an instructional handbook to reinforce key information and use as a reference when they return to work.

Among the instructors leading the courses are Rainer Thueringer, Ph.D., Technische Hochschule Mittelhessen; S. Manian Ramkumar, Ph.D., Rochester Institute of Technology; Phil Zarrow, ITM Consulting Inc.; Jennie Hwang, Ph.D., Sc.D., H-Technologies Group; Ray Prasad, Ray Prasad Consultancy Group; Gerjan Diepstraten, Vitronics Soltec; and Mike Bixenman, DBA, Kyzen.

Click here for a complete list of professional development courses and instructors.

thepcblist™

The PCB List—Find out what it's all about in the I-Connect007 booth!

Brought to you by PCB007, The PCB List is the world's most comprehensive online directory of printed circuit manufacturers, anywhere. Buyers, specifiers, designers and others looking for a PCB fabricator will appreciate the intuitive navigation, detailed search capability, and global reach of The PCB List. With a Showcase listing, a PCB fabricator can create a neat, organized presentation that puts all pertinent information at a potential customer's fingertips.

Drop by the I-Connect007 booth to see for yourself how easy it is to find a fabricator, or create a Showcase listing!

Real Time with... Interviews and Panel Discussions

This year, I-Connect007 and the Real Time with... program returns to Las Vegas, Nevada to bring you complete video coverage of IPC APEX EXPO 2014. Last year, we brought you more than 150 interviews—and this year promises to be just as prolific.

The Real Time with… team of editors, guest editors, and videographers will be working throughout this seminal event to capture the keynotes and bring you one-on-one interviews and panel discussions with the industry's top technologists, engineers, and business leaders as it happens!

Visit Real Time with... for updated information about IPC APEX EXPO 2014.

Assembly Materials for High-Temperature Applications

by Jörg Trodler
HERAEUS MATERIALS TECHNOLOGY GMBH & CO. KG

SUMMARY: Trends in the automotive market are leading to an increasing need for new solder alloys. This article will discuss the reliability of soft soldering alloys at higher temperatures, as well as possibilities for different applications.

New technology trends in the automotive market include high-power modules for e-mobility, and a combination of logic and power which will be developed for increased economy, safety and reliability. One of the most important challenges is the electrical system and the realization of complete energy management. The connection between sensor, logic and control units, as well as power transmission for electrical vehicles, is the electronics assembling technology.

This article will discuss and show results of reliability in soft soldering alloys (based on lead-free requirements) for higher temperature s (>125°C–175°C), as well as possibilities for different applications. Therefore, it will present the basis of the material and the realization for processes for the electronics assembly technology. Furthermore alternatives and development stages for temperatures above 200°C will be discussed.

Introduction

Important requirements for applications that combine power and logic devices include:

- High power density
- High reliability
- High heat conductivity
- Ambient condition more than 150°C
- Lead-free technology
- Lifetimes longer than 15 years
- Cost
- And of course, optimum methods for combining power and logic

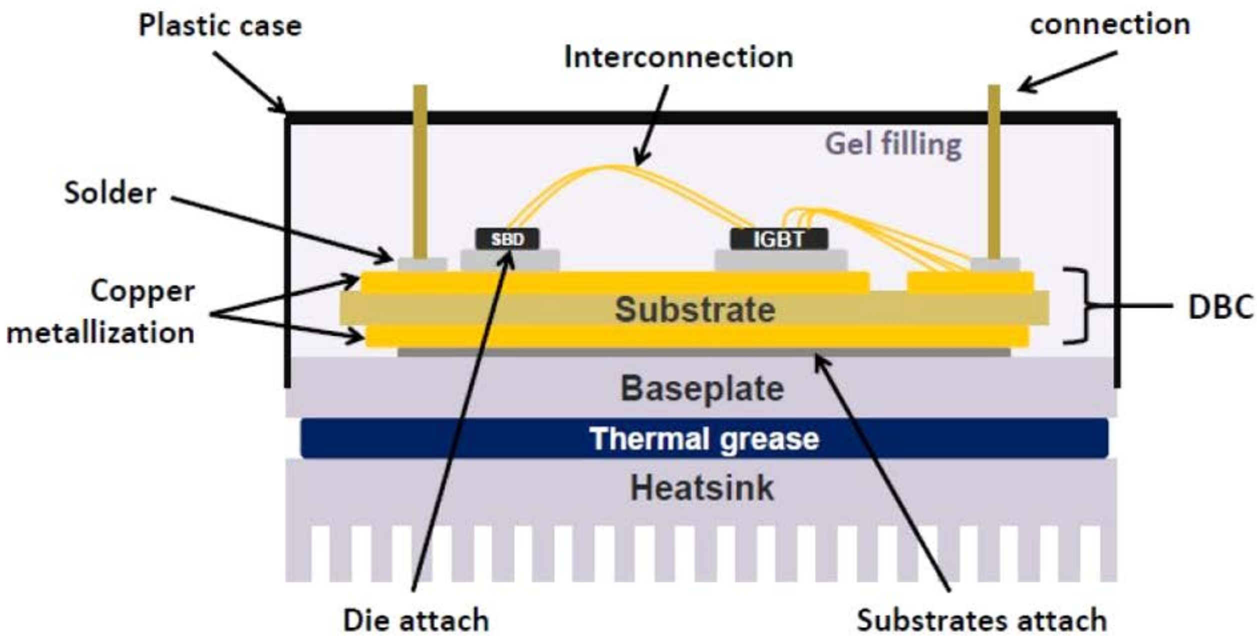


Figure 1: Assembly of a power module.

Alloy	Melting-Temperature [°C]	Remark
Sn96.5 Ag3.5	221	SnAg eutectic
Sn96.5 Ag3 Cu0.5	217	SAC Standard-alloy Under eutectic
Sn95.5 Ag4 Cu0.5	217	SAC with 4% Ag, above eutectic
InnoRel Innolot® Sn Ag3,5 Cu0,7 Ni0,125 Sb1,5 Bi3	206-218	Higher reliability on pcb Higher operation temperature, e.g. 150°C
InnoRel HT1 Sn /Ag2, 5/Cu0,5/In2/KM[2)]	210-217	Higher reliability on TF and DCB Higher operation temperature, >150°C

Table 1: Table of soft solder alloy for the electronics.

This leads to a need for assembly materials with improved properties.

As state-of-the-art for power modules' pre-forms and solder paste are based on eutectic tin/silver (SnAg3.5) or tin/silver/copper (SAC) with 3 or 4% silver, the eutectic SnAg3.5 alloy has worked up to 125°C for years. For temperature above 125°C, these alternatives can be used:

- Special alloys for soft soldering (e.g., HT1)
- Sinter paste/Sinter adhesive
- Diffusion soldering (e.g., HotPowCon [HPC])

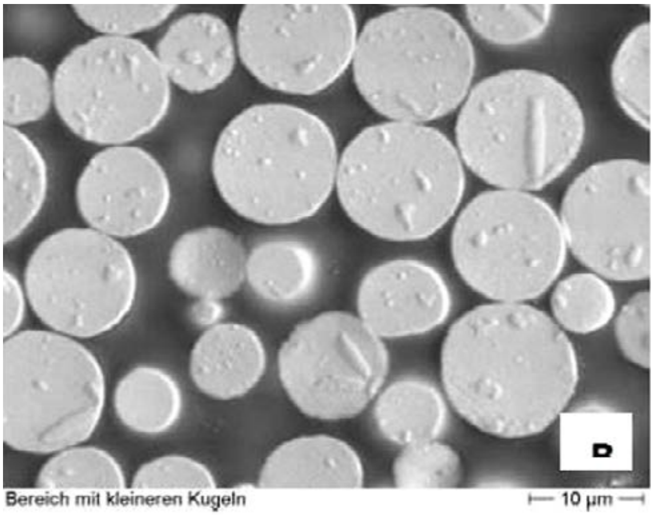


Figure 2: Cross-section after powder production (source: Müller, NMB 160804).

Soft Solder Alloy

The table in Figure 2 shows a list of soft solder alloys that are already in use for electronics. All alloys are based on tin (Sn) and thus not low-temperature alloys like SnBi.

SAC alloys have been in use for standard applications on organic PCB substrates in electronics for years. The eutectic SnAg3.5 are mostly used for thick film applications (TF), as well as power electronics based on direct copper bonding (DCB) for temperatures up to 125°C, and in some applications even higher. The application field for Innolot solder paste on PCBs is up to 150°C, and can withstand a higher number of cycles (1–3) on organic PCB substrates. But Innolot will not work for power or TF applications; the HT1 alloy has been developed for such applications.

Metallurgical Aspect for HT1

Based on an investigation for BGA balls, an alloy has been developed for increasing the resistance to thermal cycling with higher temperature differences. Due to the fact that BGA balls require a high quantity of Ag inside, it wasn't possible to realize a powder production for soft soldering alloys, because Ag3Sn intermetallic had been created during the process (Figure 2 and Figure 3a-3e).

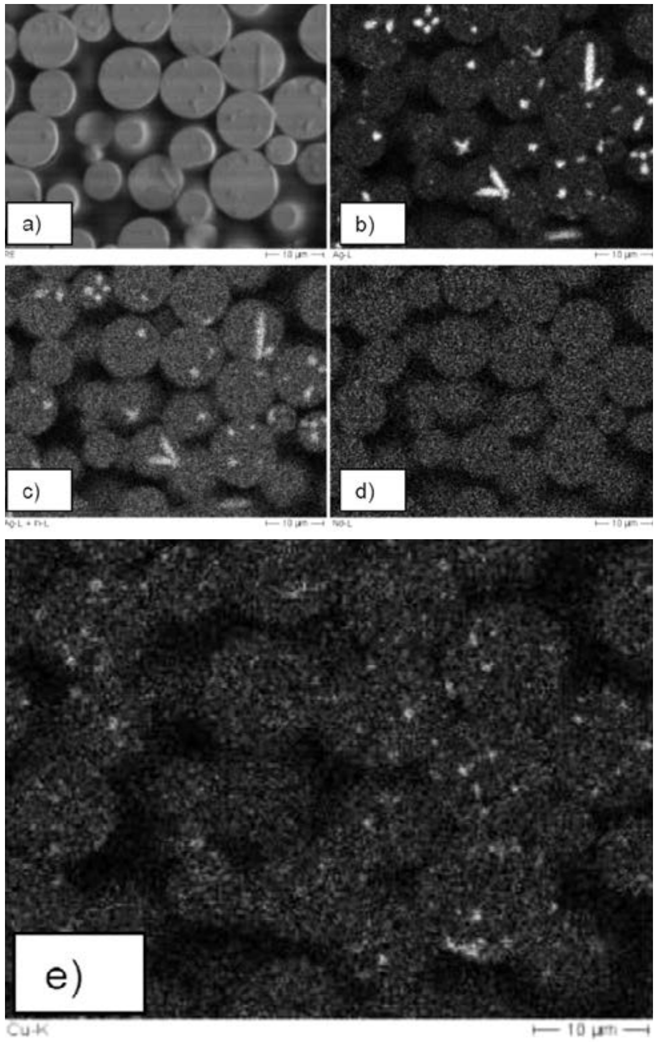


Figure 3a-3e: Mapping of the powder. Figure 3b is Ag3Sn (source: Müller, NMB 160804).

The first modification for changing the Ag3Sn structure was developed by using a crystal modification. Figures 4a and 4b compare the structure with and without that modification (KM).

One major advantage is that the structure of the critical Ag3Sn intermetallic has changed to a 3D structure (star structure). One of the causes of this phenomenon is the critical nucleus radius due to the fact that Ag3Sn and $NdSn_2$ have nearly the same radius[5]. Nevertheless, another factor is the content of silver. Different Ag contents of 2%, 2.5%, 3% and 3.75% have been invested. Different alloys were soldered onto

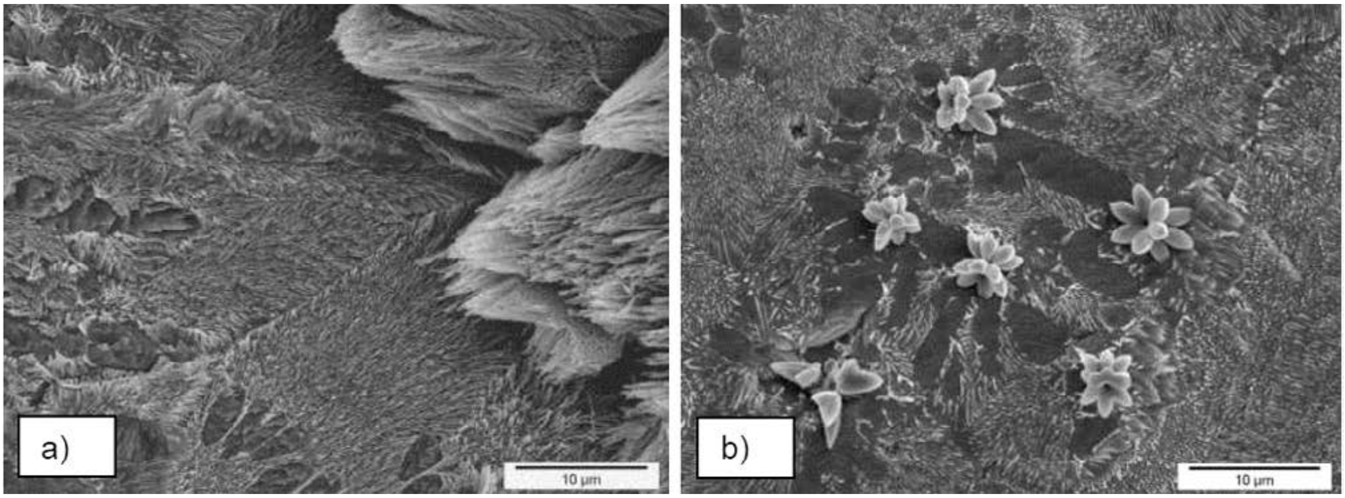


Figure 4: (a) SAC + In (without modifier); and, (b) SAC+In+KM (source: Müller, NMB 160804).

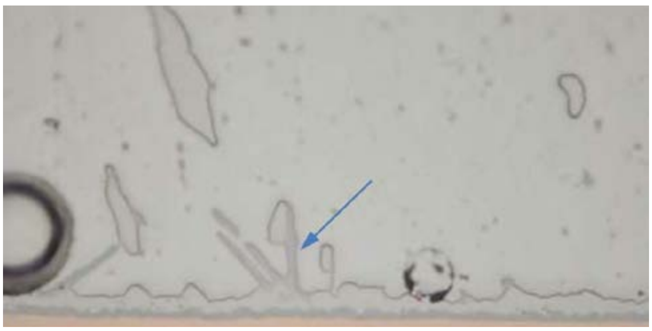


Figure 5: Cross-section with 3.75% Ag, Ag3Sn.

substrates and analyzed by cross-sections. Figure 5 shows intermetallic with a quantity of 3.75% Ag, which means the silver content was fixed at 2.5%.

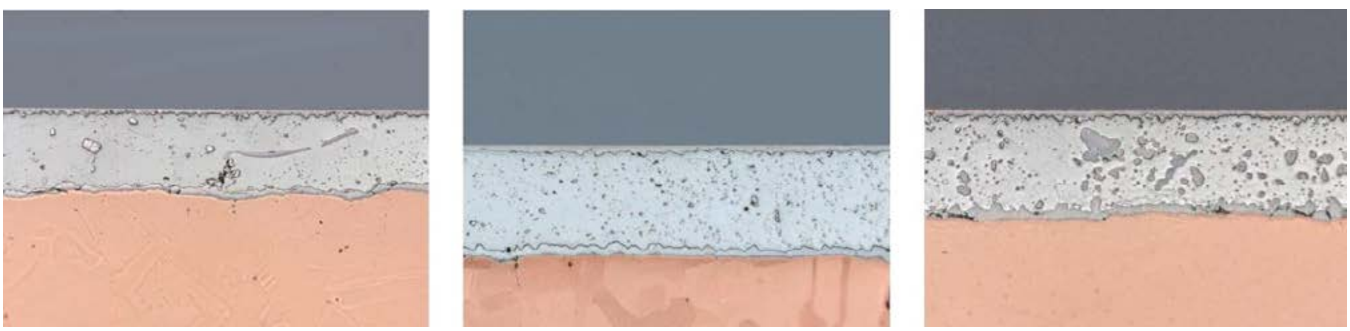
A further investigation was done by a DSC analysis to finalize the melting point/rang of those alloys. As result of that DSC, the alloy with 2.5% Ag has a melting range from 210°C to 217°C and was selected for the final alloy.

Technology Qualification for HT1

Different solder pastes/alloys on real DCBs were qualified for the technology. The steps for the qualification were:

- Printing and measurement of the solder deposits after printing
- X-ray
- Cleaning with two mediums and cleaner
- TCT 30'/10''/30 with -40/+125 and -40/175°C

The first interpretation of the results focuses on cross-section results after N=500 by -40/+175, Figures 6a to 6c.



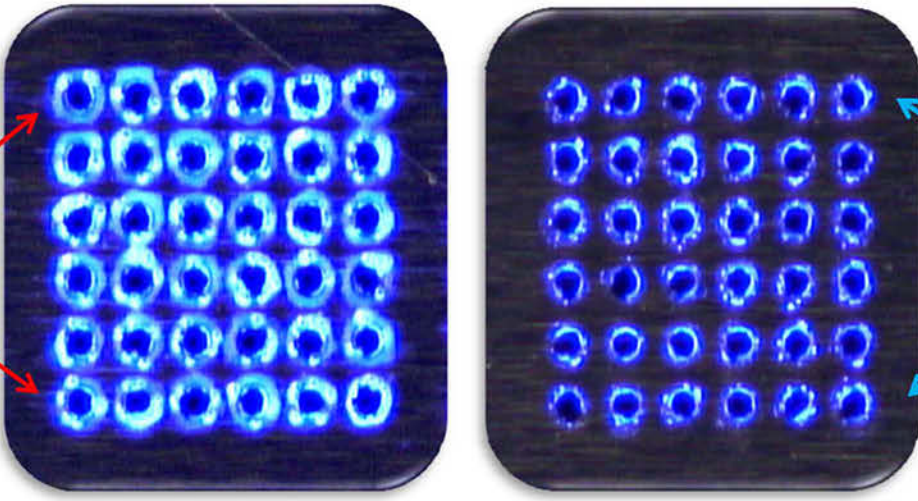
Figures 6: (a) SnAg.5; (b) HT1; and (c) Innolot.

