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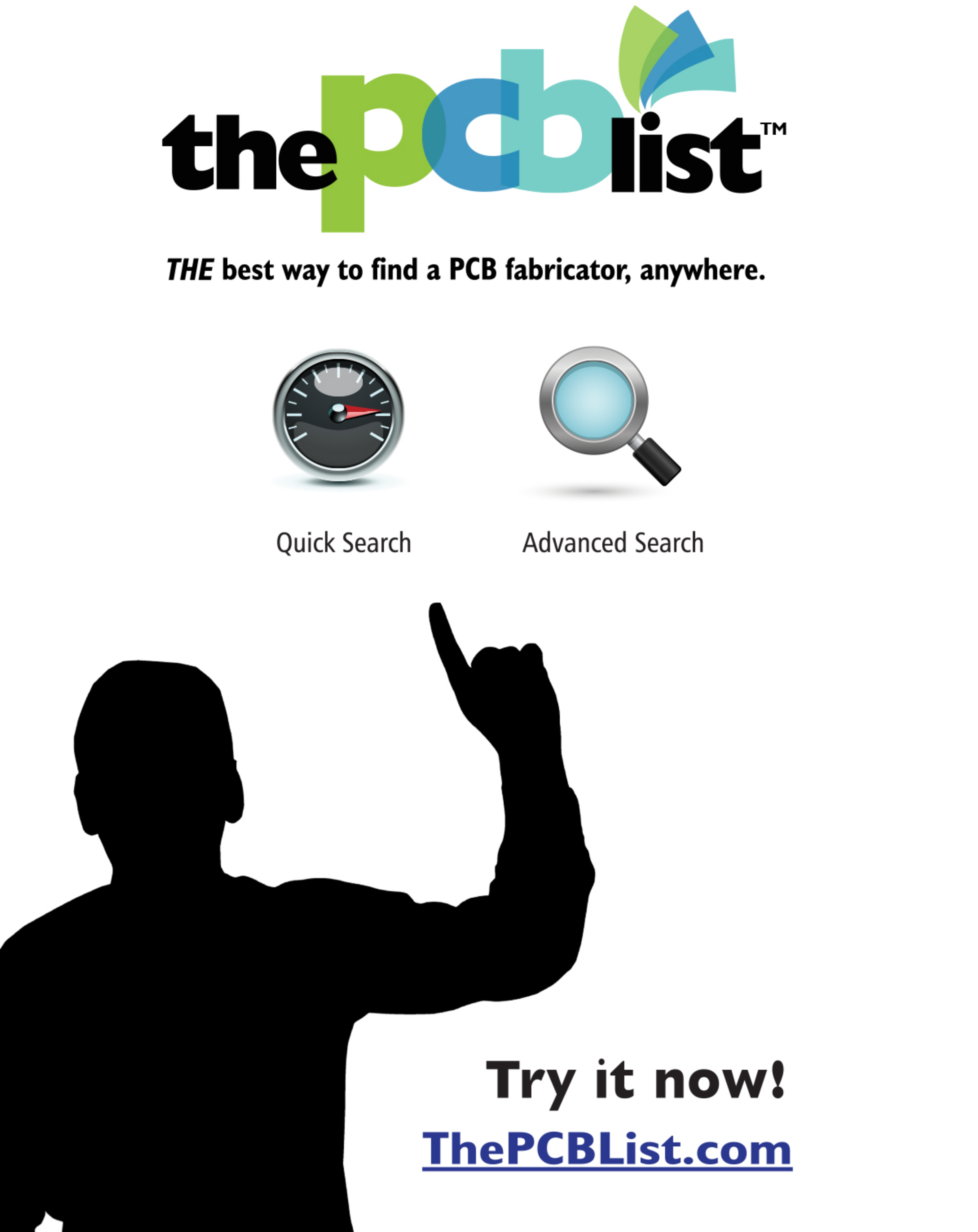
JULY 2013

THERMAL MANAGEMENT EDITION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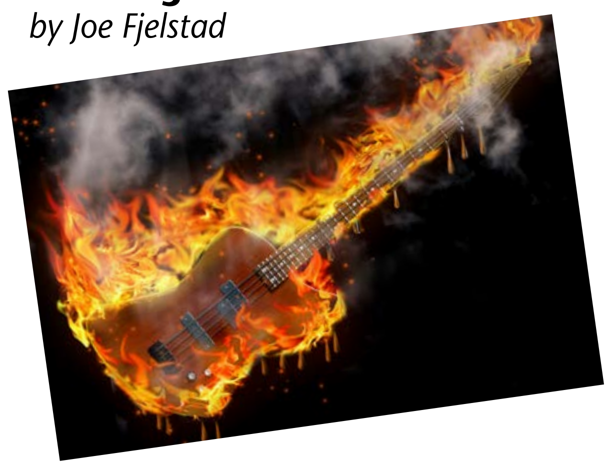
July 2013 Featured Content

THERMAL MANAGEMENT

This month, *SMT Magazine's* feature contributors include experts from Koki Company Ltd., Christopher & Associates, Air-Vac Engineering, and Verdant Electronics. Among the issues addressed: thermal management challenges, soldering applications for temperature-sensitive components, and lead-free alloys.



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COLUMN

THE WAY I SEE IT

Here We Go!

by Ray Rasmussen
I-CONNECT007

I recently talked with a friend of mine who works at Intel. He manages big OEMs that buy ICs in huge quantities for their PCs and other consumer products. We had a short conversation about the market in general, and he said that his customers were starting to put a lot of pressure on him to provide them with the information they need for their next acquisitions.

These OEMs are becoming really impatient; they seem to be under a lot of pressure themselves. My friend said something along the lines of, “I don’t know what people are talking about when they mention a slow economy. We’re not seeing it.” In his world, which slices through consumer electronics, they’re all busy. Demand is up.

It sounds to me like the normal build-up to the Christmas season is driving the demand. Maybe the big PC makers feel that if enough folks have figured out how to use Windows 8, more consumers and businesses will take the plunge and upgrade their PCs. We know Apple will likely introduce a new phone this fall (it’s already being built, I suppose), which will generate a lot of activity.

IPC sent over a press release in mid-June titled: *Slow Growth Ahead for Economy and Electronics Industry, According to IPC*. I retitled it, *IPC: Economic Growth Ahead*. Now, I’m not trying to discount the experts at IPC, but I do believe the market out there could be better than we might think. IPC did talk about the second half being potentially better. Here’s a paragraph from that news item.

Economic activity in the U.S. manufacturing sector expanded in March for the fourth consecutive month, and the overall economy grew for the 46th consecutive month. IPC’s North American Electronics Industry Performance Index reflects an outlook for slow growth in the months ahead. Another leading indicator for electronics supply chain sales growth in North America is the PCB book-to-bill ratio, which reached a 34-month high in April at 1.10, indicating that sales across the supply chain may resume positive growth momentum in the latter half of 2013.

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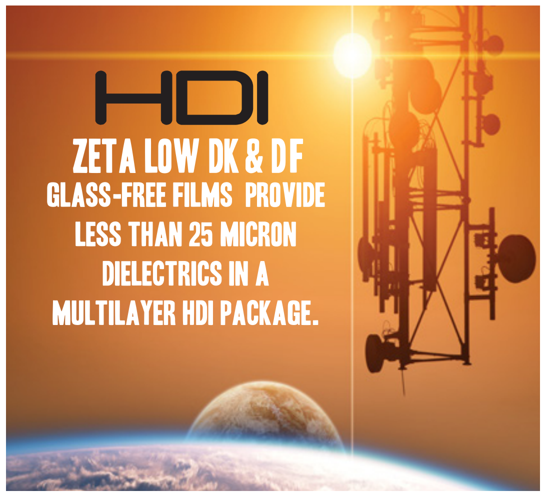

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HERE WE GO! *continues*

IPC seems to be taking a very cautious approach, not wanting to appear too optimistic. It just doesn't feel dreary and dismal out there to me, but rather bright and cheery. At least, that's how I see it.

I sent another item to a friend who works in the construction industry: Homebuilder Confidence in U.S. Rises to a Seven-Year High. That's always a good sign and bodes well for the overall economy.

Now, check out this PBS interview with Charles Morris, the man who predicted the crash of 2008. The article, Comeback: Why the U.S. Sits at the Brink of a New Boom, talks about an unprecedented recovery and boom, the likes of which the U.S. hasn't seen in decades. In the article, Morris makes this prediction: "It's the best-kept secret in the economics media: The United States is on the brink of a period of solid, long-term growth rivaling that of the 1950s and 1960s. It is not a finance-driven, self-destructive boom, like the 2000's housing bubble. No, the new economy will be durably grounded in energy and heavy manufacturing, even though it will take several years to come to full fruition."

"Morris makes this prediction: "It's the best-kept secret in the economics media: The United States is on the brink of a period of solid, long-term growth rivaling that of the 1950s and 1960s."

Things feel good right now and if Morris is right, we're in for a good ride. Not that I'm an expert, but in a 2009 column, I did say that the fundamentals would become strong and allow for a longer, stronger recovery. It just made sense to me that if you fixed the fundamentals, the rest would take care of itself. Keep in mind that the U.S. is still the largest, strongest economy in the world. When it rights itself, things will really start to move. I'm sure of it.

Irrational Exuberance

Not all is rosy out there, however. The global economy faces a variety of challenges from China.

Having experienced several boom and bust cycles over the years—in the U.S., in Japan in the '90s and with the recent European defaults—I've learned that when things get out of balance, the markets tend to seek equilibrium. The more out of balance things are, the more correction is needed. Another article from Fitch Ratings claims that China is on the verge of some dramatic "rebalancing."

Published in the Telegraph, the article, Fitch says China credit bubble unprecedented in modern world history, is a bit scary. Charlene Chu, Fitch Ratings' senior director in Beijing, said, "There is no way they can grow out of their asset problems as they did in the past. We think this will be very different from the banking crisis in the late 1990s. With credit at 200pc of GDP, the numerator is growing twice as fast as the denominator. You can't grow out of that." Chu does believe the Chinese government, with its deep reserves, can handle a potential banking crisis. They've already been trying to manage a soft landing. If you're vested in China, read this article.

For the sake of our economies and businesses, let's hope that the Chinese are able to stay on top of this. The last thing we need is to derail this fragile recovery and take the wind out of the coming boom.

Call me an optimist, but it really is our turn for a bit of good economic news. I think we can all use a break from the struggles of the last decade and a chance to enjoy the good years ahead.

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.