IMPROVE YOUR PRINTING WITH

nanoclear

Stencil Underside Post Printing (UV Tracer Added)

Heavy flux buildup



Flux contained closer to apertures

Untreated   Treated

BENEFITS:

- ✓ Improve Print Quality
- ✓ Reduce Bridging
- ✓ Improve Print Yield
- ✓ Reduce Print Variation
- ✓ Reduce Understencil Wiping
- ✓ Better Print Accuracy
- ✓ Print Smaller Apertures
- ✓ Outperform Competitive Coatings
- ✓ Survives Aggressive Wash Cycle

Improves performance of any stencil from any supplier

(858)-350-9474 • sales@aculon.com • www.aculon.com

ACULON

In these cross-sections there are not really any differences to the interface between SnAg3.5 and HT1. The HT1 is finely dispersed, and offers more homogeny, and the $SnAg_3$ shows Ag_3Sn intermetallic. The Innolot already shows some defects between the substrate and the solder joint inside the interface. Another effect with the Innolot was some die loss after the TCT, which means there was a complete crack inside the assembly. Based on that result, a product qualification with SnAg3.5 and HT1 was made.

Product Qualification for HT1

The current requirements for such DCB product qualification are N=1000 at -04/+125°C with 30'/10''/30' without any electrical defects. Therefore, the passive test was made with these requirements and the electrical analyses as well as some cross-sections after N=250/500/750/1000/1500/2000, plus end of life (EOL). Both alloys fulfill this technical requirement, which means that after N=1000 there was no electrical failure. The first electrical failure came after 1500 cycles for both alloys, but this was not due to a defect in the assembly (Figure 7). All defects were based on wire bond defects.

After N=2000 there was a delamination with the SnAg3.5 alloy between die and solder (Figure 8). That effect was temporary, which means that it wasn't for all. For example another cross

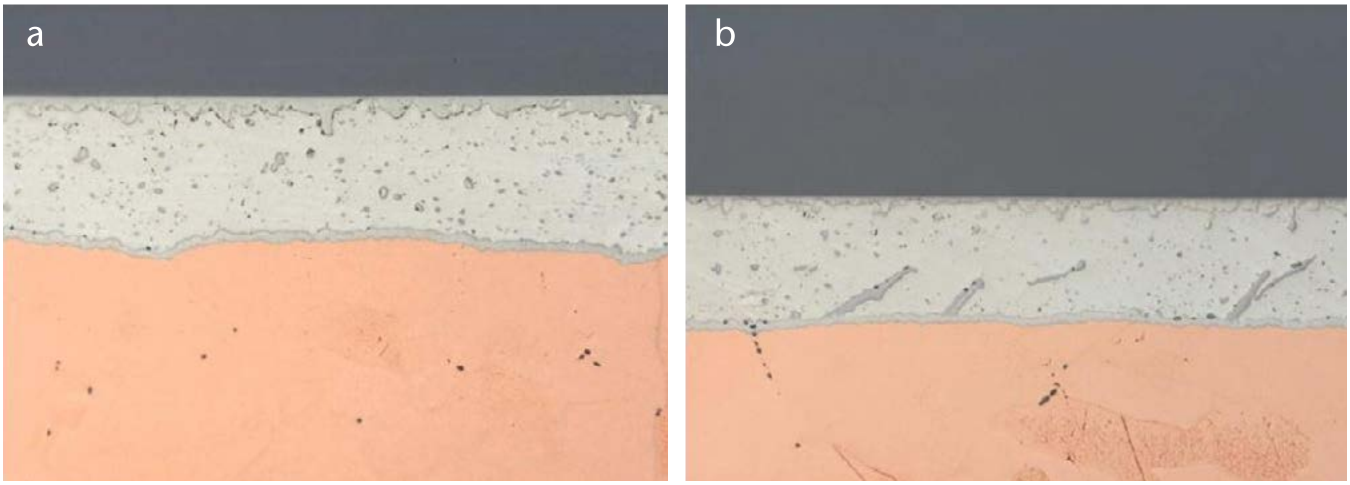


Figure 7: Cross-section after N=1500 (a) HT1 and (b) SnAg3.5.

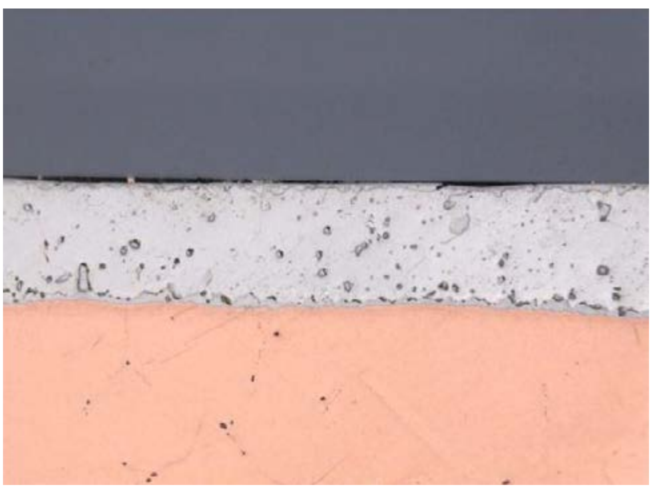


Figure 8: Cross-section of SnAg3.5 after N=2000.

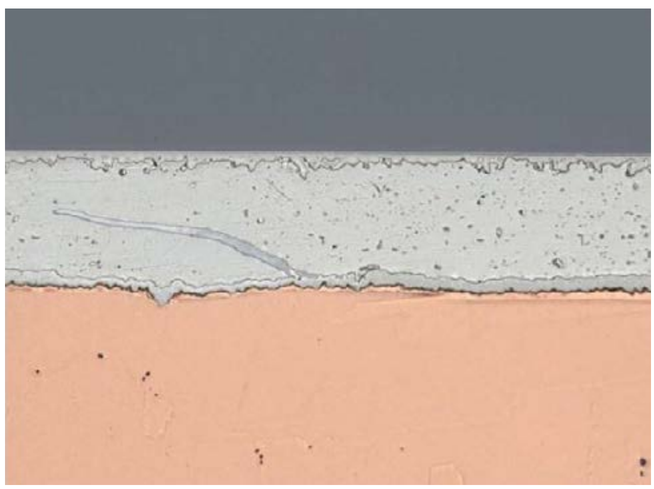


Figure 9: Cross-section of SnAg3.5 after N=3000.

section after N=3000 doesn't show that effect (Figure 9).

No delamination showed in the HT1 alloy after all cycles. Figure 10 shows the results after 4,000 cycles.

As a summary of this investigation, for standard applications SnAg3.5 is used, but when an improvement is needed for higher temperatures, the HT1 is the selected alloy.

Figure 10: Cross-section HT1 after N=4000 (source: Faunhofer ENAS).

Sintering

Soft solder alloys with or without additives does have a limit of electrical and thermal conductivity. Devices which need more of those physical properties or operate at higher temperatures (200°C), alternatives for the assembly technology are needed, including materials. One of these possibilities is sinter technology. A comparison between soft solder alloy and sinter technology is described in Figure 13.

On one hand, silver has a higher melting temperature (961°C) than Sn-based soft solder alloys; there are no aging effects when operating at higher temperatures (e.g., 200°C). On the other hand, the thermal conductivity is much higher than soft solder alloys. That guarantees a higher level of thermal management, and junction temperature is transformed and more effective.

State-of-the-art is sinter materials with nano silver particles inside (NTV)[6, 7]. This technology needs operation pressure by >30MPa for die placing. The challenge for this technology is reduction of pressure and process temperature[8]. By using nano silver[9] it is possible to come to technology without any pressure[10]. The limiting factor is thickness of silver layers up to 10 µm. With more layers, the shrinking makes an inhomogeneous structure that limits the ad-

Property	Sintering	High Lead Solder	SnAg3.5
Electrical Conductivity	10.5 - 40 MS/m	4.8 MS/m	7,8 MS/m
Thermal Conductivity	>100 W/(m?K)	25 W/(m?K)	70 W/mK
CTE	19 ppm/K	29 ppm/K	28 ppm/K
Melting Point	961 °C	<300 °C	221 °C
Process-Temperature	220 °C	340 °C	250 °C
Shear strength @ 25 °C	20 MPa	15 MPa	20 MPa
Shear strength @ 300 °C	10 MPa	n/a	n/a
Tensile strength @ 25 °C	55 MPa	29 MPa	30 MPa
Homologous temperature (operation temperature 175°C)	36 %	78 %	91 %

Table 2: Table showing the most important properties.

hesion to the die or substrate. Another factor could be the roughness of the finish itself, e.g., copper on DCB. For that challenge a concept with micro silver has been developed. This allows a process without pressure, or with low pressure, at 220°C.

Diffusion Soldering/HotPowCon (HPC)

Different investigations described[11, 12] an increase of thermal stability by using a dissolution process for creating intermetallic connections. Therefore, an increase in reliability after temperature cycling[3] means a combination of thermal solidification and isothermal solidification, which could be the basis for a new type of interconnection, as seen in Figures 11 and 12.

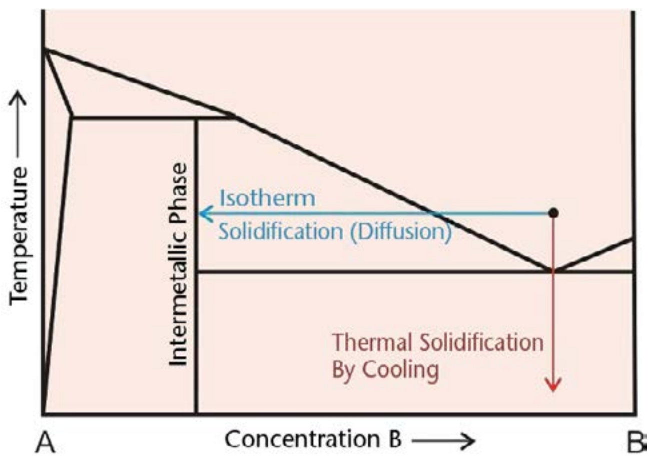


Figure 11: Phase diagram of a two element system.

From this basic investigation, the idea for this project was developed: to create structure designs by developing high melting-point intermetallic solder paste. For this purpose, a soft solder alloy was used based on Sn with a high metal concentration and additives, and the possibility of isothermal solidification at low/standard solder temperatures, as well as operating temperature above liquidus temperature after soldering. Before the project began, an investigation had been carried out on realistic DCBs with IGBTs. The process was printed with a 20 µm stencil, pick-and-place of IGBTs and soldering in vapor phase with vacuum. The solder paste was based on type 6 eutectic SnCu powder with and without Cu powder in different sizes. The result after soldering without Cu powder is shown in Figure 13.

By using this process, intermetallic in a selective connection between substrate and die was created. By using additional Cu powder, as in Figure 14, most of the solder joint was created with the standard interconnection based on the soft solder alloy and selective intermetallic of the Cu powder.

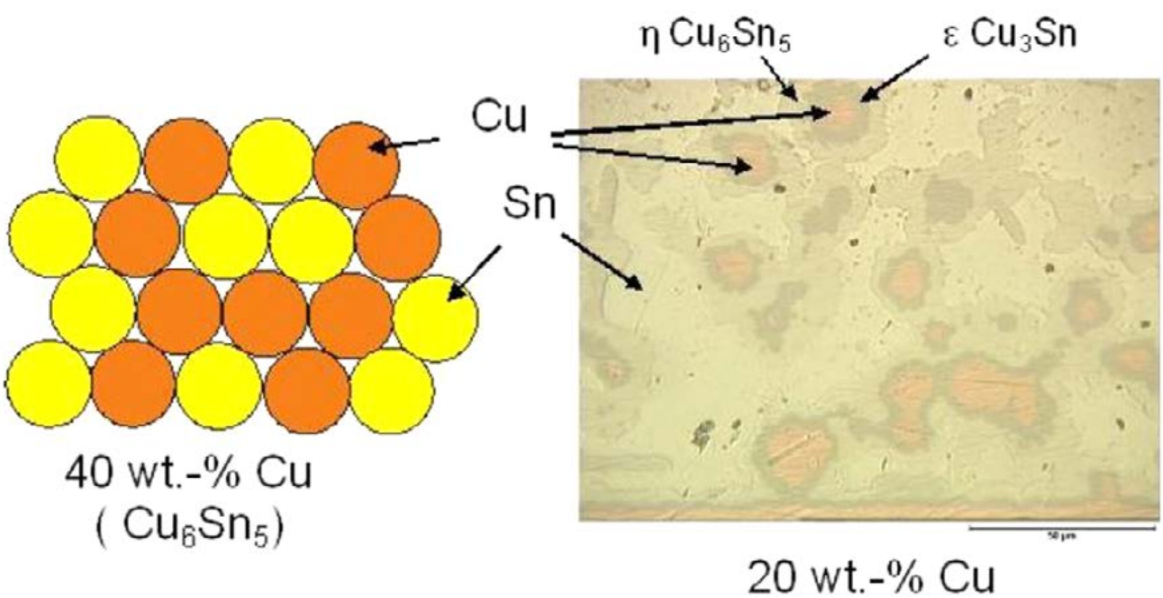


Figure 12: Creating of intermetallic with Cu in a SnCu system (Source: Fraunhofer IZM).

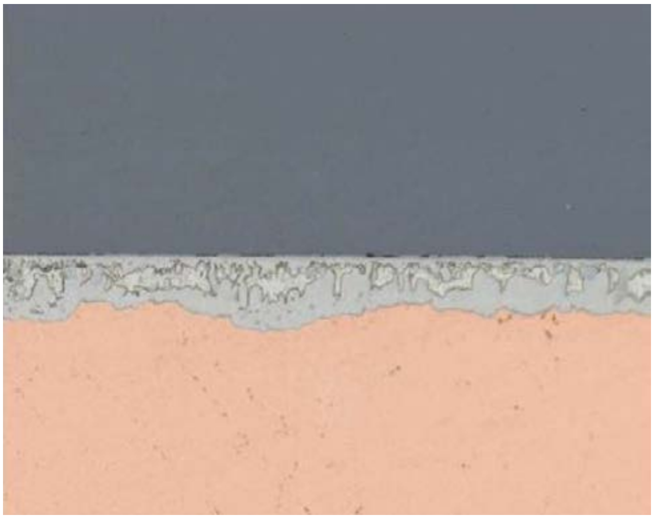


Figure 13: IGBT on DCB with SnCu solder paste (type 6) produced with a 20 µm stencil.

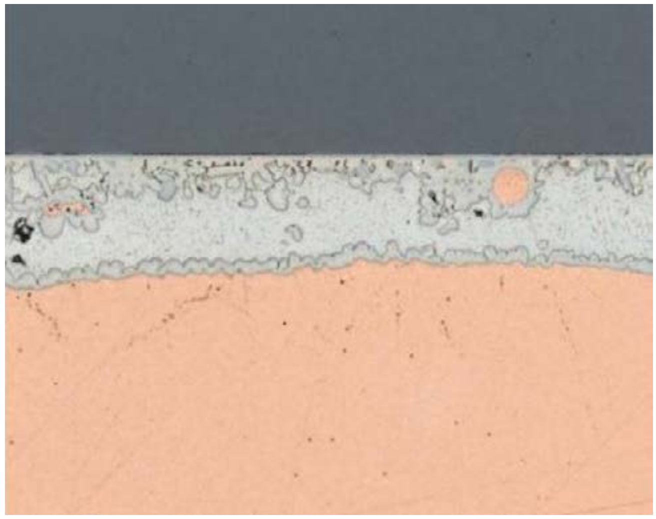


Figure 14: IGBT on DCB with SnCu solder paste (type 6) and Cu powder produced with a 20 µm stencil.

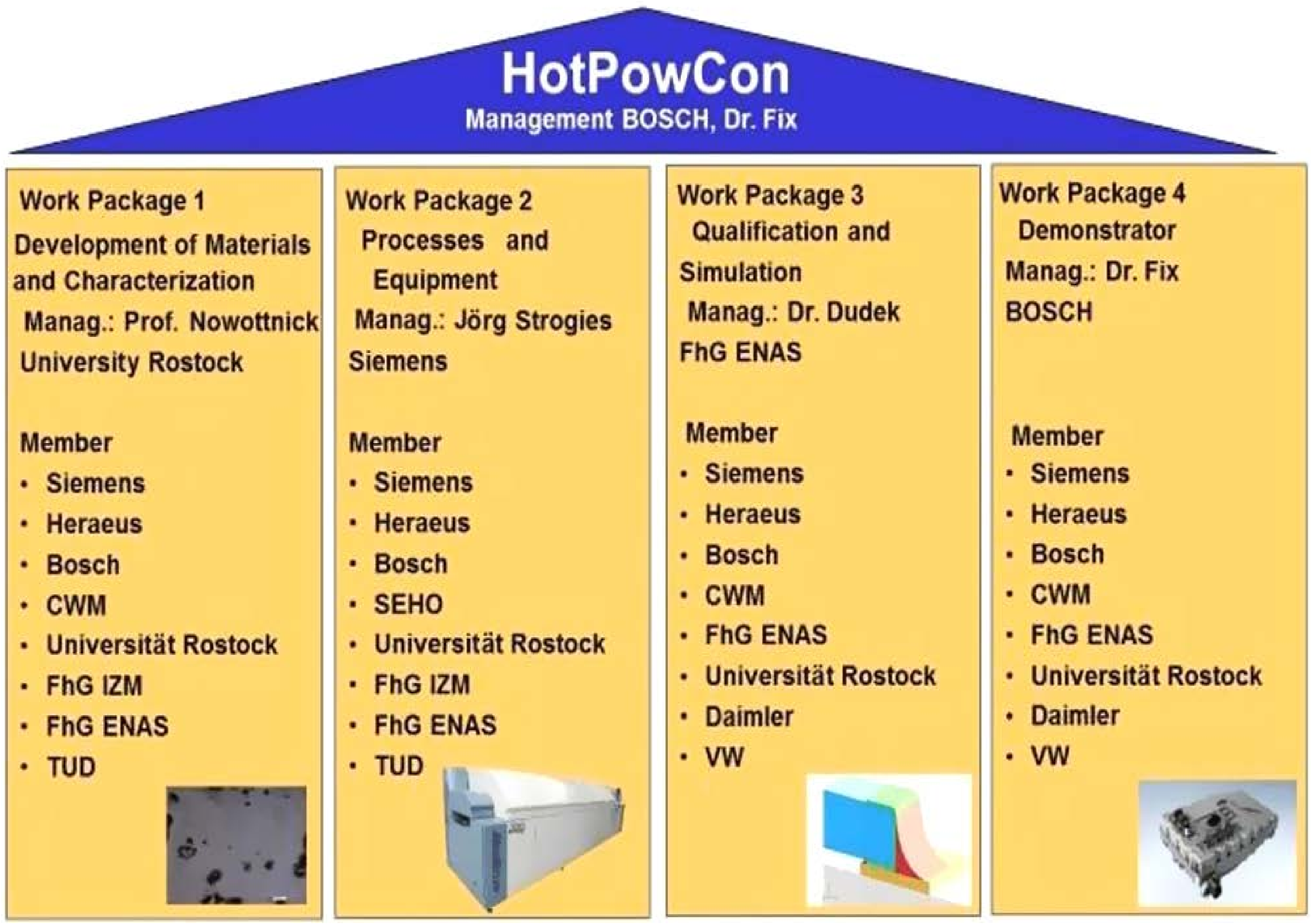


Figure 15: Transformation and structure of this project.