Applications of Low-Temperature Tin-bismuth and Tin-bismuth-silver Lead-free Alloy Solder Pastes

Courtesy of Koki Company Limited and Christopher Associates[1]

Abstract

The electronics industry has mainly adopted the higher melting point Sn3Ag0.5Cu solder alloys for lead-free reflow soldering applications. For applications where temperature sensitive components and boards are used this has created a need to develop low melting point lead-free alloy solder pastes. Tin-bismuth and tin-bismuth-silver containing alloys were used to address the temperature issue with development done on Sn58Bi, Sn57.6Bi0.4Ag, and Sn57Bi1Ag lead-free solder alloy pastes. Investigations included paste printing studies, reflow and wetting analysis on different substrates and board surface finishes and head-in-pillow paste performance in addition to paste-in-hole reflow tests. Voiding was also investigated on tin-bismuth and tin-bismuth-silver versus Sn3Ag0.5Cu soldered QFN/MLF/BTC components. Mechanical bond strength testing was also done comparing Sn58Bi, Sn37Pb and Sn3Ag0.5Cu soldered components. The results of the work are reported.

Introduction

Sn3Ag0.5Cu lead-free solders are widely used for lead-free reflow applications. In general they are compatible with most reflow applications. The drawback is the relatively high melting temperature of this alloy (217°C) which needs a reflow processing temperature between 235°C to 260°C. For assembly of heat-sensitive components and boards, there is a need to look at lower-temperature lead-free solder alloys as an alternative to high-temperature SnAgCu solder as well as a need for a temperature hierarchy for different soldering operations on the board. The main lead-free alloys which could be used for these lower-temperature soldering operations are tin-bismuth (Sn58Bi) and tin-bismuth-silver (Sn57-57.6Bi0.4-1Ag), with a melting temperature of 138°C and a reflow processing temperature of around 180°C. When using low

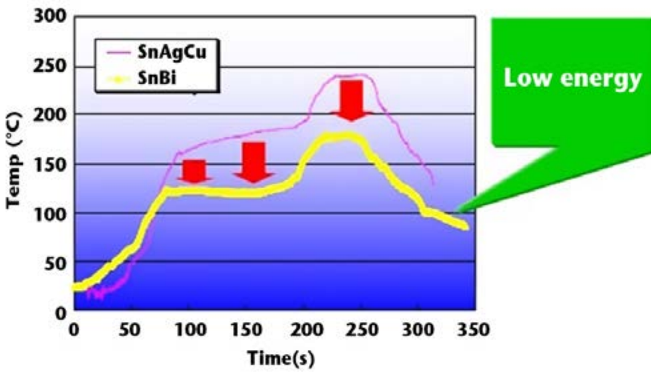

Figure 1: A comparison of a typical lead-free tin-bismuth and tin-silver-copper reflow profile.

melting temperature tin-bismuth based solder paste, there would also be lower energy usage versus Sn3Ag0.5Cu paste in the reflow oven as indicated in Figure 1.

The main drawback in bismuth usage in lead-free solder is the amount of bismuth available in the world. There is a spare capacity per year of 4,000 tons of bismuth, so for an 180,000-ton solder market a lead-free alloy with only 2wt% bismuth would be useable as shown in Table 1. For niche applications for specific low melting temperature requirements, the Sn58Bi solders could be used and are being used in production today.

In terms of the development in the use of tin-bismuth based lead-free solders, Hua et. al[1] conducted work comparing Sn58Bi and Sn-57Bi2Ag against Sn37Pb soldered joints. The thermal fatigue life of Sn57Bi2Ag was found to be greater than Sn37Pb solder whereas Sn58Bi was less than Sn37Pb solder during thermal cycling studies from -20°C to +110°C. In this study, when mixing Sn58Bi solder paste with SnPb-coated component terminations and board surface finishes the Bi30Pb18Sn ternary phase was formed at 96°C which caused a decrease in thermal cycling reliability in the soldered joints during temperature cycling from 0°C to 100°C, which would necessitate the removal of lead from component and board coatings when assembling with tin-bismuth based solders.

Based on the need from customers to use a lower melting temperature lead-free tin-bismuth based solder evaluations on Sn58Bi, Sn57.6Bi0.4Ag and Sn57Bi1Ag solder pastes were conducted, which are reported in the following sections.

Experimental

A series of evaluations were conducted in the development of tin-bismuth halide-free no-clean solder pastes. The testing included the following areas:

1. Paste printing
2. Reflow/wetting
3. Head-in-pillow
4. Pin-in-paste
5. Voiding
6. Solder paste durability
7. Solder joint bond strength
8. Solder joint cross-sectional analysis

Paste Printing

Paste printing studies were done on Sn58Bi Type 3 Paste A and Sn57.6Bi0.4Ag Type 4 Paste A on 0.4mm pitch QFP and 0.3mm pitch BGA/CSP board pads over 200 paste printing strokes on a company test vehicle board to assess printability of the solder paste. In addition, viscosity measurements were conducted on Sn58Bi Type 3

Global Solder Market per year (Approximate)	**Global Bismuth Metal Usage per year (Approximate)**
180,000 tons solder	Global bismuth usage: 6,000 tons
Solder paste: 20,000 tons	World capacity: 10,000 tons
Wave solder: 160,000 tons	Spare capacity: 4,000 tons
	Maximum percentage of bismuth for a lead-free solder alloy: 2wt% Bi

Table 1: Global solder market and bismuth metal usage and spare capacity per year.

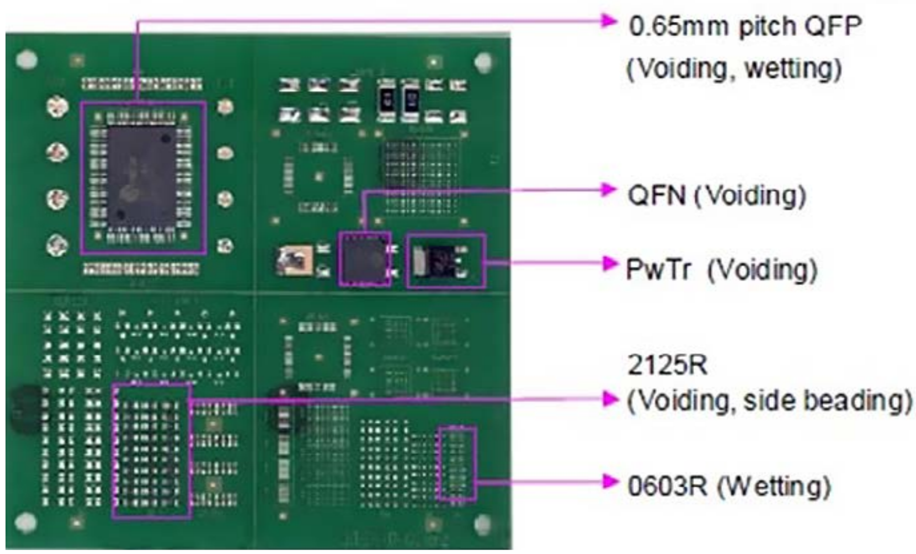

Figure 2: Solder reflow test vehicle.

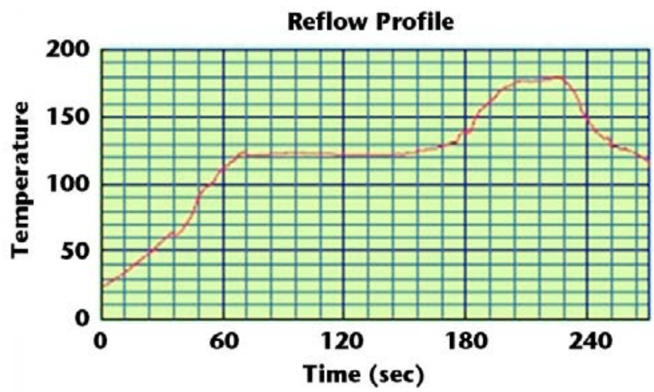

Figure 3: Sn58Bi and SnBiAg solder reflow profile.

Paste A at intervals after up to 3,000 continuous solder paste printing strokes with the squeegee blade to understand any changes in paste viscosity during the continuous printing process.

The Sn58Bi Type 3 Paste A was also assessed after 30 minutes stencil idle time followed by printing on 0.4 mm pitch QFP and 0.3mm pitch BGA/CSP board pads on the same test vehicle board.

Reflow/Wetting

Sn58Bi Type 3 Paste A was evaluated after reflow on different metal test pieces including copper, brass, alloy 42 (Fe42Ni) and nickel to assess the spreadability of the reflowed solder paste. The Sn58Bi Type 3 Paste A was then used to assess soldering to 0603 [0201] pure tin-coated chip and 0.65mm pitch pure tin-coated QFP components on reflowed company test boards as shown in Figure 2.

Sn57.4Bi0.4Ag Type 4 Paste A was also tested on assembled boards with 0603 [0201] pure tin-coated chip and 0.65mm pitch pure tin-coated QFP components on OSP, Sn and NiAu board surface finish versus Sn57.4Bi0.4Ag Type 4 Paste B. Solder balling evaluations were conducted with Sn57.6Bi0.4Ag Type 4 Paste A versus SnBi0.4Ag Type 4 Paste B on 2125 [0805] pure tin-coated chip components on OSP, Sn and NiAu board surface finishes.

Reflow was conducted in an air atmosphere in all cases with the reflow profile in Figure 3, which had a peak temperature of 180°C with a time over 138°C of 65 seconds and a soak time between 120°C to 130°C of 110 seconds.

Head in Pillow

Head-in-pillow testing was conducted with Sn57.6Bi0.4Ag Type 4 Paste A versus Sn57.6Bi0.4Ag Type 4 Paste B and $Sn_3Ag0.5Cu$ Type 4 Paste C by inserting the Sn3Ag0.5Cu solder ball sphere into the reflowed solder paste at various time intervals to determine solder paste coalescence with the solder ball sphere as shown in Figure 4. The hot plate temperature for the tin-bismuth based solder pastes were 200°C whereas that used for Sn3Ag0.5Cu paste was 275°C.

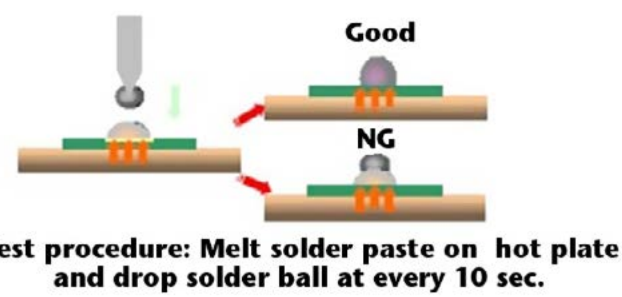

Figure 4: Head-in-pillow solder paste test procedure.