Conclusion

In this investigation, a variety of possibilities were created, forming the basis for a project with experts from different companies. One of the first steps was to formulate criteria necessary for the final solution, including:

- Printability with type 6 paste, what about thinner stencil and type 7 or 8 paste
- Dispensing
- Copper ball quality and quantity (size)
- Temperature profiling
- Tempering
- Combination power electronic and SMT
- How many IMC are necessary
- Vacuum and/or soldering with pressure
- Thermal and electrical conductivity **SMT**

References

1. Final report on Innolot, BMBF Project; Förderträger: Forschungszentrum Jülich, NMT; Förderprogramm: MaTech; Förderkennzeichen: 03N3083A; Laufzeit: 01.03.2000-28.02.2004.

2. Scheel W., Wittke K.; Nowottnick M.; Innovative Produktionsprozesse für Hochtemperaturelektronik am Beispiel der Kfz-Elektronik; 1. Auflage; Verlag Dr. Markus A. Detert, Templin Deutschland.

3. Materialmodifikationen für geometrisch und stofflich limitierte Verbindungsstrukturen hochintegrierter Elektronikbaugruppen “LiVe”; 1. Auflage; ISBN-13: 978-3-934142-57-2; Verlag Dr. Markus A. Detert, Templin Deutschland.

4. J. Albrecht, Jörg Trodler, H. Walter; New Generation of Lead-Free Solder Spheres and Paste; ISMP 2004; 3.9.2004, Seoul, Korea.

5. Müller, NMB, Test report Nr.: 160804.

6. Klaka, Sven. Eine Niedertemperatur-Verbindungstechnik zum Aufbau von Leistungshalbleitermodulen. 1995. ISBN 3-89588.

7. Mertens, Christian. Die Niedertemperatur-verbindungstechnikder Leistungselektronik. 2004. ISBN 3-18-336521-9.

8. Silbersintern bei niedrigen Temperaturen und Drucken mit mikroskaligen Silberpulvern für die Aufbau- und Verbindungstechnik. Schmitt, Wolfgang und Krebs, Thomas. München : s.n., 2010. Imaps 2010.

9. Bai, Guofeng. Low-Temperature Sintering of Nanoscale Silver Paste for Semiconductor Interconnection. s.l.:Virginia Polytechnic Institute and State University, Dissertation 2005.

10. Novel Silver Contact Paste Lead Free Solution for Die Attach. Schmitt, Wolfgang. Nürnberg : s.n. CIPS 2010.

11. Patent DE102007010242A1.

12. Schneider-Ramelow, Tutorial High Temperature Packaging; SMT-Hybrid 2010.

Jörg Trodler is a process engineer with Heraeus Materials Technology GmbH & Co. KG. He specializes in new interconnection technologies and materials, especially for lead-free and high-temperature applications.

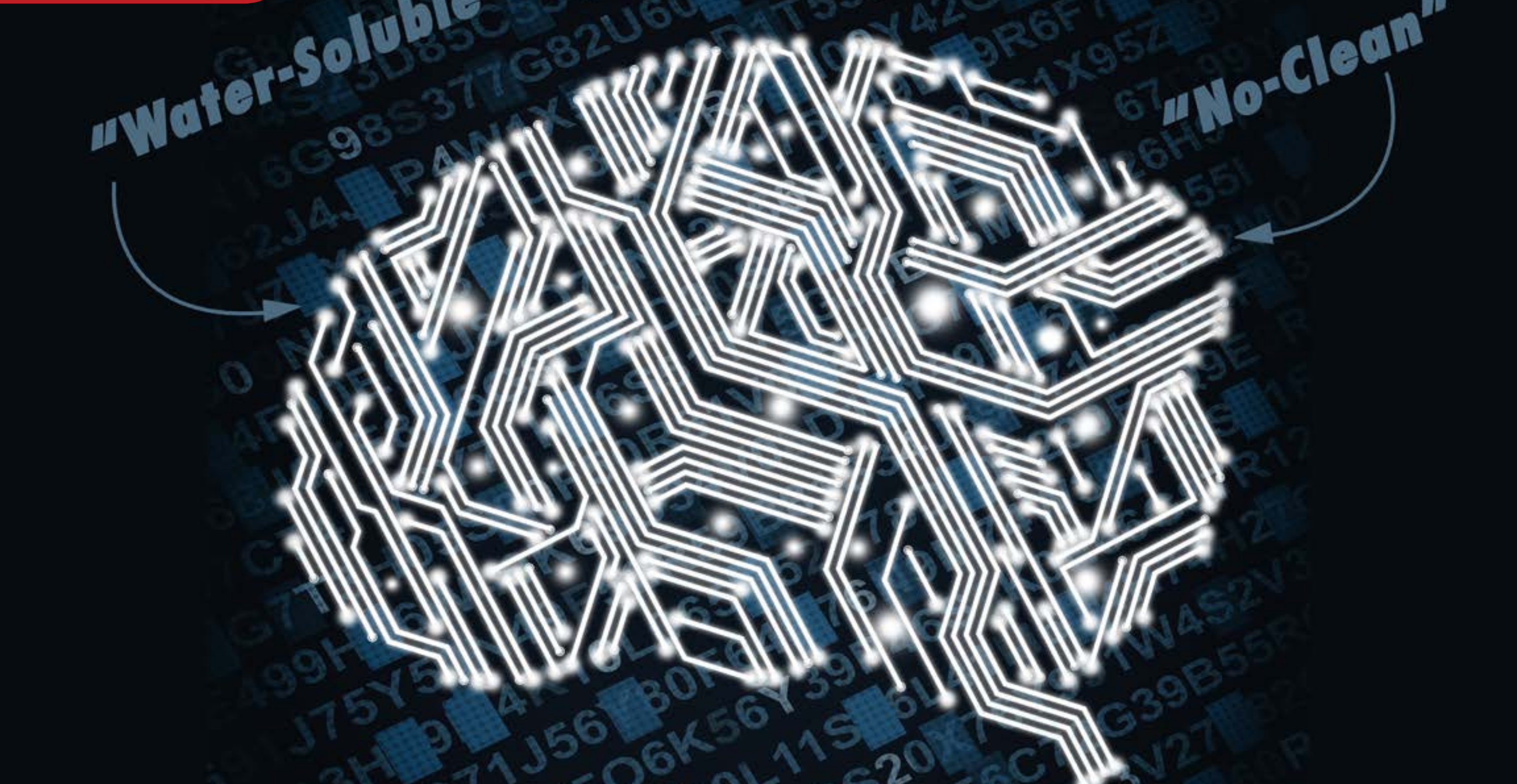
Improving Electronic Devices Using Holograms

Researchers from the University of California, Riverside and Russian Academy of Science have demonstrated a new type of holographic memory device that could provide unprecedented data storage capacity and data processing capabilities in electronic devices.

The device uses spin waves, a collective oscillation of spins in magnetic materials, instead of the optical beams. Spin waves are advantageous because they are compatible with the conventional electronic devices and may operate at a much shorter wavelength than optical devices, allowing for smaller electronic devices that have greater storage capacity.

“The results open a new field of research, which may have tremendous impact on the development of new logic and memory devices,” said lead researcher and UC Riverside Research Professor Alexander Khitun.

A paper, “Magnonic Holographic Memory,” which describes the finding, has been submitted for publication in the journal Applied Physics Letters. An advance copy of the paper can be accessed here.



Reliability Assessment of No-Clean & Water-Soluble Solder Pastes, Part I

by Emmanuelle Guéné and Steven Teh
INVENTEC PERFORMANCE CHEMICALS

SUMMARY: This article will highlight the differences between the water-soluble and no-clean families of solder pastes to help guide technologists in their choice.

Abstract

Looking back 25 years ago, the solder pastes residues had to be cleaned after reflow due to their corrosive nature. Two ways of cleaning were possible, either using solvent or water, with or without detergent. Now the assembly world is mainly no-clean: Paste formulation is safer in terms of chemical reliability and process costs are reduced without cleaning.

However, some applications (i.e., military, aerospace, high-frequency, and semiconductors) require a perfect elimination of the residue after reflow. There are several options to achieve this result: the use of a no-clean paste whose residue can be removed with the most suitable cleaning method, or the use of a paste designed to be cleaned, as a water-soluble solder paste.

The water-soluble solder pastes generally show great wettability because of their strong activation, but they are also known to have shorter stencil life and to be more sensitive to working conditions such as temperature and humidity, compared to the no-clean pastes. Additionally, with components' stand-off getting smaller and smaller, washing residues with water only is becoming more challenging due to its high surface tension. Often, the addition of detergent becomes necessary.

The purpose of this article is to highlight the differences between these two families of solder pastes to guide users in their choice. This will be achieved through the comparison of several recent water-soluble and no-clean formulations for reliability. First the printing quality will be evaluated (viscosity, tack, cold slump, printing speed according to pressure, stencil life, idle time, printing consistency). Then the reflow properties will be compared (hot slump, solderballing, reflow process window, wetting

ability on different finishes). Finally the residue cleanability will be assessed. The IPC SIR test (method IPC-TM-650 2.6.3.7) will be also performed to conclude the study. Both standardized tests and production tests will be used to evaluate the performance of these two kinds of solder pastes.

Introduction

Solder paste is a compound that typically consists of a fusible alloy and some type of deoxidizing flux. Different pastes can have a variety of compositions, though a typical formula consists of powdered solder mixed in with a gel-like flux material. According to standard J-STD-004 "Requirements for Soldering Fluxes," solder pastes are classified into three types based on the flux types: (1) rosin-based, (2) water-soluble and (3) no-clean. In the past, solder pastes were cleanable. There are generally two different types of cleanable pastes: water cleanable type (water-soluble paste) and chemical cleanable type (cleaned by solvent or detergent).

With the increase in packaging density, combined with the complete ban on CFCs by the year 2000 (the Montreal Protocol), the electronics industry was strongly driven to implement water cleanable process and no-clean processes. Furthermore, as the workability and reliability requirements of the process are becoming stricter and more precise, water-soluble solder paste and no-clean solder pastes have been developed accordingly. As the name implies, flux residues from the water- soluble solder paste are designed to be cleaned using water. For example, for RF circuits and high-speed circuits, for performance reasons it is usually essential that assemblies have no flux residue after reflow. Many electronics manufacturers with a wide variety of products also prefer clean assemblies, such as medical equipment and military assemblies.

With the current challenges of the miniaturization of SMT components, narrower spacing between components and substrates, lower stand-off and higher temperatures used for lead-free applications, solder paste residue becomes more difficult to clean. Water-soluble pastes are also commonly used in hard-to-solder applications when solvent cleaning is not feasible or in applications where no-clean residues may pose cosmetic issues. Water cleaning is an easy process to control, and the equipment is relatively easy to maintain, though the cost-effectiveness issue comparing to solvent base cleaning, becomes one of the hot debate topics in recent times.

From the application point of view, the obvious advantage of converting to water-soluble solder paste is the elimination of CFCs from PCB cleaning processes. However, this solder paste technology is more sensitive to normal processing variables. Water-soluble materials often exhibit production sensitivity to moisture: Moisture which enters the paste can degrade printability and promote solder balling. It has also been noted that water-soluble pastes typically have reduced tack times and may be less compatible with long reflow profiles. The lower level of activation associated with no-clean pastes may reduce the process window for full solder wetting of components.

The properties of six recent lead-free solder pastes will be described: three of them are water-soluble and three of them are no-clean. The characteristics of each paste will be reviewed. Then, printing performances will be evaluated through standardized laboratory tests such as viscosity, tackiness and slump and through tests in a printing machine. The reflow properties will be investigated through both standardized

Paste	A	B	C	D	E	F
Nature	Water-soluble	Water-soluble	Water-soluble	No-clean	No-clean	No-clean
Alloy	SnAg3Cu0.5					
Particle size	Type 3					
Flux type	ORH0	ORH1	ORH1	ROL0	ROL0	ROL1
Metal Content	88.0	89.0	89.5	88.0	88.5	88.5

Table 1: Solder pastes characteristics.

and production tests (hot slump, solderballing, wettability, reflow process window, graping ability). Finally, the cleaning ability will be assessed.

Experiments

The pastes used for this evaluation were all made of SnAg3Cu0.5 (SAC305) alloy with type 3 (25/45 microns,-325/+500 mesh) particle size. The selected water-soluble pastes are named A, B and C and the no-clean pastes are named D, E and F. The flux designation according to J-STD-004A and the metal content are gathered in the Table 1.

We ensured that all the pastes used for the study were recently manufactured (4–8 weeks). Before starting the evaluation, the aspect and the viscosity of the pastes were checked in order to ensure that they were compliant with the initial specifications.

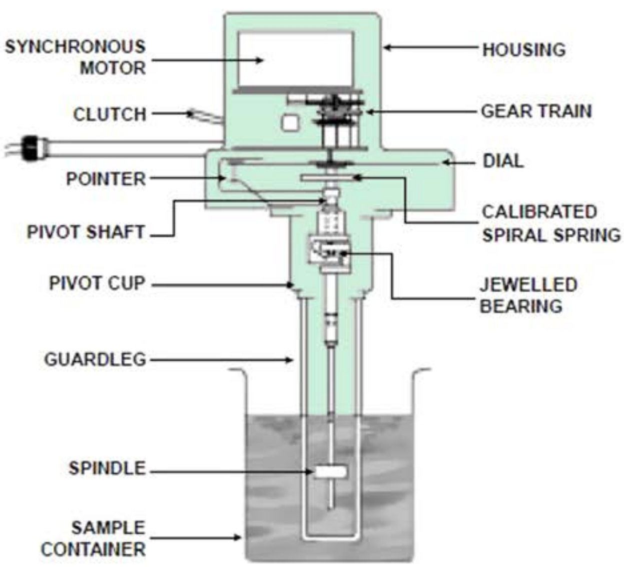
Acid Index, Non-Volatile Residue and Viscosity

The metal contents of the solder pastes (MC, expressed in percentage) and their non-volatile residues (NVR, expressed in percentage of the total flux medium) were measured although the ability of a solder paste residue to be cleaned is more linked to its quality than to its quantity. The acid index (Ia) was determined by acid-base titration.

The dynamic viscosity was determined using two types of viscometers: Brookfield and Malcom (Figure 1). The viscosity was first measured with a spindle type viscometer Brookfield DVII at 5 rotations per minute (RPM) using a TF spindle. Measures were made without mixing, and after mixing, at 20°C and 25°C according to the test method described in IPC-TM-650 method 2.4.34. The viscosity with a spiral pump viscometer Malcom PC1-TL was determined at 10RPM and 25°C. The results are listed in Table 2. The viscosity data are given in Pascal-seconds (Pa.s). All the results were found in accordance with the initial specifications. The highest viscosity was found for paste C, which also had the highest metal content. The acid indexes of the water-soluble solder pastes were low compared to the ones of the no-clean pastes: a value of 5 was even found for paste B. The non-volatile residues were a bit higher for water-soluble solder pastes than for no-clean ones.

Tackiness

The tackiness was assessed using our internal test which is designed to measure the tack force of a solder paste with an applied force of $1g/mm^2$ or $4g/mm^2$: Low applied forces are more representative of the actual use of a solder paste at the pick-and-place step and allow a



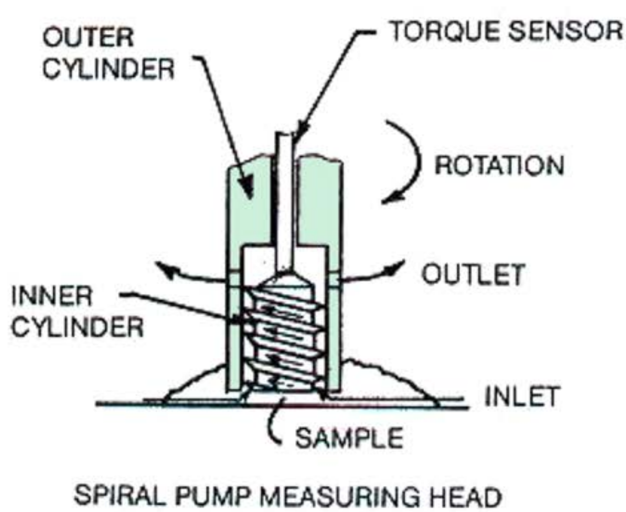


Figure 1: Schematic representation of a) Brookfield viscometer (source: Brookfield) and b) Malcom viscometer (source: Malcomtech).

Paste	A	B	C	D	E	F
MC measured	87.5	88.5	89.2	87.6	88.2	88.3
NVR (%)	61	72	86	53	66	63
Ia	55	5	67	105	112	130
Brookfield viscosity 20°C	1130 / 940	1010 / 920	1230 / 1160	950 / 880	1050 / 950	1060 / 930
Brookfield viscosity 25°C	1000 / 850	890 / 780	1120 / 1030	850 / 750	920 / 830	950 / 800
Malcom viscosity 25°C	205	165	180	150	175	170

Table 2: Metal content, non volatile residue, acid index and viscosity measurements.

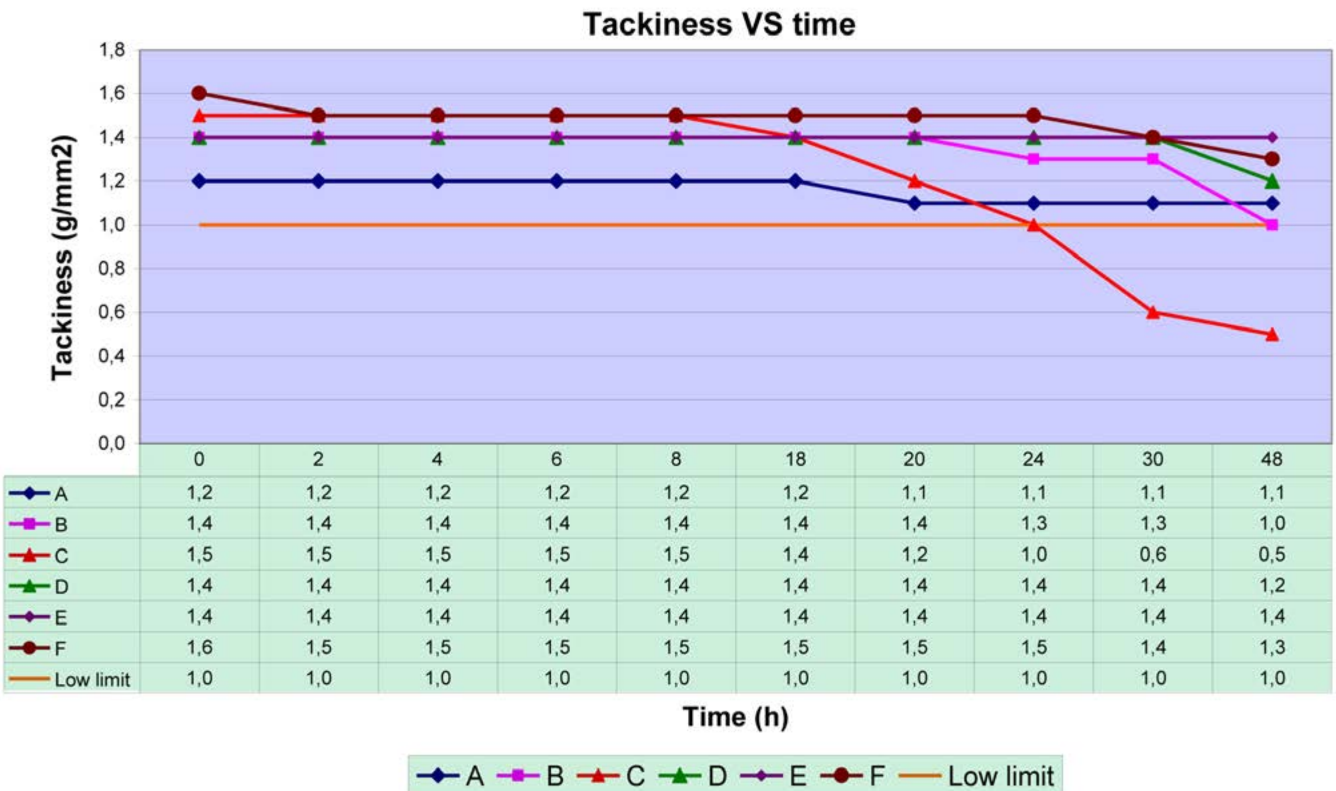


Figure 2: Tackiness vs. time.

better tack force discrimination from one paste to another. The common standards measure the cohesion of a solder paste at higher forces, 15 g/mm² for IPC-TM-650, method 2.4.44.