Pin-in-Paste

Pin-in-paste testing was conducted with Sn57.6Bi0.4Ag Type 3 Paste A versus Sn57.6Bi0.4Ag Type 3 Paste B printed into 0.6mm diameter through-holes on a 1.6mm thick (63mil) OSP-coated company test vehicle with 0.5mm diameter brass lead wires inserted into the through-holes after paste printing followed by reflow in air atmosphere using the reflow profile in Figure 3.

Voiding Studies

Voiding studies were conducted on 6432 [2512] pure tin-coated chip component, Sn3Ag0.5Cu 1mm pitch BGA and pure tin-coated power transistor components using Sn58Bi Type 3 Paste A versus Sn3Ag0.5Cu Type 3 Paste C on the OSP-coated company test vehicle in air atmosphere. The reflow profile used for the Sn58Bi paste was as shown in Figure 3. The reflow profile used for Sn3Ag0.5Cu paste was as shown in Figure 1.

This was followed by voiding evaluations on Sn57.6Bi0.4Ag Type 4 Paste A versus Sn57.6Bi0.4Ag Type 4 Paste B using the pure tin-coated power transistor component on OSP, Sn and NiAu board surface finishes on the company test vehicle in air atmosphere.

A follow-on study was then conducted to evaluate the affect of silver in the lead-free solder on voiding with the pure tin-coated power transistor component using Sn58Bi Type 3 Paste A versus Sn57.6Bi0.4Ag Type 4 Paste A versus Sn57Bi1Ag Type 4 Paste A. Reflow was conducted in an air atmosphere.

Solder Paste Product Durability

Once initial studies were conducted on paste printing, reflow, head-in-pillow, pin-in-paste and voiding, evaluations were conducted on Sn57.6Bi0.4Ag Type 3 Paste A over a period of five days of continuous use to determine if there were any variations in viscosity and thixotropic index of the paste. Print quality on 0.3mm pitch BGA/CSP and 0.4mm pitch QFP components was assessed along with reflow behavior on 0603[0201] pure tin-coated chip components and large 6330 [2512] chip board pads on the OSP-coated company test vehicle.

In addition Sn57.6Bi0.4Ag Type 3 Paste A was assessed for voiding behavior on the pure tin-coated power transistor components during the continuous print and reflow studies over the five days in air atmosphere with the reflow profile used in Figure 3.

Bond Strength Data

Once print and reflow assessments were completed, solder joint bond strength was assessed for various soldered chip and lead-frame components. The chip testing equipment used is shown in Figure 5 and the QFP pull testing methodology used is shown in Figure 6.

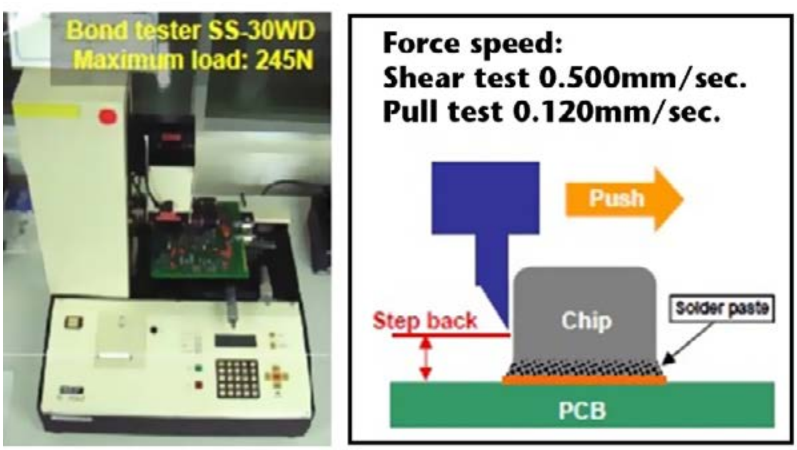

Figure 5: Chip testing equipment.

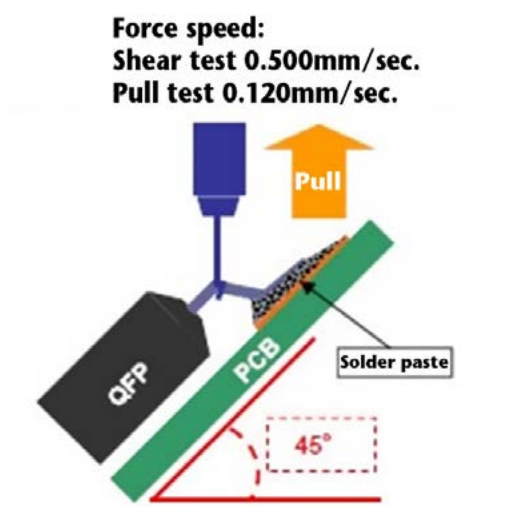

Figure 6: QFP pull testing methodology.

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Initial pull tests were done using 0.65mm pitch pure tin-coated QFP components and initial shear testing was accomplished using pure tin and NiAu-coated 3216 [1206] coated chips, pure tin 2012 [0805] and pure tin 1608 [0603]-coated chips reflowed with Sn58Bi Paste A, Sn3Ag0.5Cu Paste C and Sn37Pb Paste D.

Follow on studies looked at pull testing of 0.65mm pitch pure tin-coated QFP and shear testing of pure tin-coated 3216 [1206] chip and 2012 [0805] chip components with Sn58Bi Paste A, Sn57.6Bi0.4Ag Paste A and Sn57Bi1Ag Paste A to understand the affect of silver content in the lead-free SnBi based solders on mechanical pull and shear test solder joint results.

Cross-Sectional Analysis

Cross-sectional analysis was done on 3216 [1206] pure tin-coated chip components reflow soldered with Sn58Bi Paste A, Sn57.6Bi0.4Ag Paste A and Sn57Bi1Ag Paste A.

Results and Discussion

Paste Printing

Continual printing tests for Sn58Bi Type 3 Paste A and Sn57.6Bi0.4Ag Type 4 Paste A on 0.4mm pitch QFP and 0.3mm pitch BGA/CSP pads after over 200 print strokes showed good results in terms of solder paste deposition on the board pads as indicated in Figures 7, 8 and 9.

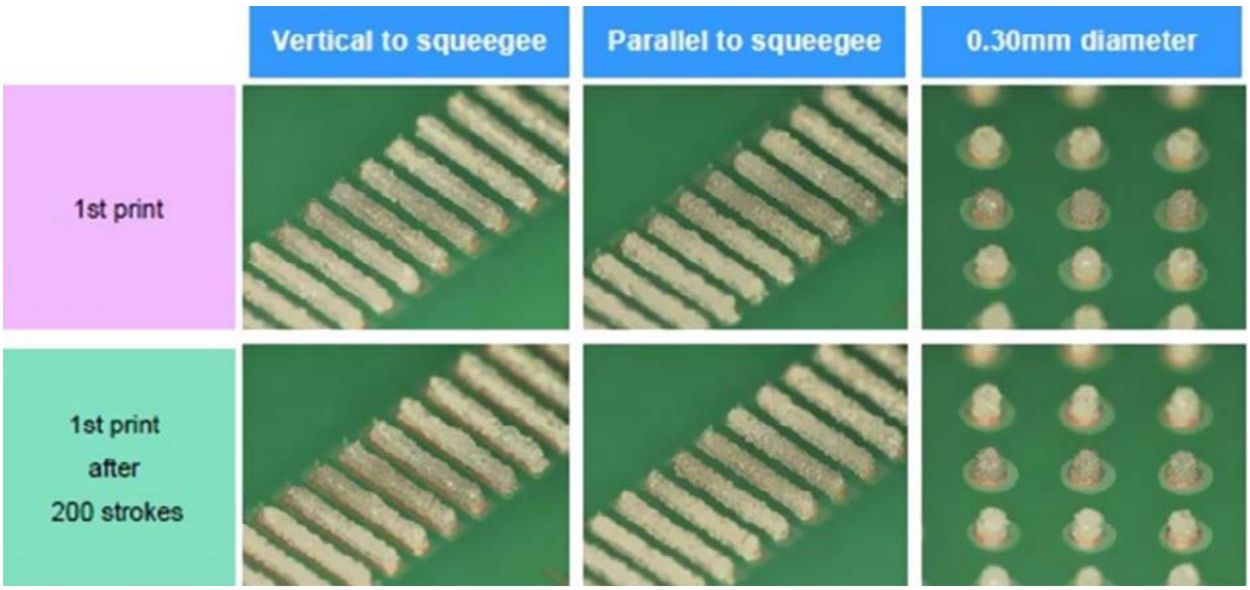

Figure 7: Continual paste printing results with Sn58Bi Type 3 Paste A on 0.4mm pitch QFP and 0.3mm pitch BGA/CSP board pads.

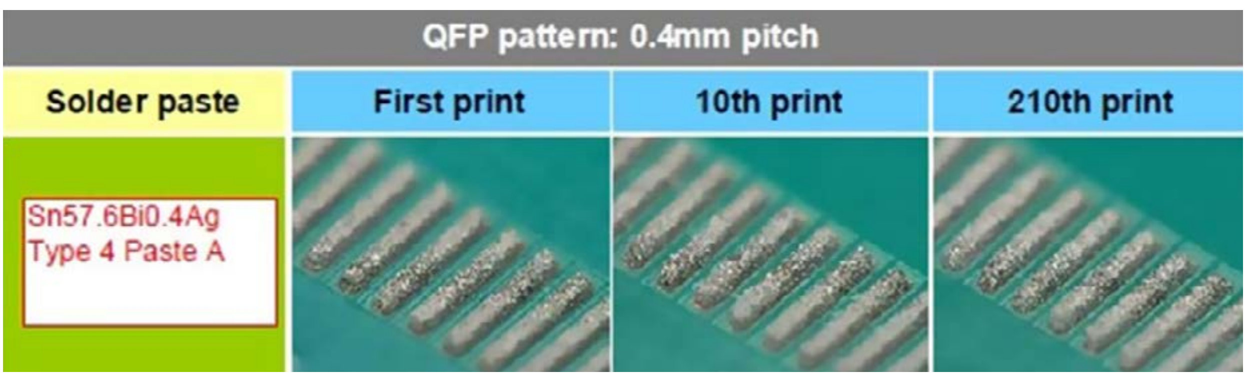

Figure 8: Continual paste printing results with Sn57.6Bi0.4Ag Type 4 Paste A on 0.4mm pitch QFP and 0.3mm pitch BGA/CSP board pads.