The measurements were performed at room temperature (21°C +/-3°C) and (50% +/-10%) relative humidity. The first measure was done after printing and the evolution of the tackiness was followed. The follow-up of tackiness with an applied force of 1 g/mm² according to time is shown in Figure 2. The low limit is 1 g/mm² (equal to the force applied). The pastes exhibit initial values between 1.2 (paste A) and 1.6 (paste F). All the pastes keep a tackiness above the limit for 24 hours except the paste C which adhesion starts to decrease between 8 and 18 hours. Internally, we have correlated the tackiness with the abandon time (idle time) on the stencil during printing: If a solder paste does not lose its tackiness for 24 hours during this

Soldering and Reliability

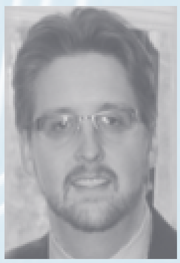
INTERNATIONAL CONFERENCE ON SOLDERING AND RELIABILITY

May 13–15, 2014

Workshops: May 13 • Conference: May 14–15
Toronto Expo & Tech Forum: May 15
Four Points by Sheraton Toronto Airport • Toronto • Ontario, Canada

CONFERENCE OVERVIEW

Electronic products, particularly consumer products have become more complex with greater circuit density, finer lines and spacings and more functionality. Reliability issues continue to be a major concern for industrial, bio-medical, aerospace and automotive applications and require materials, manufacturing, test and quality engineers and scientists to be creative in planning for the future. Challenges such as the use of finer powders in solder paste, the greater need for heat dissipation, the use of novel components and technologies are included. Due to cost considerations, new low silver or silver free alloys are being studied. The use of tailored alloy systems, the variety of alloy choices, and smaller passive components are among the concerns being addressed. Now, a new group of engineers and scientists involved in the design and manufacture of (a) medical devices, and (b) monitoring and control instruments must be ready for the requirements of RoHS recast, also known as RoHS 2. This EU directive officially required that it be made into national laws by January 2, 2013 and these two new categories of electronics must become compliant by July 22, 2014. Soldering and reliability professionals need to come together to share their knowledge and their vision for addressing these challenges.



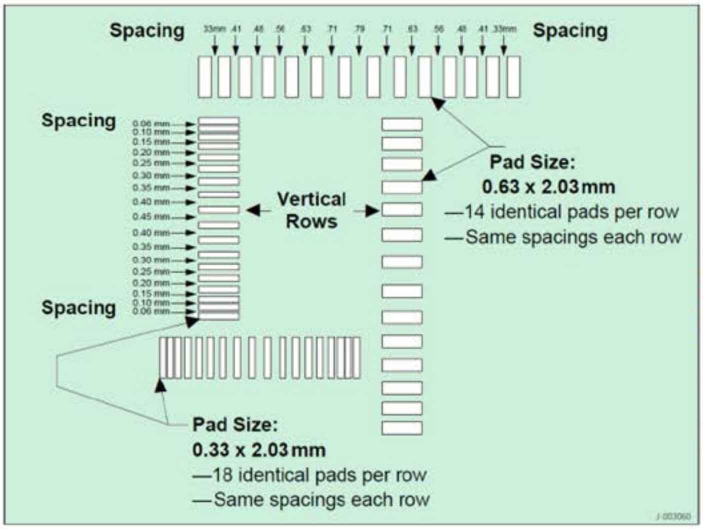
KEYNOTE ADDRESS May 14, 2014 | 8:50am

A View of the Electronics Industry Process, Reliability, and Materials Research Landscape

Martin Anselm, Ph.D., *Manager AREA Consortium, Universal Instruments Corporation*

Today, the electronic industry's OEMs and CMs are forced to comply with market trends in technologies — due to part availability or cost, and reliability testing for validation. The term "reliability" is often misused, since these tests are evaluation or qualification tests — based upon internal or customer driven standard practices, or on industry accepted standards which do not always provide pass/fail criterion. These tests are employed as best guesses for the reliability of products in the field. This condition is primarily a consequence of limited materials understanding.

We cannot ignore the current state of the economy and the evolution of business practices over the past two decades, paired with significant legislative changes, which contributes to the rate at which leaps in our understanding are being achieved. As a result OEMs and CMs have little time to perform fundamental research and often spend more time in support of individual product needs. As new materials and components become mainstream, manufacturing and "reliability" testing becomes less and less effective in producing predictable results in yield and reliability. The more fundamental research to understand the fundamentals of mechanics of failures, reliability and material properties falls on academia and consortia. Martin will discuss the current mainstream North American research landscape, reviewing some of the research groups in the industry and how each fits into the electronics market. Specific research topics will be used as examples to illustrate value for each program.



STENCIL IPC-A-21 (0,2 mm thick)					
Pad size 0.63 x 2.03			Pad size 0.33 x 2.03		
Spacing mm	Hor.	Vert.	Spacing mm	Hor.	Vert.
0.79			0.45		
0.71			0.40		
0.63			0.35		
0.56			0.30		
0.48			0.25		
0.41			0.20		
0.33			0.15		
			0.10		
			0.06		

Figure 3: IPC A-21 stencil (extracted from IPC TM-650 2.4.35).

test, the abandon time on the stencil is about four hours for 0.4 mm pitch and 120 µm stencil thickness at room temperature.

Slump

The slump was tested according to IPC-TM-650 method 2.4.35. The pastes were printed on alumina substrates through the IPC-A21 0.2 mm thick stencil (Figure 3).

For cold slump the substrates were observed after 10–20 minutes at ambient conditions (25 +/-5°C and 50+/-10% relative humidity): the minimum spacing at which the bridges are formed is noted. The paste shall show no evidence of bridging when spacing is 0.56 mm or greater (for 0.63x2.03 pad size) and 0.25 mm or greater (for 0.33x2.03 pad size) to conform to J-STD-005 paragraph 3.6.1.

No bridge was seen on 0.63x2.03 pad size whatever the paste. Bridges with spacing of 0.06 to 0.10 mm was observed for 0.33x2.03 pad size. None of the pastes are prone to cold slump. Pastes A and C results are shown in Figure 4.

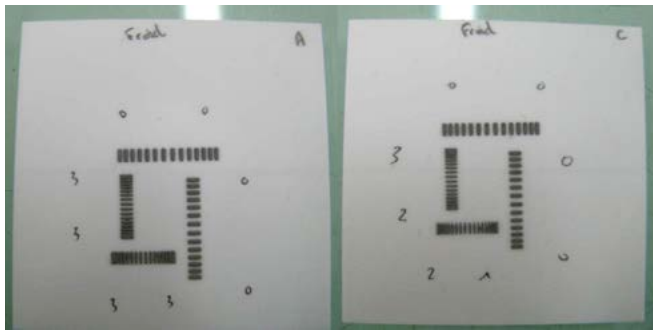


Figure 4: Cold slump a) paste A, and b) paste C.

For hot slump, the substrates were observed after 10–15 minutes at 150°C preheating and cooling to ambient temperature. The paste shall show no evidence of bridging when spacing is 0.63 mm or greater (0.63x2.03 pad size) and 0.30 mm or greater (0.33x2.03 pad size) to conform to J-STD-005, paragraph 3.6.1. The general trend is to obtain better results with no-clean solder pastes than with water-soluble (WS) solder pastes: The no-clean are all below the limits. Among the WS, Paste A is more prone to slump than the other pastes and exceeds the limits. Because a quick preheat at 150°C does not really reflect the reality of a thermal profile, a slower preheat was evaluated: First, the substrate is placed on a hotplate at 100°C during one minute, then immediately on another hotplate at 140°C for one minute and finally on a hotplate at 160°C for one minute. The slump behavior was improved for all the pastes and only paste A was still above the limit. Pictures of pastes A and C are gathered in Table 3 and all the results are summarized in Figure 5 and 6.

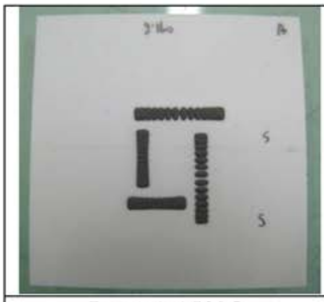
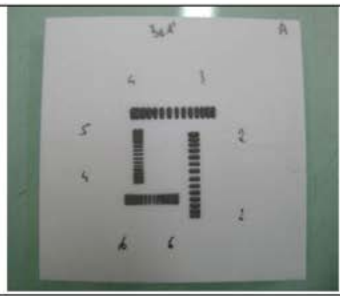
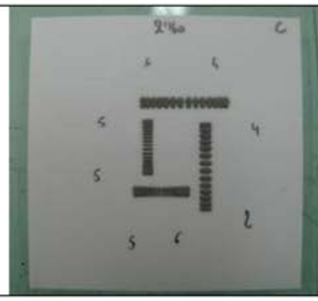
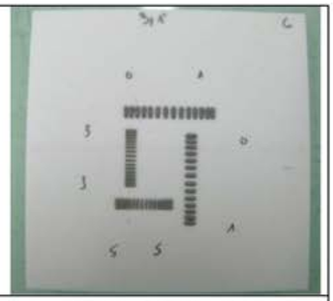
			
Paste A 150°C	Paste A 3x1 min	Paste C 150°C	Paste C 3x1 min

Table 3: Paste A and C slump test.

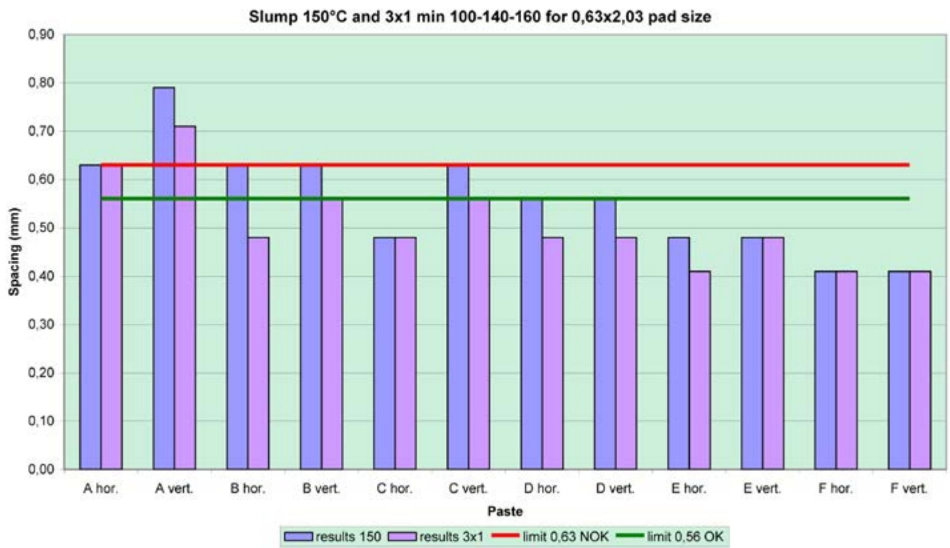


Figure 5a: Slump for 0.63x2.03 pad size.

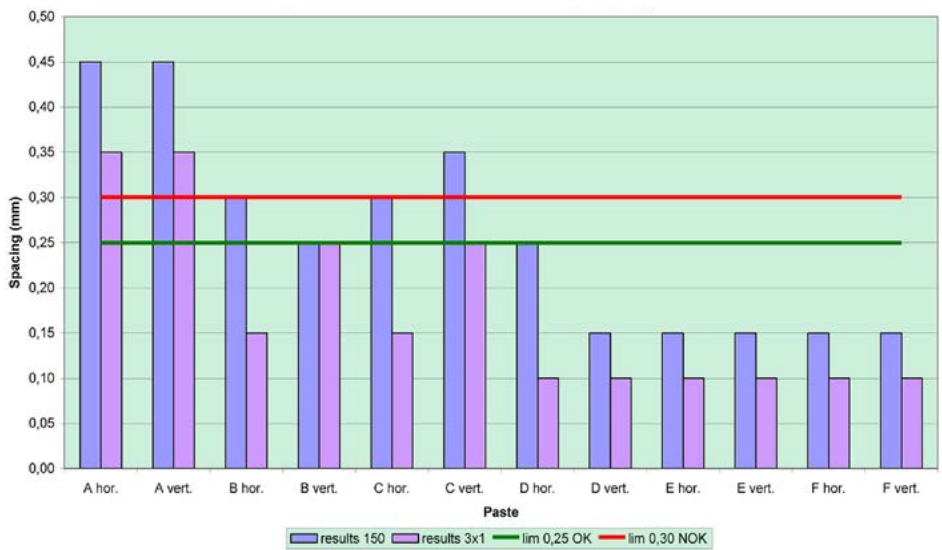


Figure 5b: Slump for 0.33x2.03 pad size.

The last revision of IPC-TM-650 method 2.4.35 procedure mentions a change in the preheat temperature: The samples shall be tested at a temperature of 35°C below the melting point which means 180°C for SAC 305 solder pastes. The test was performed at 180°C: A, B, C and D were above the defined criteria.

Stability at Elevated Temperature

The stability of the paste being part of its reliability, the influence of storage at elevated temperature was examined: The pastes were stored at 40°C and checked after four days and seven days. A decantation phenomenon occurred for paste A after four days: After mixing many lumps were found in the paste. Paste C surface looked dry and dull after seven days but resumed its shiny appearance after mixing. The other pastes did not exhibit any change. A simple printability test was done: The pastes were printed on an alumina substrate using a 0.250 mm thick stencil with round openings of 5 mm diameter. Only paste A was difficult to print correctly, resulting in a non-planar surface. The tackiness was also measured on each paste after seven days. Paste A showed a higher tackiness but the decrease was fast; it lost completely its tackiness after eight hours. There was no significant change for the other pastes neither in value nor in duration. Slump trials showed an “improvement” for paste A at 150°C but no change for pastes B, C, D, E and F. The modification of paste A properties is due to an internal reaction due to the exposure to temperature: This paste is sensitive to temperature. Pictures and results are given in the Table 4 for paste A, B, C and E.

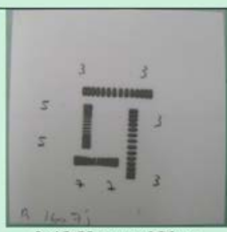
	Paste A	Paste B	Paste C	Paste E
Appearance after 7 days 40°	 Decantation lumps	 OK	 Dull OK after stirring	 OK
Printability After 7 days 40°C	 Bad	 Good	 Good	 Good
Tack T0 before storage	1.2	1.4	1.5	1.4
Tackiness T0 After 7 days 40°C	**1.8**	1.5	1.5	1.5
Tack 8h before storage	1.2	1.4	1.6	1.4
	Paste A	Paste B	Paste C	Paste E
Tack 8h after 7 days 40°C	**0.5**	1.4	1.5	1.4
Slump after 7 days 40°C	 0.48 Hor. and Vert. 0.30 Hor. 0.40 Vert	x	x	x

Table 4: Pastes A, B, C, E after 7 days at 40°C.

Viscosity over Time

A more drastic viscosity test was conducted on each solder paste: The test consists in the follow-up of viscosity over time using a Malcom spiral pump viscometer at 25°C and 10RPM. The test simulates solder paste ageing when it is submitted to a permanent mixing and reproduces the shearing it undergoes during printing. The measure of viscosity evolution versus time during the stirring allows predicting the premature solder paste ageing by correlation.

A stable paste keeps a constant viscosity over time (Figure 6a). On the contrary, an unstable paste leads to a sudden increase of viscosity after a few hours only (Figure 6b). The overall appearance of the curve gives additional indications of the paste behavior.

The viscosity curves as a function of time are summarized in Figure 7. No sudden increase was seen. However, pastes A viscosity increased during the three first hours before decreasing. Pastes A and C curves are irregular while B, D, E and F curves are smoother. According to these results, it is likely that A and C have a lower printability performance.

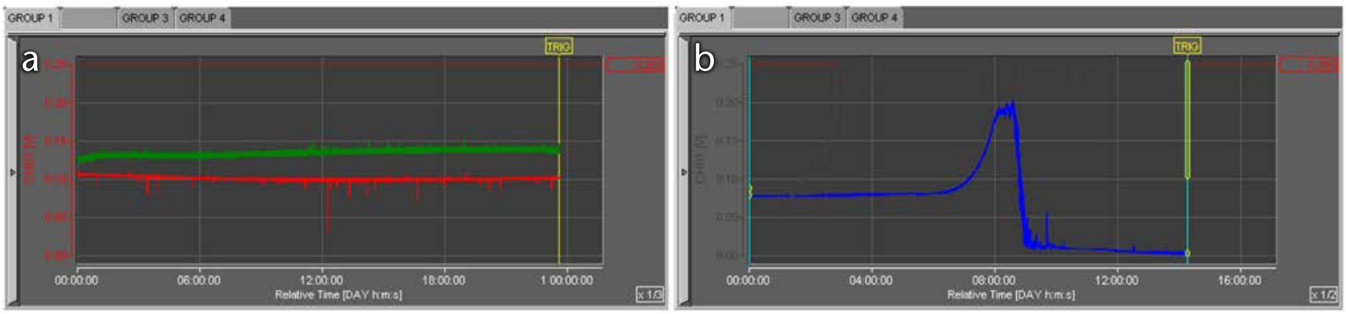


Figure 6: a) Stable viscosity and b) sudden increase of viscosity after seven hours.

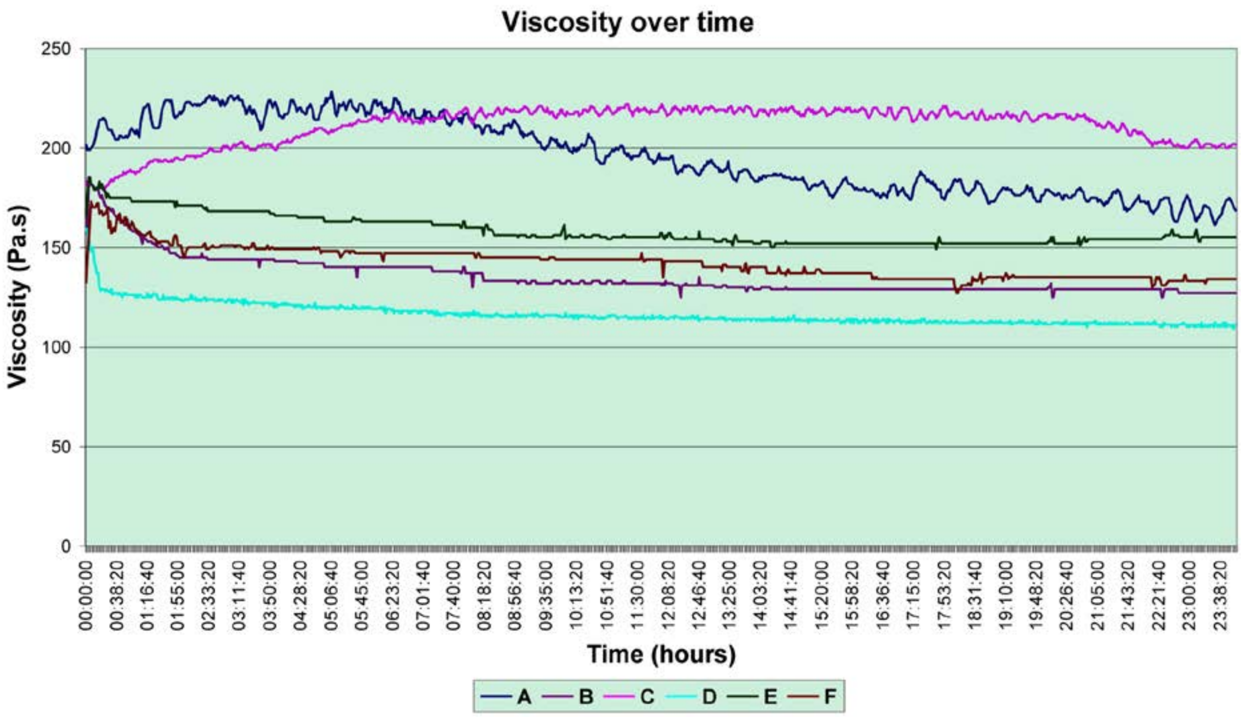


Figure 7: Viscosity curves over time.

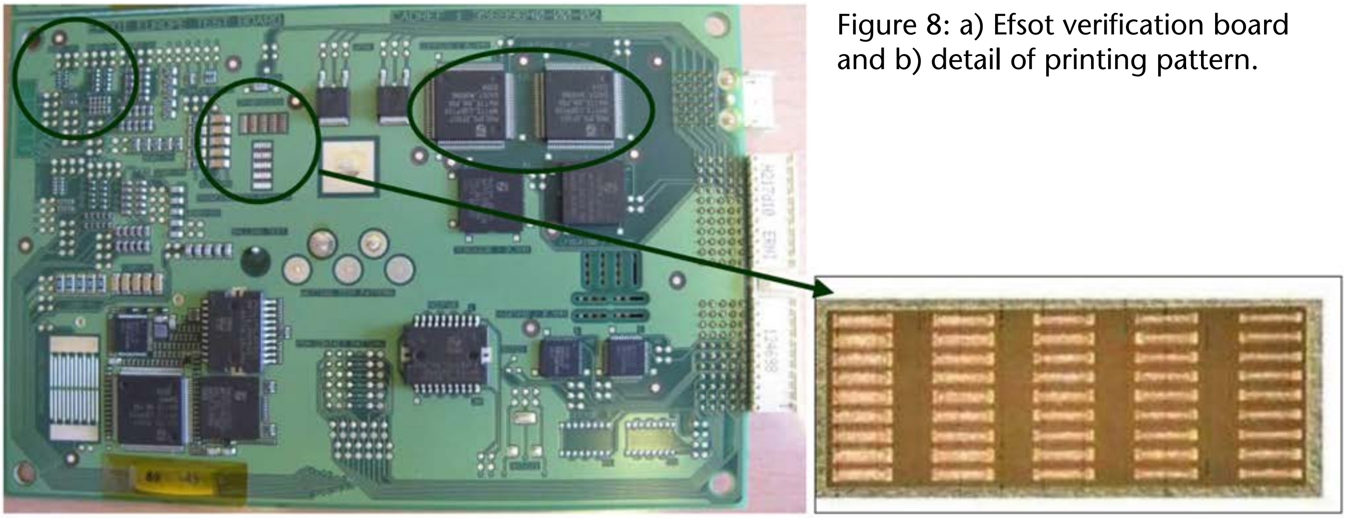


Figure 8: a) Efsot verification board and b) detail of printing pattern.

Printing Performance

Printing tests were performed at 25°C in a DEK Horizon 05 printer using the Efsot Verification board[1] with a 120 microns laser cut stainless steel stencil and 250 mm length squeegees. The test board includes a printing pattern test area (horizontal and vertical), 0.4 mm pitch QFN, 0402 and 0201 printing areas (Figure 8). The minimum pressure according to printing speed was determined (Table 5, Figure 9). Paste C requires much more pressure than the other pastes and is not able to stand high printing speeds (Figure 10).

The printing quality was assessed mainly on the printing test patterns using criteria according to Philips Notation[1]: The results are rejected if the smearing result is below or equal to 2 on 0.27 mm opening width and 0.13 mm space width or if the printing result is below or equal to 2 on 0,22/0,18: under stencil cleaning is then required. The details to assess printing quality are explained in Figures 11 and 12.

The printing definition and the smearing ability were evaluated for each solder paste at a medium speed of 50 mm/s. The pressure applied is the minimum pressure determined before plus one bar additional. The first board is printed and the quality is visually inspected, then, without any cleaning, a second board is printed, etc., until the criteria are reached. Table 6 shows the example of pastes C and F. For shorts, paste C reached the criterion after 13

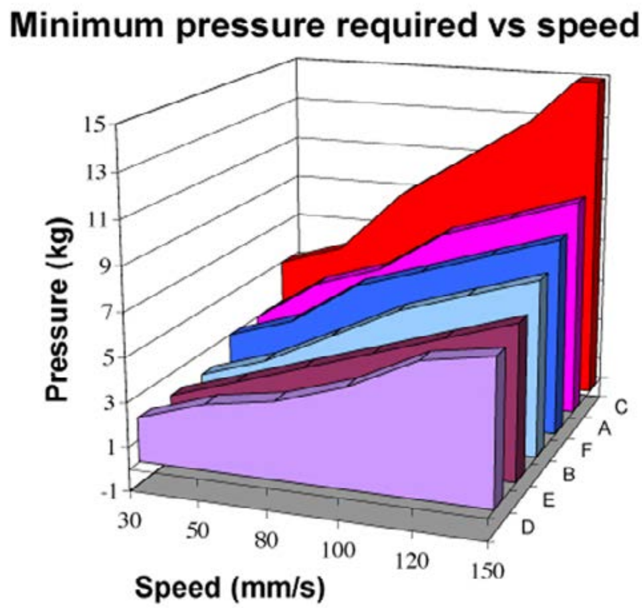


Figure 9: Graph of pressure according to speed.

	A	B	C	D	E	F
Speed	Pressure	Pressure	Pressure	Pressure	Pressure	Pressure
30	3	2	5	2	2	3
50	5	3	6	3	3	4
80	6	4,5	9	3,5	4	6
100	8	6	11	4,5	5	7
120	9	7	13	6	6	8
150	10	8	16	6,5	7	9

Table 5.

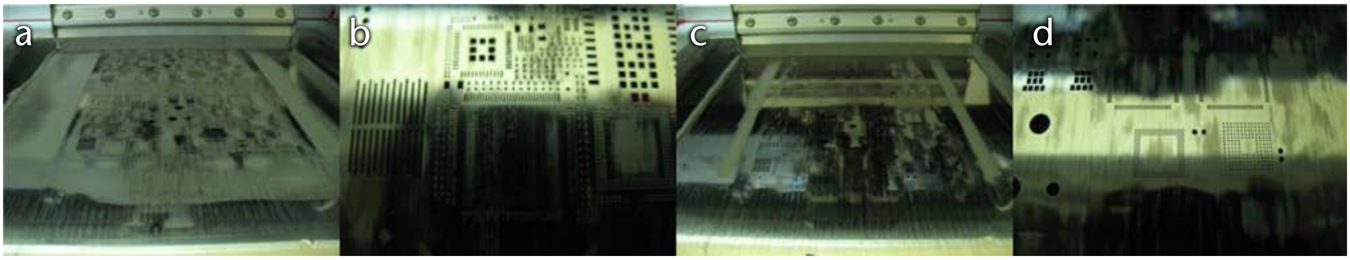


Figure 10: a) and b) Insufficient pressure; c) and d) minimum pressure.

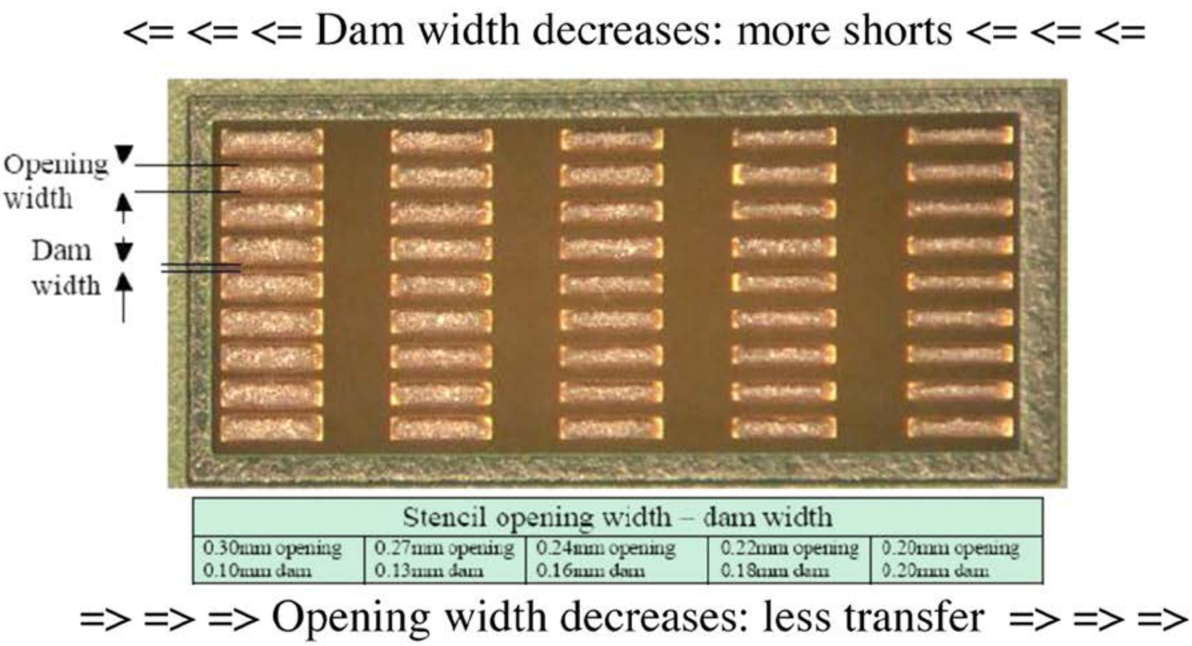


Figure 11: Printing pattern opening width and dam description.

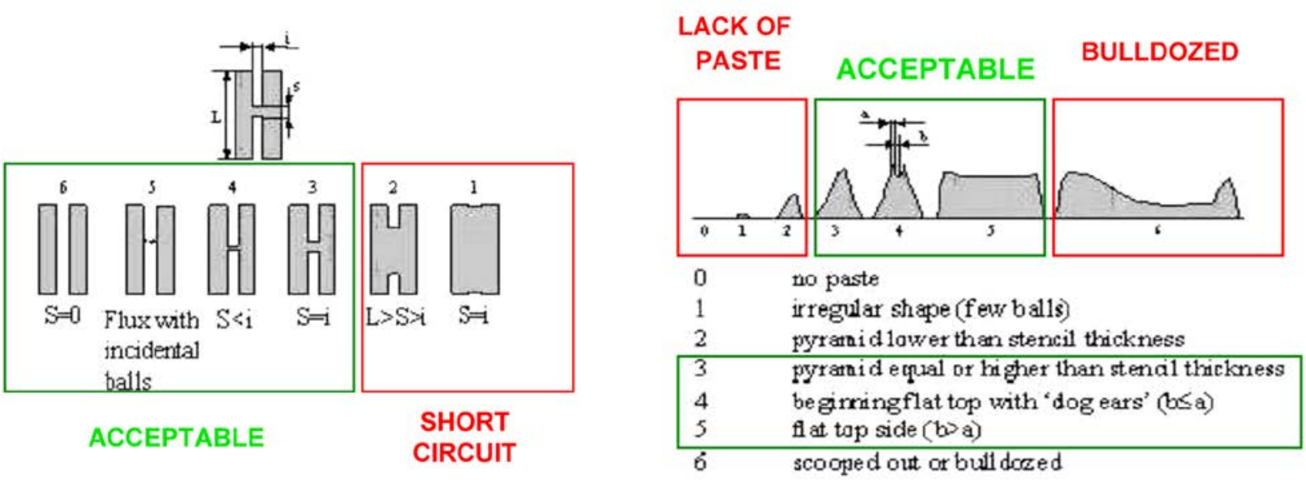


Figure 12: a) Evaluation criterion for smearing/shorts, and b) evaluation criterion for printing definition.

Board Number	Pad width/Pad distance perpendicular to print 120µm stencil																			
	0,3/0,1 - C		0,3/0,1 - F		0,27/0,13 - C		0,27/0,13 - F		0,24/0,16 - C		0,24/0,16 - F		0,22/0,18 - C		0,22/0,18 - F		0,2/0,2 - C		0,2/0,2 - F	
	Print definition	Shorts	Print definition	Shorts	Print definition	Shorts	Print definition	Shorts	Print definition	Shorts	Print definition	Shorts	Print definition	Shorts	Print definition	Shorts	Print definition	Shorts	Print definition	Shorts
1	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6
2	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6
3	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6
4	5	5	5	5	5	6	5	6	4	6	4	6	5	6	5	6	5	6	5	6
5	5	5	5	5	5	6	5	6	4	6	4	6	5	6	5	6	4	6	4	6
6	5	4	5	4	5	6	5	6	4	6	4	6	4	6	4	6	3	6	4	6
7	5	4	5	4	5	6	5	6	4	6	4	6	4	6	4	6	3	6	4	6
8	5	4	5	4	5	5	5	5	4	6	4	6	4	6	4	6	3	6	4	6
9	5	3	5	4	5	5	5	5	4	6	4	6	3	6	4	6	3	6	4	6
10	5	3	5	4	5	5	5	5	4	6	4	6	3	6	4	6	3	6	3	6
11	4	3	4	3	5	4	5	4	4	6	4	6	3	6	3	6	3	6	3	6
12	4	3	4	3	4	4	4	4	4	6	4	6	3	6	3	6	3	6	3	6
13	4	2	4	3	4	3	4	4	4	6	4	6	3	6	3	6	2	6	3	6
14	4	2	4	3	4	2	4	4	4	5	4	6	3	6	3	6	2	6	3	6
15	4	2	4	2	4	2	4	3	4	5	4	6	2	6	3	6	2	6	3	6
16	4	2	4	2	4	2	4	2	4	5	4	6	2	6	3	6	2	6	2	6
17	4	2	4	2	4	2	4	2	4	5	4	5	2	6	2	6	2	6	2	6

Table 6: Pastes C and F printing quality.

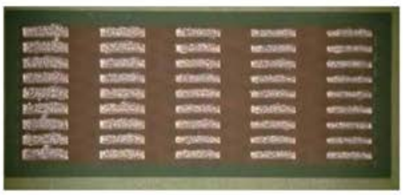
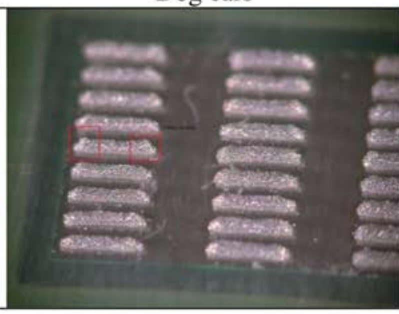
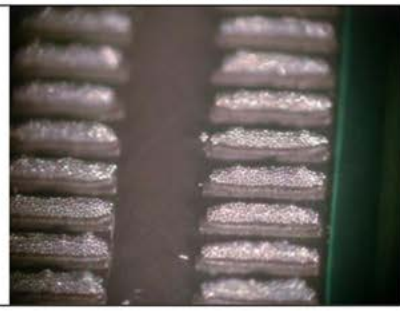
Shorts on 0.3/0.1 and 0.27/0.13	Dog ears	Insufficient volume
		

Table 7: Examples of printing defects.

Paste	A	B	C	D	E	F
Maximum abandon time (idle time)	2h	2h	1h30	3h	3h30	3h

Table 8: Idle time.

prints and paste F reached this criterion after 15 prints. Printing definition was better for paste F too: 16 prints against 14) prints. A detailed table for A, B, D and E is not reported. Pastes B, D and E were almost similar to F whereas A was below. The final ranking was, from the best to the worst: F, E, B, D, A and C. Examples of printing defects are illustrated in Table 7.

The idle time was determinedand defined as the maximum time allowed for the paste to remain on the stencil for a good restart without the need of under-stencil cleaning. The same criteria were used: Paste E showed the best idle time (3h,30) followed by F and D, then A and B, then C (1h,30). Results are summarized in Table 8.

Paste aging under shearing was assessed: 600 printing cycles without paste consumption at 50 mm/s were made. All the pastes still looked smooth after the test, so the Brookfield viscosity at 20°C was measured. A decrease was observed due to the shearing for all the pastes, as seen in Table 9.

Paste	A	B	C	D	E	F
Initial viscosity	940	920	1160	880	950	930
Viscosity after cycling	720	800	1050	690	810	830

Table 9: Viscosity after cycling test.

Class 1	Class 2	Class 3	Class 4	Class 5
5 solderballs maximum	6 - 10 solderballs	11 - 20 solderballs	21 - 50 with possibility of a slight lisere	> 50 solderballs with clusters and lisere

Table 10: Solderballing classification (NF-C-90550).