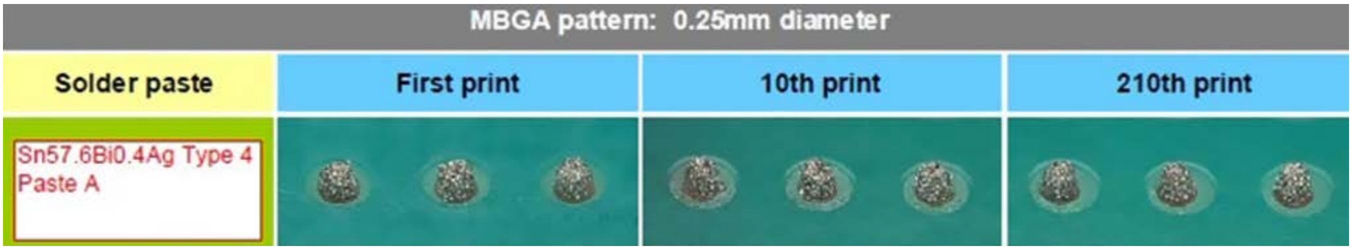

Figure 9: Continual paste printing results with Sn57.6Bi0.4Ag Type 4 Paste A on 0.3mm pitch BGA/CSP board pads.

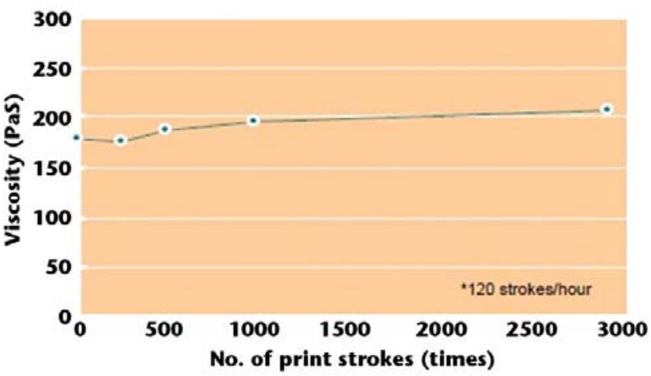

Figure 10: Viscosity variation during continuous printing of Sn58Bi Type 3 Paste A.

The viscosity variation of the Sn58Bi Type 3 Paste A was found to be minimal over 3,000 paste print strokes tested as shown in Figure 10.

Evaluation of paste printed deposits after a stencil idle time of 30 minutes showed good results for Sn58Bi Type 3 Paste A in terms of paste deposits on the 0.4mm pitch QFP and 0.3mm pitch BGA/CSP board pads as shown in Figure 11.

Reflow/ Wetting

Sn58Bi Type 3 Paste A was evaluated after reflow for spreading on different material test pieces including copper, brass, alloy 42 and nickel as shown in Figure 12. The spreading on the copper and brass substrate was over the area that the solder paste was printed after reflow which was a good result. There was partial spreading on the alloy 42 and nickel substrates after reflow which was to be expected for these hard to solder surfaces. Reflow was done in an air atmosphere with the reflow profile used in Figure 3.

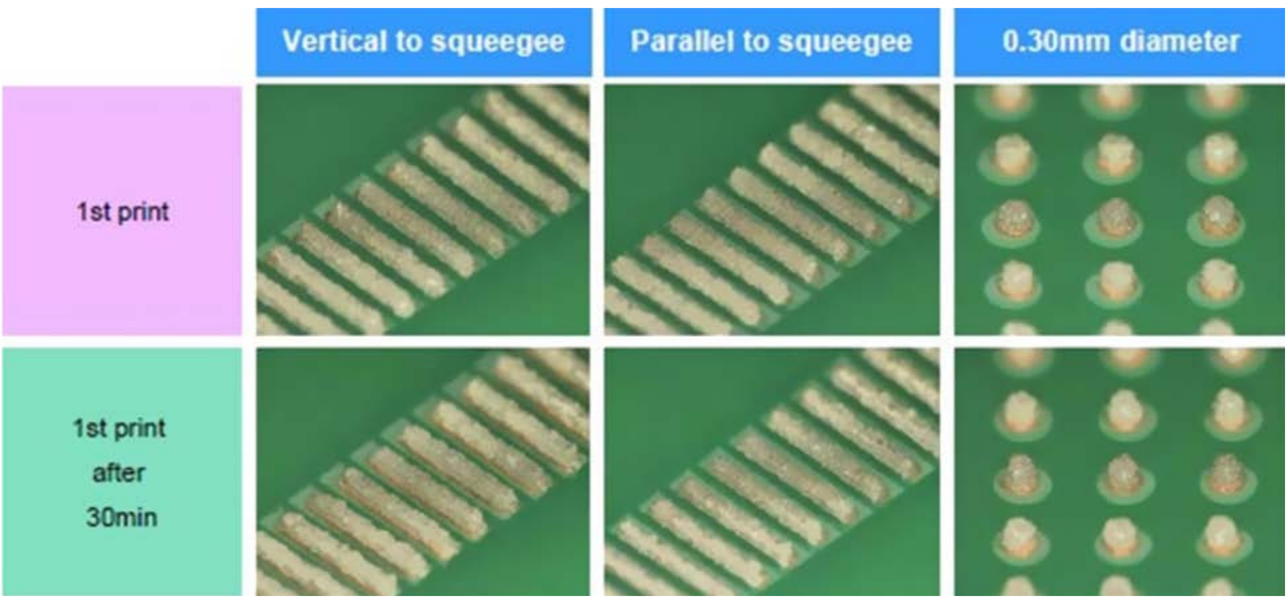

Figure 11: Printing after 30 minutes stencil idle time with Sn58Bi Type 3 Paste A on 0.4mm pitch QFP and 0.3mm BGA/CSP board pads.