Paste	A	B	C	D	E	F
	Solderballing on fresh paste					
No preheat	C1	**C5**	C1	C1	C1	C1
160°C 2 min	C2	C1	C1	C1	C1	C1
140°C 2 min	C1	C1	C1	C1	C1	C1
100°C 3 min	C1	C1	C1	C1	C1	C1
100-140-160 1min/1min/1min	C1	C1	C1	C1	C1	C1
180°C 2min	C4	C3	C5	C3	C2	C2
	Solderballing after 4 hours at 21°C / 50%RH					
No preheat	**explosion**	**explosion**	C1	C1	C1	C1
160°C 2 min	C1	**C4**	**C5**	C1	C1	C1
140°C 2 min	C1	C1	C1	C1	C1	C1
100°C 3 min	C1	C1	C1	C2	C1	C1
100-140-160 1min/1min/1min	C1	C2	C3	C1	C1	C1
180°C 2min	C5	C4	C5	C4	C2	C2

Table 11: Solderballing test.

Solderballing

Solderballing performances were checked on a hotplate using our internal procedure. The pastes are printed on alumina substrates through a 0.250 mm thick stencil with two round opening of 5 mm diameter, with a distance between centers of 25 mm. The temperature of the hotplate was set at 250°C and several temperatures and times of preheat were tested. The goal was to classify the paste according to preheat. The solderballing classification ranks from class 1 to class 5, the balls being counted with 30x magnification (Table 10).

Solderballing was class 5 for paste B without preheat. Otherwise, the pastes gave good results whatever the preheat, except for the most demanding condition (180°C, 2 during 2 minutes) where solderballing ranked from class 2 to class 5. After four hours at ambient conditions (21°C/50%RH), pastes A and B have exploded upon contact with the hotplate and a significant degradation occurred for B and C after 2

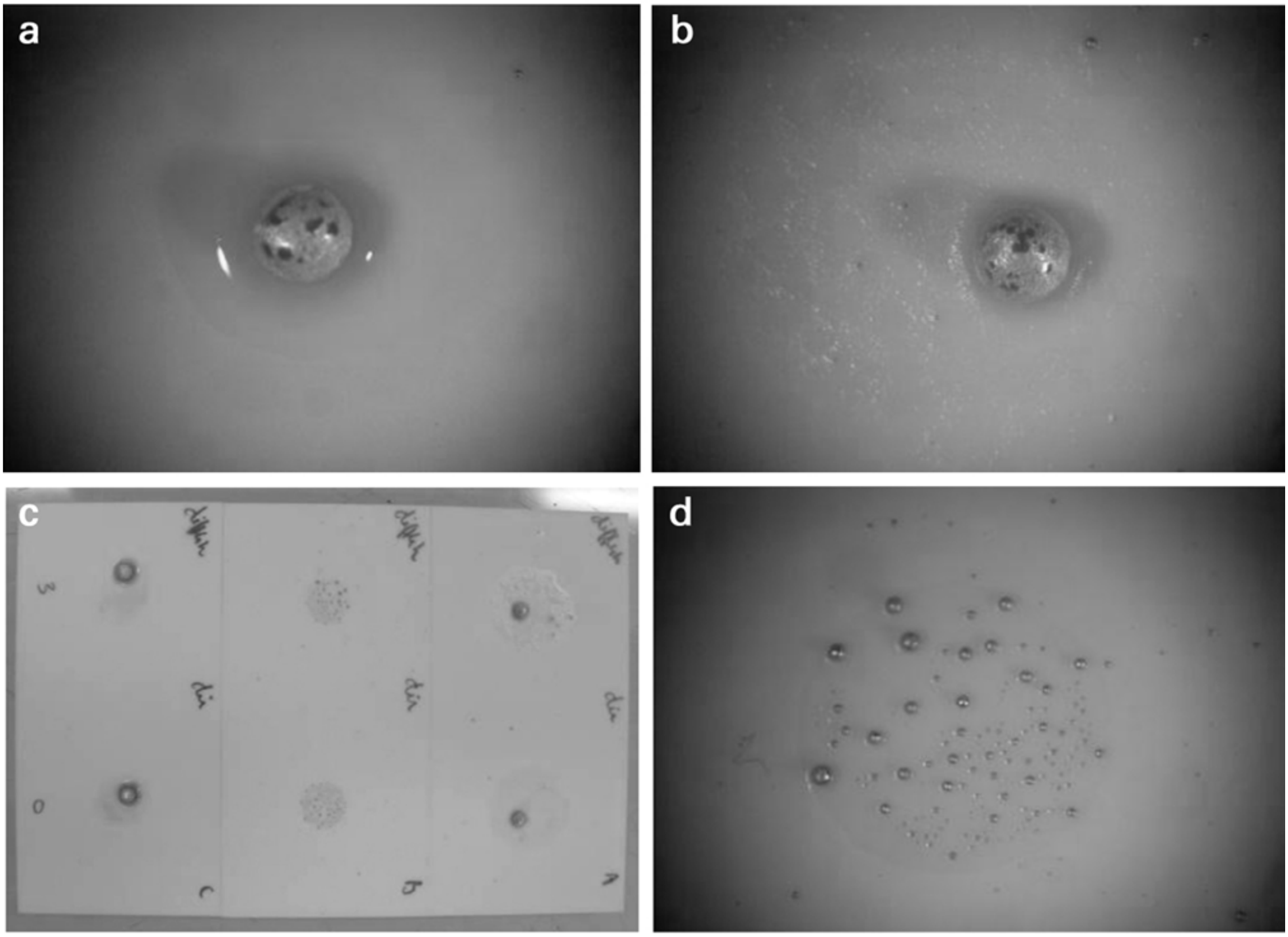


Figure 13: a) Class 1, b) class 4, c) A, B, C without preheat after 4 hours at ambient temperature and d) explosion.

minutes at 160°C, respectively class 4 and class 5 instead of class 1 for both initially. The summary is presented in Table 11 with images in Figure 13.

Discussion

After checking the initial properties of the pastes, which were all in their specification in terms of metal content and viscosity, several tests were done to evaluate their printing performance. In terms of viscosity, spiral pump type viscometer results and spindle type viscometer results showed the same tendency, except for paste A and C. These two pastes also had a different behavior and a different curve shape, compared to B, D, E and F as far as viscosity according to time was concerned. Paste C was far the worst in terms of high printing speed ability. Regarding tackiness, adhesion of paste C started to decrease before the other pastes, the idle time was also the lowest.

Hot slump was generally worse for the WS pastes than for the no-clean pastes. Paste A was extremely sensitive to storage at 40°C and lost its printing properties after four days only. The printing definition as well as the anti-bridging ability all along the prints was acceptable for all the pastes and, although C and A ranked last, the difference was not significant enough to draw any conclusion. The exposure to ambient conditions (21°C, 50%RH) between printing and reflow led to a degradation of solderballing performance for all the water-soluble solder pastes whereas the no-clean pastes were not affected at all.

Conclusion

The purpose of the paper was to highlight the reliability differences between water-soluble and no-clean solder pastes to guide users in their choice. To achieve this goal, six lead-free pastes were extensively studied, three being water-soluble and three being no-clean. The first part of the study focused on printing performance. The pastes were characterized using standardized tests and internally developed tests: dynamic viscosity, tackiness, slump and solderballing. The influence of accelerated storage at elevated temperature, the influence of time and conditions between printing and reflow and the influence of continuous shear according to time were shown.

The printing performances were also evaluated in a printer. Although the number of pastes studied was restricted, the water-soluble pastes generally yielded results below the no-clean pastes with sensitivity to temperature and humidity, a tendency to slump during preheat and a narrower printing window. Water-soluble solder pastes must be stored, handled and used with more caution before reflow.

In the second part of the paper, the reflow properties will be compared: wettability, reflow process window, anti-graping properties. Finally the residue cleanability with water, then with water and detergents will be examined. The cleanliness will be assessed using visual inspection, ionic contamination and surface insulation resistance tests. **SMT**

References

1. EFSOT Project.

Emmanuelle Guéné is electronics applications manager with INVENTEC Performance Chemicals in Bry sur Marne, France.

Steven Teh is Asia applications manager with INVENTEC in Selangor, Malaysia.

Mil/Aero007 News Highlights

U.S. Army, Lockheed Demo Autonomous Convoys

The two have demonstrated the ability of fully autonomous convoys to operate in urban environments with multiple vehicles of different models. The test involved driverless tactical vehicles navigating hazards and obstacles such as road intersections, oncoming traffic, stalled and passing vehicles, pedestrians, and traffic circles.

TT electronics-IMS' Ohio Facility Earns Nadcap Accreditation

"We are extremely proud of this recognition for our efforts in Perry, Ohio. Over the past two years, news of Nadcap accreditation across our global facilities has been well received by our customers as they see the mutual benefits of partnering with a global supplier that stands for the Nadcap ethos," said Mark R. Kray, VP and general manager.

UAV Market to Hit $114.7B by 2023

A new report says the global UAV market size can be expected to grow to more than $8 million by 2018. HALE/MALE/SUAV market has the highest business potential throughout the study period, whereas the U.S. and Israel will be the maximum revenue generator among the countries manufacturing UAVs.

Army Must be Prepared for Threats to Energy Sector

Cybersecurity threats to the United States' energy industry and infrastructure are rising and require increased preparedness by the U.S. Army and DoD, according to a new paper from Rice University's Baker Institute for Public Policy.

Ducommun Income Impacted by Boeing & Embraer Losses

Anthony J. Reardon, chairman and CEO, stated, "We are clearly disappointed in the execution of these programs. To expand our content on such platforms, we bid somewhat aggressively and, unfortunately, did not meet our planned productivity improvements at the required pace."

Global Comm Sat Imaging Market Sees Demand Increase

According to "Commercial Satellite Imaging Market—Global Industry Analysis, Size, Share, Growth, Trends, and Forecast, 2013-2019," published by Transparency Market Research, the market for commercial satellite imaging globally is forecast to reach US $5,018.6 million by 2019.

Mahindra Opens First India Manufacturing Facility

Telephonics Corporation announced that their joint venture partnership, Mahindra Telephonics Integrated Systems (Mahindra Telephonics), has opened the first private sector aerospace and electronics joint venture manufacturing facility in India.

SMTA, CALCE Counterfeit Symposium Seeks Abstracts

Both organizations are pleased to announce the 2014 Symposium on Counterfeit Electronic Parts and Electronic Supply Chain. This symposium is the best forum in the country for presenting and learning about the latest technology and policy developments in the area of electronics supply chain and counterfeit electronics prevention.

Day Two of DARPA Robotics Challenge Wraps

December 20–21, 2013, 16 teams were the main attraction at the DARPA Robotics Challenge (DRC) Trials, where they demonstrated their prototype robots' ability to perform a number of critical real-world disaster-response skills.

Pro-Tech Earns AS9100 Rev C Certification

The company has achieved full certification to AS9100C Quality Management Systems—Requirements for Aviation, Space and Defense Organizations. The successful completion of the requirements and the certification means that Pro-Tech Interconnect Solutions is now certified to AS9100C:2009, ISO 9001:2008 Quality Systems, ISO 13485:2003, MIL-PRF-31032/MIL-PRF-55110, along with ITAR registration.

KRAMER ON COMPONENTS

Investigations, Evidence, and an Unclear Solution for 2014

by Todd Kramer
SECURE COMPONENTS INC.

In November of 2011, when the United States government publicly got involved in attempting to curb the epidemic of counterfeits in the supply chain, it was a little too late. The Senate Arms Services Committee, led by Senators John McCain and Carl Levin, gave Americans their first glimpse into the catastrophic dangers that our Department of Defense and the aerospace community was facing. The Committee on Armed Services held a hearing regarding the investigation of counterfeit electronic parts in the defense supply chain and revealed alarming facts about how easy counterfeit components can infiltrate the supply chain.

At the request of McCain and Levin, an investigation was performed by the Government Accountability Office (GAO), which involved the creation of a fictitious company with the intent of gaining membership in two Internet platforms offering electronic components. This false company was provided with an owner, employees, mailing address, e-mail addresses, a website and a listing on the Central Contractors Registration. Report: Counterfeits in the Supply Chain

As a result of this investigation, the GAO-12-375 report was released to the public on February 21, 2012. Heavily involved in this project was Tim Parsons, chief scientist of the GAO. Recently, I had the opportunity to catch up with Parsons and discuss what he felt were the most important findings uncovered or learned as a result of this investigation. He said, "To summarize the key findings of our investigation report, we found that counterfeit electronic parts were indeed found in the supply chain of a number of key weapons systems (which often have multi-decadal life cycles), were relatively easy to acquire through internet platforms, and were increasingly sophisticated such that advanced inspection and authentication techniques were required to classify them as suspect counterfeit."

Figure 1: Senate Arms Services Committee led by Senators McCain and Levin.

Counterfeits Components: Worldwide

The GAO investigation discovered that suspect counterfeit and bogus electronic components— parts which are not associated with any actual electronic parts—are readily available across numerous Internet-based purchasing platforms. This declaration was confirmed when none of the 16 parts provided to GAO by various vendors proved to be genuine. Although there are different terms used to describe bogus parts, such as suspect, fraudulent, or counterfeit, the term "suspect counterfeit," which applies to the first two categories of parts that were tested by the GAO, is the strongest term that was used by an independent testing lab taking part in the study. The term "suspect counterfeit" represents a poten-

INVESTIGATIONS, EVIDENCE, AND AN UNCLEAR SOLUTION FOR 2014 *continues*

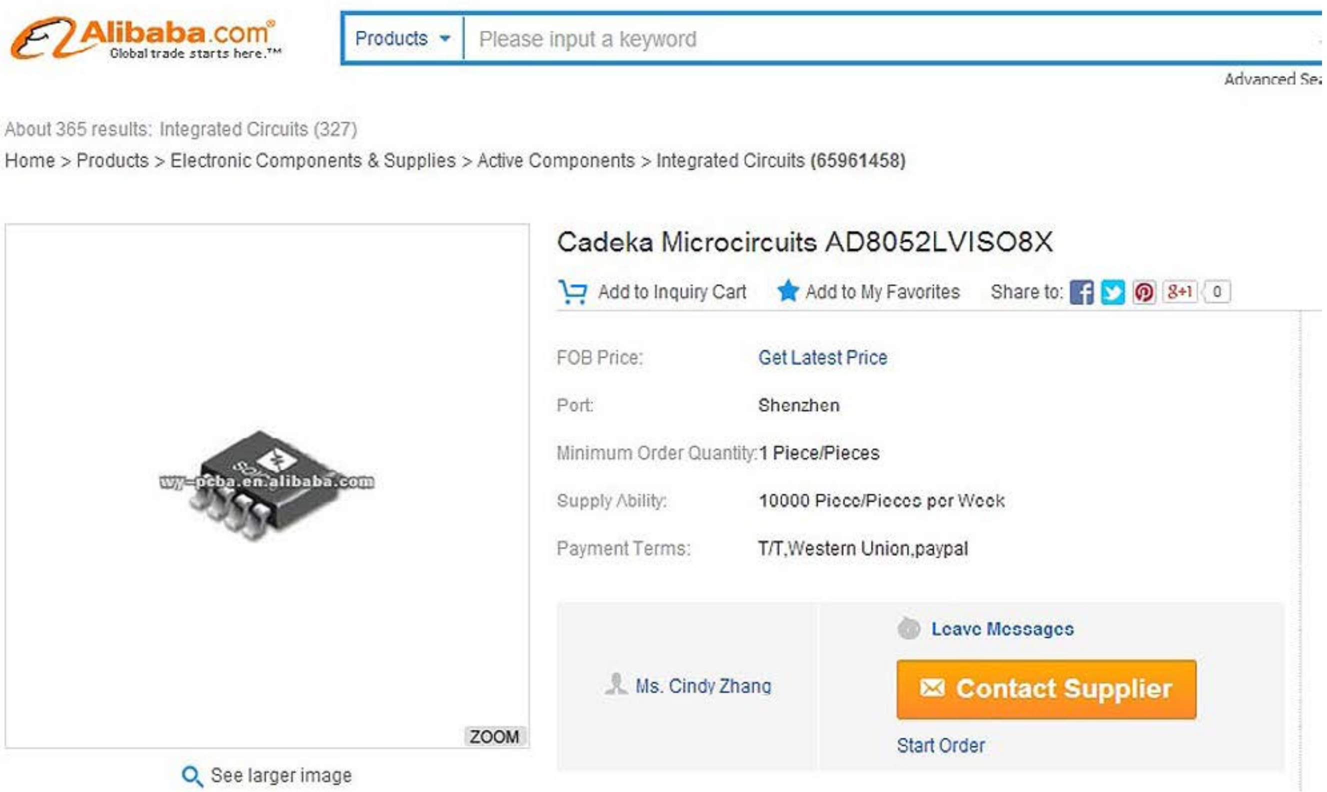


Figure 2: Global trading network—a place where buyers search for product.

tially serious violation of intellectual property rights, copyrights, or trademark laws.

According to GAO 12-375, "After disseminating requests for quotes on various platforms, GAO received responses from 396 vendors, of which 334 were located in China; 25 in the United States; and 37 in other countries, including the United Kingdom and Japan." Ironically, the responses sounded very familiar to veterans of the industry. For all 16 parts to be purchased, each vendor responded that the components were "in stock" with just a couple of days' leadtime. To choose which vendor to purchase the parts from, the GAO selected "the first of any vendor among those offering the lowest prices that provided enough information to purchase a given part, generally within two weeks." As it turned out, using the GAO methodology, all 16 parts were purchased from vendors in China.

The GAO report explained that "Specifically, all 12 of the parts received after GAO requested rare part numbers or postproduction date codes were suspect counterfeit, according to the testing lab. Multiple authentication tests, ranging from inspection with electron microscopes to X-ray analysis, revealed that the parts had been re-marked to display the part numbers and manufacturer logos of authentic parts."

X-ray analysis helps match up the wire bonds to what is called out in the schematic drawing. It was revealed that the parts had been re-marked to display the different part numbers and manufacturer logos representing other functionalities of authentic parts. To the naked eye, these would have looked as good as new. According to the GAO, "For the parts requested using postproduction date codes, the vendors also altered date markings to represent the parts as newer than when they were last manufactured." The fact that these parts were not produced at the dates given was verified by the original component manufacturers. Additionally, the submission of requests for phony parts using invalid part numbers yielded four parts from four vendors that have never been produced; for all intents and purposes, these parts never existed!

According to the GAO, the motivation behind GAO-12-375 is the fact that "Counterfeit parts—generally the misrepresentation of parts' identity or pedigree—can seriously disrupt the Department of Defense (DoD) supply chain, harm weapon systems' integrity, and endanger troops' lives." Ultimately, counterfeit components endanger our sons and daughters, who brave the front lines in the field. Some of the preliminary findings from the GAO investigation of the procurement and testing of select electronic components which have the potential to enter the supply chain of the U.S. Department of Defense are presented in GAO-12-213T, released in November of 2013.

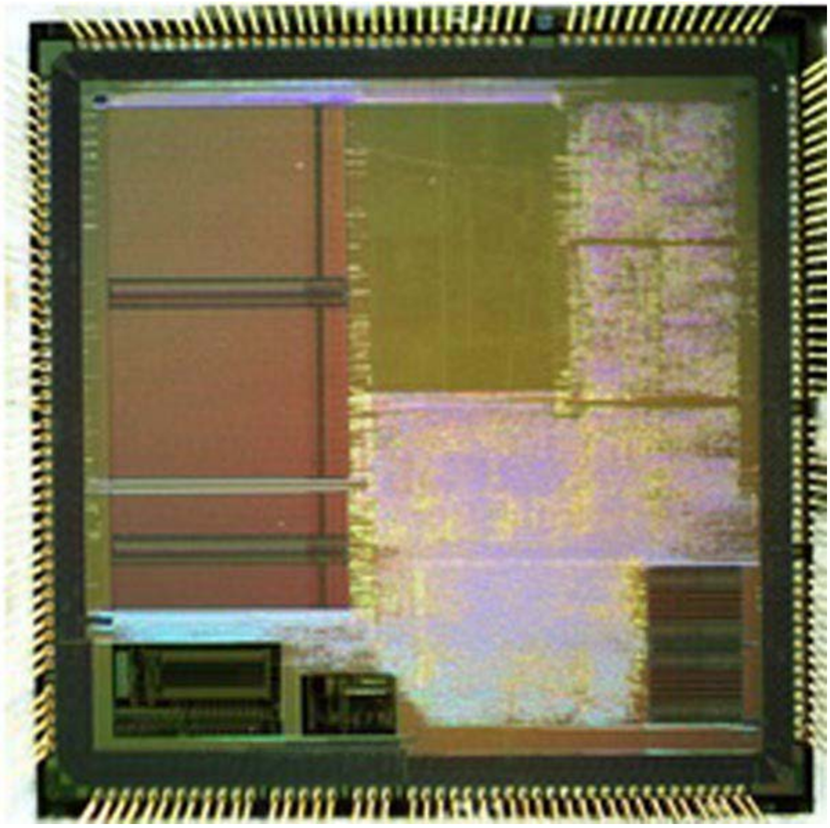


Figure 3: Part of the authenticity testing is to X-ray the product.

As reported in last month's column, many programs to re-use and recycle materials were developed with good intentions, but they wind up being used to create counterfeit electronic parts. Known as "e-waste," this material is shipped from the United States and other countries to desperate parts of the world, where the e-waste is disassembled in dirty, dangerous environments, and transformed to deceive the buying community. In an effort to counteract this practice, President Obama signed into law Section 818 of the National Defense Authorization Act for 2012. It applies to all contractors who supply electronic parts or products that include electronic components. DoD contractors are required, whenever possible, to obtain electronic parts that are in production or currently available in stock from the original component manufacturer (OCM) of the parts or their authorized/franchised distributors. In addition, electronic parts that are not in production or are out of stock must be purchased from "trusted suppliers." The term "trusted suppliers" is not well defined in the legislation and further clarification is needed.

Section 818 Requires Change Throughout the Supply Chain

Reporting requirements under Section 818 is a new necessity that trustworthy suppliers must implement into their procedures. A contractor who knows or "has reason to suspect" that he has received a counterfeit electronic part is required within 60 days to report to the appropriate government authority, the Government Industry Data Exchange Program (GIDEP). As an example, just this week, Secure Components, following an extremely aggressive quality protocol, determined that an electronic component delivered to the company and headed to the Defense Department was detected to have failed "resistance to solvent" testing. Further testing revealed the part was remarked and carried a false date code. Once these anomalies were identified, it was our responsibility as the contractor to report and quarantine the counterfeit parts. As the GIDEP representative,

Figure 4: Industry and governmental reporting will help minimize potential disasters.

I drafted a letter to the supplier including the alert I was about to report to GIDEP. By being proactive and complying with this reporting, I was able to provide a greater number of parties with a heads-up about this part and also served to minimize potential liability due to the protection offered under Section 818 relative to "reasonable effort." Obviously, no contractor wants to be assessed with the penalties addressed under the section, as they can climb as high as $15 million—and even imprisonment—for individuals who intentionally or recklessly facilitate the availability of counterfeit goods in the supply chain.

While, according the [Federal Register, Volume 78, Number 95, Section II](), "the intent of Section 818 is to hold contractors responsible for detecting and avoiding the use or inclusion of counterfeit electronic parts or suspect counterfeit electronic parts," there were some specific areas that were identified requiring either modification or additions to Defense Federal Acquisition Regulation System (DFARS). The register identified these areas as:

- Definitions—several definitions including "electronic part, legally authorized source, counterfeit part" are waiting to be finalized
- Contractor responsibilities for detection and avoidance of electronic components
- What are unallowable costs of rework and corrective actions?
- Government's role—in reviewing and monitoring contractors' processes and procedures for detecting and avoiding counterfeit parts

Due to the confusion and lack of clarity in parts of Section 818, the Department of Defense held a public meeting for the industry at large to contribute their concerns with the legislation. Along with other leaders in the supply chain, Secure Components sent Vice President of Sales Travis Thoman to Washington D.C. to provide input into the discussions relative to the Defense Federal Acquisition Regulation Supplement: Detection and Avoidance of Counterfeit Electronic Parts (DFARS Case 2012-D055). Thoman had the opportunity to provide testimony which can be read here. Upon return from the conference, he and I discussed his perception of what is to be proposed by DoD. It appears DoD is proposing to amend the DFARS in partial implementation of a section of the National Defense Authorization Act for Fiscal Year 2012, and a section of the National Defense Authorization Act (NDAA) for Fiscal Year 2013, relating to the detection and avoidance of counterfeit electronic parts.

The implementation of the changes is directed by the Defense Acquisition Regulations System (DARS), which develops and maintains acquisition rules and guidance to facilitate the acquisition workforce as it acquires the goods and services the DoD requires ensuring America's warfighters continued worldwide success. They are working on implementing portions of the section 818 of NDAA for 2012 to add:

1. Definitions specific to counterfeit parts
2. Definitions of contractors responsibilities
3. Clarification of the government's role

Action is Critical

I believe the need for immediate and swift action is essential from all levels of the supply chain. The evidence of counterfeit material entering the U.S. military's supply chain is overwhelming. I am hopeful that the DoD will adopt clear language and guidance for industry in order to defeat the counterfeit threat. The Defense Logistics Agency has led this fight with swift action of its own with the DNA marking requirement for all microcircuits and a strict policy regarding qualified suppliers. While I believe it's unlikely the DoD will follow the exact path the Defense Logistics Agency's has implemented, I am hopeful it will utilize some of the tools that the G-19 committee and other subject matter experts have worked so hard to create. With mitigation standards such as the SAE AS6081 Counterfeit Avoidance Standard for Distributors and the SAE AS5553 Counterfeit Avoidance Standard Manufacturers, which have been adopted by the DoD, it would seem like a logical part of the solution. I am hopeful that the leaders of our nation, our military, and our aerospace and defense industries will not forget who the ultimate customer is. At the end of the day, it's the brave men and women who put their lives on the line to defend our freedom who need action. Bureaucracy and procrastination will do little to ensure their safe return home. I urge everyone reading this article to recognize the threat counterfeit electronics pose to our nation and do their part to protect their industry, their customers and their families.

Much of the information presented in this article was drawn from the "GAO-12-375" report to the Committee on Armed Services, U.S. Senate, "Suspect Counterfeit Electronics Parts Can Be Found on Internet Purchasing Platforms." Published, February 21, 2012; publicly released March 26, 2012. The full text may be accessed here. **SMT**

Todd Kramer is CEO of Secure Components LLC, a leading independent distributor of electronic components, hardware, and mechanical parts to the Aerospace, Defense, & Commercial Industries. Kramer is an active member of organizations such as SAE G-19C, the current chairman of U.S. National Committee (USNC/IECQ) and the International Working Group 06 (Counterfeit Avoidance). His new column, Kramer on Counterfeits, will run monthly in SMT Magazine. To contact Kramer, click here.

Video Interview

Hunter Moves To a New Facility

by Real Time with...
PCBDesign007

Joe O'Neil, CEO of Hunter Technology, discusses the company's recent move to a new facility, and his plans for the new year, including hiring more employees.

realtimewith.com

SMTonline Market News Highlights

Conference Board LEI for Germany Up in November

The Conference Board Leading Economic Index (LEI) for Germany increased 0.6% in November to 108.2 (2004 = 100), following a 0.2% increase in October, and a 0.2% decline in September.

Wearable Computing Devices Driven by Sports, Health

ABI Research projects the wearable device sales volumes in 2014 to come from healthcare and sports and activity trackers. The commercial launch of several smart glass products, including Google Glass, will continue to drive interest in the wearable space, but it will not be a significant commercial success in 2014.

Demand for Hydrogen for Fuel Cells to Climb Sharply

Since 2011, interest in hydrogen for the energy storage market, combined with the rise in usage of hydrogen in the fuel cell sector, has seen increased utilization of hydrogen outside of petroleum refining and chemical manufacturing.

UAV Market to Hit $114.7B by 2023

A new report says the global UAV market size can be expected to grow to more than $8million by 2018. HALE/MALE/SUAV market has the highest business potential throughout the study period whereas the U.S. and Israel will be the maximum revenue generator, among the countries manufacturing UAVs.

Global Comm Sat Imaging Market Sees Demand Increase

According to a new market report “Commercial Satellite Imaging Market—Global Industry Analysis, Size, Share, Growth, Trends, and Forecast, 2013–2019,” published by Transparency Market Research, the market for commercial satellite imaging globally is forecast to reach US $5,018.6 million by 2019.

India’s Li-ion Battery Market Driven by Smart Devices, EVs

Lithium ion (Li-ion) batteries are rechargeable batteries witnessing increasing adoption in consumer electronics and automotive applications. India is one of the major Li-ion markets, exhibiting double digit growth.

Report: Power Electronics for Electric Vehicles 2013-2023

Research and Markets has announced the addition of the “Power Electronics for Electric Vehicles 2013–2023: Forecasts, Technologies, Players” report to their offering.

Sales of Portable Power Batteries to Top $12.4 Billion

Significant improvements in battery technologies and, in some cases, the introduction of completely new battery chemistries are transforming the ways in which people charge portable devices, from smart phones to power tools. According to a new report, worldwide sales of advanced batteries for portable power will surpass $12.4 billion annually by 2023.

MAPI: Manufacturing Sector Continues Upswing

The U.S. manufacturing sector is showing incremental improvement with only a few potential speed bumps in the near-term, according to the quarterly “Manufacturers Alliance for Productivity and Innovation MAPI Business Outlook.” The December 2013 composite index improved to 67, from 66 in the September survey—the fourth straight quarterly advance.

Chinese Smart Phone Sales Top 320 Million Units

The Chinese smartphone market in the third quarter of 2013 reached around 87.4 million units, up 13.4% sequentially. Overall, Chinese smart phone sales totaled around 230.5 million units in the first three quarters of 2013, up 93.3% year-on-year.

SMT TRENDS & TECHNOLOGIES

What is Your Real Output?

by Eric Klaver
ASSEMBLÉON

How should you define your output? Highest area productivity, lab speed, actual speed, optimum speed, IPC speed or maximum speed? And is it speed or throughput we should be looking at? Neither is clearly defined, and we all have our rules of thumb (e.g., actual speed is 60% of IPC speed, which is 60% of maximum speed).

Currently, there is only one standard representing a fair comparison between pick-and place equipment: IPC-9850. It measures equipment speed (providing that components are placed within the specified accuracy of the equipment itself). IPC established IPC-9850 in 2002, defining the measurement procedures for specifying, evaluating and verifying surface mount placement equipment. With machine manufacturers producing a wide range of accuracies and outputs, it details how measurements must be made consistently, and is therefore the only real way to compare them. It has become a basic industry reference, but unfortunately doesn't tell the whole story. Several pick-and-place machine manufacturers, for example, currently claim the industry's fastest placement speeds on the basis of the IPC reference speed.

One key difference lies between the IPC-9850 speed and the actual speed you will reach in a particular application. And that is where IPC-9850 falls short.

For this reason, IPC published an updated version in January 2012: IPC-9850A. Since the release of this update, it has been adopted by… practically nobody. Admittedly, the new standard is far from perfect, as applications are usually still more complex than even it allows for. It is a step closer to the truth, though. Why have so few adopted it? Why do most manufacturers avoid publishing the results? It seems that this minor change in specification degrades output results so drastically that it is commercially too sensitive.

WHAT IS YOUR REAL OUTPUT? *continues*

IPC-9850 and IPC-9850A: the Differences

IPC-9850 speeds are measured by placing a simple matrix of components (for example 80 SOIC-16s or 400 identical 0603 capacitors) on a 200x200 mm substrate. However, the standard says nothing about the electrical value of these 400 capacitors, for example. That allows sequential placement machines to use gang pick (simultaneous pick by multiple placement heads) using an optimized placement path. Gang pick, however, artificially inflates the performance figure since it can virtually never be used in an actual customer application. You just don't get many circuits incorporating hundreds of identical 27-nF capacitors on a board in a small matrix in a 200x200 mm area.

IPC-9850A is simplified. It uses a new board layout, and it requires two different parts (previously only one) and five unique code numbers

Part no.	Geometry	# Placements	Place Angle	# Placements
A	0402 (1005)	207	0	50
			90	52
			180	49
			270	56
B	0201 (0603)	103	0	23
			90	25
			180	28
			270	27
C	0402 (1005)	51	0	18
			90	15
			180	13
			270	5
D	0201 (0603)	26	0	6
			90	5
			180	6
			270	9
E	0402 (1005)	13	0	3
			90	3
			180	4
			270	3

Figure 1: Number and quantity of unique components placed on IPC-9850A substrate (source IPC-9850A).

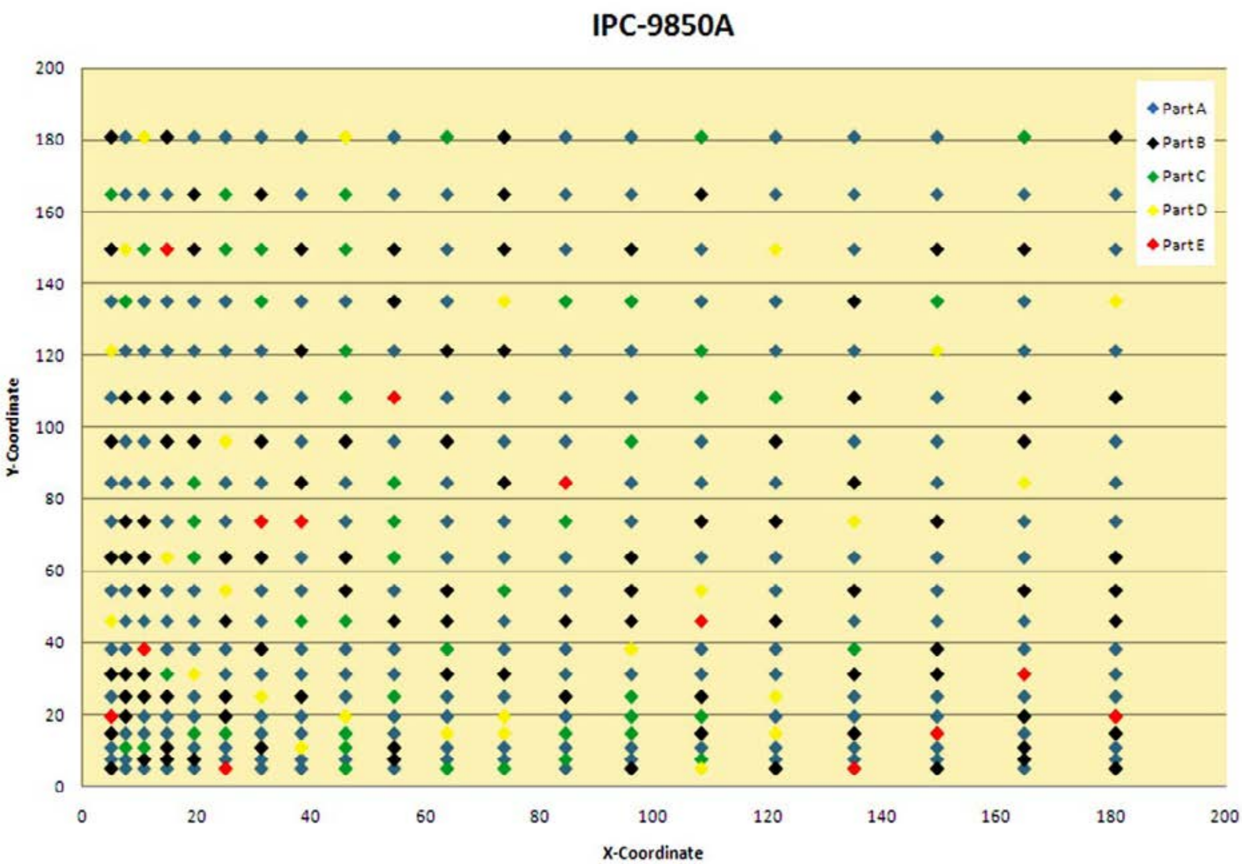


Figure 2: Distribution of components on the IPC-9850A substrate.

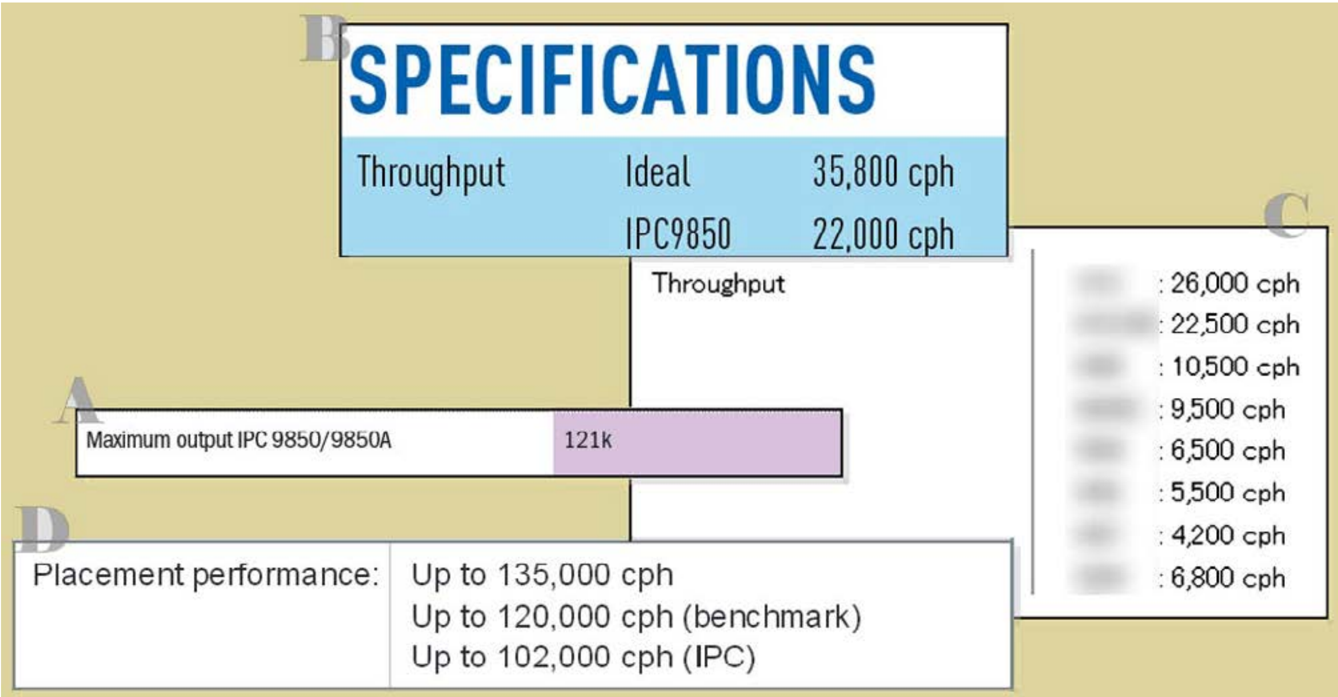


Figure 3: Examples of how specifications are published by different pick-and-place manufacturers, with only one referencing IPC-9850A.

that are randomly distributed (previously none were defined). The 0603 components have also been replaced by 0402 (01005 metric) and 0201 (0603 metric).

For now, that is good enough for a fair comparison. However, many of today's processes and today's technology would actually use a mix of 0201 and 01005 components. These really show whether a pick & place machine can cope. Perhaps the standard will be updated again in the future, when vanishingly small components like 03015 metric are common. The standard could perhaps also usefully define a test run and let the customer decide which components should go through.

In the meantime, though, let's dig slightly deeper to see what an IPC-9850A closer-to-reality application actually looks like.

IPC 9850A in Practice

IPC 9850A places five unique parts (Parts A–E in Figure 1) randomly on the substrate, with non-linear column distances (Figure 2).

For a revision of an accepted industry standard that was released more than two years ago, it is again strange that virtually no manufacturers—even the ones who praised the new standard at the time—have converted their equipment specifications. There seems to be a barrier to publishing something closer to the truth. As I've said, this has to be for commercial reasons. Unfortunately, if nobody adopts it, the impact of the standard is devalued within the industry. So for now, you will have to be satisfied with the figures a manufacturer provides to you (Figure 3).

Consistent labeling would, however, help to eliminate confusion. And customers should apply pressure. At your next purchase, you could ask, "What is your IPC-9850A output?" **SMT**

Eric Klaver has been with Assembléon since 1998 and specializes in vision technology and feeding. He is currently the chairman of IEC work group TC40WG36, which specializes in component packaging. To read past columns, or to contact Klaver, click here.

SMTonline Supplier/New Product News Highlights

i3 Electronics: $7M Contract for HyperBGA Assemblies

i3 Electronics Inc. announced that an industry leading computing & hardware firm has awarded the company a $7 million contract for the supply of i3's HyperBGA assemblies. The contract will run through Q4 of 2014.

Tera-Barrier Films Invents Alternative Stretchable Plastic

Tera-Barrier Films invents alternative stretchable plastic for prolonging shelf-life of pharmaceuticals, food, and electronics.

Indium Intros New Solder Paste Technology

The company announced BiAgX, a high-melting, lead-free solder paste technology designed for high-reliability electronics assembly applications. Designed as a drop-in replacement for standard high lead-containing solder pastes, it has passed MSL1 and thermal cycle testing at several power semiconductor customers.

BEST Introduces New Plastic Film Stencils

The company has developed a line of Kapton SMT stencils for the prototype assembly market. These stencils, available in 4-, 5-, and 6-mil thicknesses, present very flat coplanar printing surfaces for solder paste printing and are designed to be used when there are very few boards to be made at one time and the pitch of the components is 1.00 and above.

Needle Valve From Dymax Offers Dispensing Precision

The Model 400 pneumatic, normally closed-needle valve is designed to deliver precise dots or very fine beads of low- to medium-viscosity fluids. Accurate, repeatable dispensing can be achieved by utilizing the valve's material flow adjustment to control shot volume. The lightweight, wand-style valve body is compact and lightweight, making it easy and comfortable to handle.

Manncorp Reconfigures, Expands SMT Solutions

The company has recently reconfigured and expanded its exclusive selection of SMT turnkey packages, including stencil printing, pick-and-place, and reflow soldering equipment, to accommodate a wider range of production levels and budgets.

New ALPHA LED Materials Introduced in February

The company will introduce its new line of ALPHA LED specialty materials technologies at Strategies in Light Exposition & Conference, February 25-27, 2014. These new product technologies reach across levels one through five of the LED lighting system manufacturing process: die attach & package, package on board, luminaire module, power driver/supply, and control systems.

Indium Names Tim Jensen Senior Product Manager

Indium Corporation announces that Tim Jensen has been named senior product manager for Engineered Solders.

BEST to Hold Advanced X-ray Inspection Seminar

Presentation topics on April 3 will include: "Advanced Package X-ray Inspection," "BGA and X-ray Rework Inspection," and "Small Spot Size X-ray Inspection of POPs, BGAs and Leadless Devices." The sessions will feature hands-on "how to" sessions as well as advanced theoretical sessions.

ZESTRON Presents Core Webinar: "Why Clean PCBs"

ZESTRON, the global leading provider of high-precision cleaning products, services, and training solutions, is pleased to announce the first installment of ZESTRON Academy's 10-part 2014 Cleaning Webinar Series titled "Why Clean PCBs."

10 Common Stencil Questions

by Rachel Miller-Short
PHOTO STENCIL LLC

There are a wide range of stencils and stencil technologies available and many questions arise when the time comes to select one. This month's Short Scoop answers the 10 most common questions our customers ask.

1. What type of stencil do I need?

The need to satisfy more rigorous printing requirements due to finer pitch components leads to a natural hierarchy of stencil technologies based on the application. A few general stencil technologies are available on the market today. They include stencils that are laser-cut on some form of stainless steel material, laser cut stencils on 100% nickel foils, and electroformed stencils for the most challenging applications. With each of these basic stencil types there are many coatings and post-process steps available to tailor the basic stencil further. The specific stencil types and options available are dependent on the supplier selected. Each of the key technologies and secondary processing options has its qualitative benefits for specific applications, and it is not uncommon in the industry today to see stencil users deploying a combination of all three stencil types in their factories. There are three main questions to ask and answer to help determine the correct stencil:

1. What is the smallest pitch to be printed?
2. What is the mix of components being placed on the board?
3. What is the area ratio calculation of the smallest component?

Stencil users who optimize the correct stencil technology for their specific application and processing parameters typically enjoy greater yields and significantly lower rework. As always, it is about selecting the right tool for the job.

2. How much will it cost?

Customers are continually pushing for cost reductions. The improved capabilities of available stencil materials, combined with high-performance lasers, enable many applications to be fulfilled using straight laser-cut stencils. If that option works for your application, it provides a fast turn, low price-point option to satisfy your application. The use


APEX EXPO IPC
MEETINGS & EDUCATION › March 23-27, 2014
CONFERENCE & EXHIBITION › March 25-27, 2014
Mandalay Bay Resort and Convention Center
Las Vegas, Nevada
NEW IDEAS...
FOR NEW HORIZONS
› TRUST in the expertise of IPC.
› EXPLORE emerging technologies and the latest innovations.
› COMPARE equipment, materials and supplies.
› LEARN about the latest research and processes.
› BE INSPIRED with new ideas and approaches.
"We bring a team of engineers to APEX with us each year. The professional development courses, broaden the expertise of our engineers while keeping them abreast of new technologies, challenges and methods.
This provides a basis for our well-educated team; one that can build an effective forward-looking technology roadmap, and keep us lean and competitive in our markets."
Jeff Hempton
BAE Systems
Strategic Technology Process Lead
REGISTER TODAY
www.IPCAPEXEXPO.org
DESIGN | PRINTED BOARDS | ELECTRONICS ASSEMBLY | TEST

of laser-cut stencils has had a dramatic positive effect on the amount companies spend on stencils. Depending on your needs, there are also frameless stencil options available that can lower prices even further. While the addition of coatings, steps in the stencil, or fabrication of electroformed stencils come with an increased price, the overall benefit of the added cost may be more than made up for with improved process yield.

3. How long will this stencil last?

What is the life of a stencil? That is the golden question almost every customer wants answered, but the answer is not terribly straightforward. Because there are so many variables that have to be taken into consideration, there truly is no average actual lifespan of a stencil. Paste type, blade pressure, blade type, board layout, stencil thickness, cleaning chemistry, and cleaning frequency all affect the stencil's life. I am aware of customers running stencils for over 100,000 print cycles, and then I know of other customers who replace stencils as soon as they cross the 40,000-print cycle mark. In the most optimized printing environments there should be no struggle with a good stencil printing successfully for 75,000 prints.

4. How does area ratio impact the stencil type?

Paste transfer is a competitive process. 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 away from the aperture walls. The larger the wall area compared to the pad area beneath the aperture, the more difficult it is for the paste to release from the aperture walls. Because of this, identifying area ratio ranges for the stencil and pairing them with the appropriate stencil technology is key. Doing so helps lessen rework and aids in the success of stencil printing.

5. Do I really need a coating on my stencil?

Many companies today use a nano-coating of some type to enhance the properties of the stencil. These benefit the printing process by providing slight paste release and under-screen cleaning improvements. Since most of these coatings are not permanent, it can be difficult to determine how long the coating will last in relation to the life expectancy of the stencil. Often a change in the coating becomes apparent only after process yields start to shift or cleaning becomes more difficult. More permanent coatings are hitting the market and some are colored for a visual indication of their presence on the stencil.

> ***"Because there are so many variables that have to be taken into consideration, there truly is no average actual lifespan of a stencil. Paste type, blade pressure, blade type, board layout, stencil thickness, cleaning chemistry, and cleaning frequency all affect the stencil's life."***

6. What type of frame do I need?

Due to the countless types of printers used by manufacturers, the variety of frame types needed to service the industry is in the hundreds. Fortunately, high-volume stencil sizes are fairly regular in size, typically coming in as 8x10, 12x12, 20x20, 23x23, and 29x29 inch frames. Many of these frames are available as standard frames, or as frames with space-saving options. Customers who can move to standard frame types usually enjoy cost savings compared to those using less common frame types.

7. Can you fix the stencil I have?

Yes, many stencil providers will add apertures and remount existing stencils into different frames. In some cases, the time, effort, and costs associated with shipping the stencil back and forth and remounting or adding apertures to an existing stencil make procuring a new stencil a more appealing choice.

8. When can I get my stencil?

That's usually the first question we're asked. The trend of shrinking lead times directly affects the available manufacturing time for everything from bare boards to the stencils and everything in between. With the advent of laser-cut nickel blanks the industry now has a high-performance solution that can be shipped out as a same-day stencil. If your application requires an electroformed stencil, it still has to be "grown," and it takes longer to fabricate due to the process involved. While not all stencils require a same-day or 24-hour turnaround, the percentage of customers who want quick-turn fabrication is definitely growing. Fortunately, most stencil providers have been able to increase throughput capacity as well as make adjustments in logistics to accommodate customers. Of course, if you need it shipped overnight, that option is always available, but this has a large impact on lead time and the overall cost. Overnight shipping is expensive, no matter where the supplier is located.

"Fortunately, most stencil providers have been able to increase throughput capacity as well as make adjustments in logistics to accommodate customers. Of course, if you need it shipped overnight, that option is always available, but this has a large impact on lead time and the overall cost. Overnight shipping is expensive, no matter where the supplier is located."

9. How important are design standards?

IPC's stencil design guidelines are, in many cases, the fundamental basis of companies' design guidelines. The design can affect the stencil's performance in countless ways, both positive and negative. It can even influence the life of a stencil, so it's advantageous to use standards that have been shown to provide the best results. Most large multiple-site stencil users have design standards which are used across the board at all of their locations. Companies that get this right enjoy design and print success coupled with reduced rework and printing challenges. If your company is not following a design standard, start by looking at your key defects and evaluating what improvements can be made. Once those are identified and tested, they should become part of your design guidelines.

10. What, I need a special blade?

This question has to do with the importance of the blade in the printing process. As we discussed in the June 2013 Short Scoop, blades are not as simple as they sound. There are multiple technologies available, from ultra-robust hard blades to fairly soft 100% nickel blades. Each of these blade types is geared for a particular application. The right blade type and the quality of the blade play large roles in the success or lack thereof in stencil printing. An old worn-out blade with dings on the edge can cause printing defects as well as damage to the stencil. Many customers forget to look at blade types and the quality of their blade, and they overlook an easy opportunity to improve their print process and save the company time and money.

As always, your stencil manufacturer is there to provide the best product for your particular application. While some questions are fairly general, the subtlety of your design needs should be addressed when you initiate a new design. **SMT**

Rachel Short is vice president of sales and marketing at Photo Stencil LLC. To read past columns, or to contact the columnist, click here.

TOP TEN

News Highlights from SMTonline this Month

① Optomec to Discuss 3D Printing at IEEE Webinar

Optomec has announced that Mike O'Reilly, the company's Aerosol Jet product manager, will participate in an IEEE Webinar, "3D Printing: From Prototype to Production." Also presenting in the Webinar will be Melba Kurman, technology analyst and co-author of "Fabricated: The new world of 3D printing."

② CEA to Discuss "The State of Distracted Driving"

The Consumer Electronics Association (CEA) will contribute to a panel discussion on "The State of Distracted Driving" at a summit hosted by the U.S. Senate Committee on Commerce, Science and Transportation.

③ Lyytinen Resigns as Kitron's Chairman of the Board

Kitron announces that Asa-Matti Lyytinen has informed the company of his decision to resign as chairman of the board. To facilitate an orderly transition, he will stay in position until a new chairman has been elected.

④ Conference Board LEI for Germany Up in November

The Conference Board Leading Economic Index (LEI) for Germany increased 0.6% in November to 108.2 (2004 = 100), following a 0.2% increase in October, and a 0.2% decline in September.

5 Elecsys Adds George Semb to Board of Directors

Elecsys Corporation, a provider of innovative machine-to-machine (M2M) communication technology solutions, data acquisition systems, and custom electronic equipment for critical industrial applications, has announced that George Semb was appointed to the company's Board of Directors.

6 John C. Johnson Joins IEC's Board of Directors

W. Barry Gilbert, chairman and CEO, commented, "I am pleased John has been elected to our Board of Directors. John is an accomplished individual with wide and deep experience in the military, aerospace, and defense industry."

7 Telehealth Devices & Services Revenue to Swell to $4.5B in 2018

The global telehealth market is expected to grow by more than a factor of 10 from 2013 to 2018, as medical providers increasingly employ remote communications and monitoring technology to reduce costs and improve the quality of care, according to IHS Technology.

8 Potential Role of Internet of Things Drive Energy Harvesters

The Internet of Things adds connectivity to things. It is a broad term referring to applications as diverse as Internet-connected vehicles to consumer electronics such as smart phones.

9 TT electronics-IMS' Ohio Facility Earns Nadcap Accreditation

"We are extremely proud of this recognition for our efforts in Perry, Ohio. Over the past two years, news of Nadcap accreditation across our global facilities has been well received by our customers as they see the mutual benefits of partnering with a global supplier that stands for the Nadcap ethos," said Mark R. Kray, VP and general manager.

10 Intel, Apple Rumored to Cut Deal for Fab 42

Last month, Intel announced it would indefinitely postpone equipping its Fab 42 in Chandler, Arizona. This facility is currently a shell and was intended to have a built-out capacity of 40,000 300 mm wafers per month. The company has stated that it expects the facility to be used for manufacturing at the 10nm process node after first ramping and running 14nm production.

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.

Dallas Expo & Tech Forum
March 4, 2014
Plano, Texas, USA

NORDIC HDI 2014
March 5–6, 2014
Copenhagen, Denmark

Houston Expo & Tech Forum
March 6, 2014
Stafford, Texas, USA

SMTA Webtorial: Tin Whiskers—All You Should Know
March 11 and 13, 2014
Online

IPC APEX EXPO 2014
March 23–27
Las Vegas, Nevada, USA

Electronics New England
March 26–27, 2014
Boston, Massachusetts, USA

Printed Electronics Europe 2014
April 1–4, 2014
Berlin, Germany

Internet of Things and WSN Europe 2014
April 1–2, 2014
Berlin, Germany

South East Asia Technical Conference on Electronics Assembly
April 8–10, 2014
Penang, Malaysia

Intermountain (Boise) Expo & Tech Forum
April 17, 2014
Boise, Idaho, USA

Smart Fabrics & Wearable Technology 2014
April 23–25, 2014
San Francisco, California, USA

PUBLISHER: **BARRY MATTIES**
barry@iconnect007.com

PUBLISHER: **RAY RASMUSSEN**
(916) 294-7147; ray@iconnect007.com

SALES MANAGER: **BARB HOCKADAY**
(916) 608-0660; barb@iconnect007.com

MARKETING SERVICES: **TOBEY MARSICOVETERE**
(916) 266-9160; tobey@iconnect007.com

EDITORIAL:
GROUP EDITORIAL DIRECTOR: **RAY RASMUSSEN**
(916) 294-7147; ray@iconnect007.com

MANAGING EDITORS: **LISA LUCKE**
(209) 304-4011; lisa@iconnect007.com,
and **ANDY SHAUGHNESSY**
(770) 315-9901; andy@iconnect007.com

TECHNICAL EDITOR: **PETE STARKEY**
+44 (0) 1455 293333; pete@iconnect007.com

MAGAZINE PRODUCTION CREW:
PRODUCTION MANAGER: **SHELLY STEIN** shelly@iconnect007.com
MAGAZINE LAYOUT: **RON MEOGROSSI**
AD DESIGN: **SHELLY STEIN, MIKE RADOGNA**
INNOVATIVE TECHNOLOGY: **BRYSON MATTIES**
COVER ART: **SHELLY STEIN**

SMT® (Surface Mount Technology) is published by BR Publishing, Inc., PO Box 50, Seaside, OR 97138

March 2014, Volume 29, Number 3 • SMT© (Surface Mount Technology©) is published monthly, by BR Publishing, Inc.

ADVERTISER INDEX

Coming Soon to *SMT Magazine:*

Don't miss our upcoming issues!

April:
SMT Assembly, Part 3: After the Soldering Process

May:
Test and Inspection of Electronic Assemblies

If you can't make it to IPC APEX EXPO, don't worry. We'll bring you full coverage, live from Vegas!