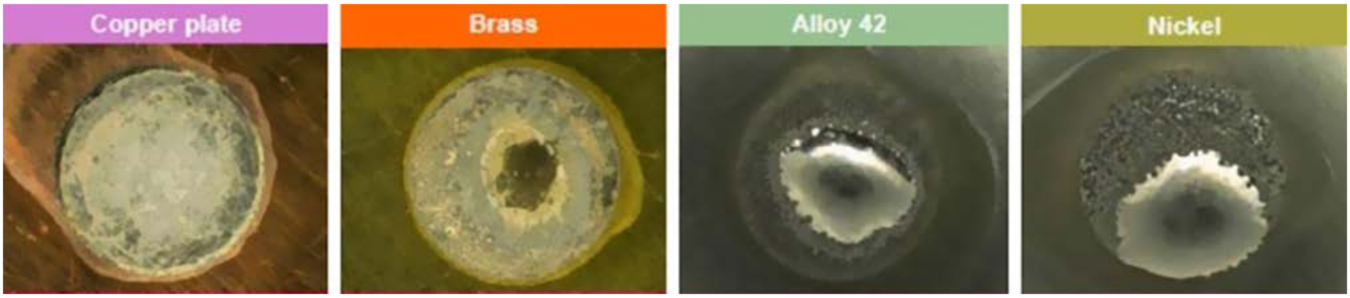

Figure 12: Sn58Bi Type Paste A reflow spreading on copper, brass, alloy 42 and nickel material test pieces.

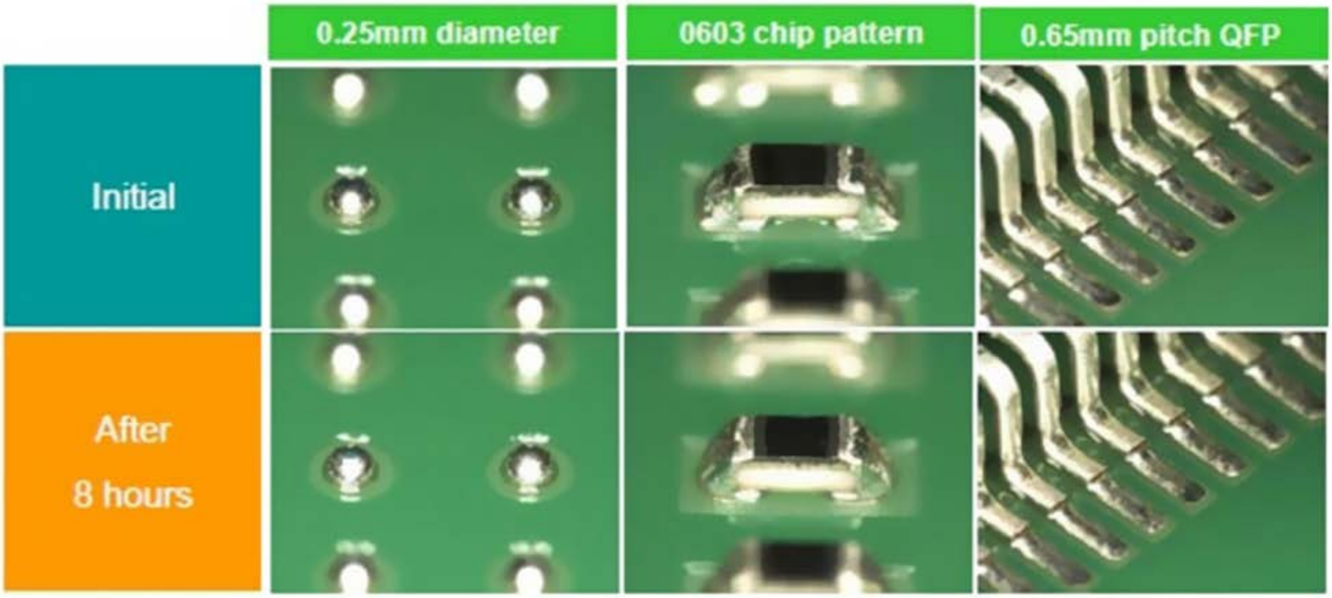

Figure 13: Sn58Bi Paste A wetting on 0603 [0201] chip and 0.65mm pitch QFP components at time zero and after eight hours of rolling the solder paste on the stencil before printing on the test board followed by reflow.

Sn58Bi Type 3 Paste A was then assembled on test boards with 0603 [0201] chip and 0.65mm pitch QFP components with good wetting to the components at time zero and after eight hours of rolling the solder paste on the stencil before printing the paste on the test board followed by reflow as shown in Figure 13.

Sn57.6Bi0.4Ag Type 4 Paste A was used to reflow 0603 [0201] chips and 0.65mm pitch QFP components on OSP, Sn and NiAu board surface finish test boards in comparison with Sn57.6Bi0.4Ag Type 4 Paste B. The results from Figures 14 and 15 show good wetting with each paste used for the chip components and reasonable wetting on the QFP components with each paste.

Solder balling evaluations were conducted with Sn57.6Bi0.4Ag Type 4 Paste A versus Sn57.6Bi0.4Ag Type 4 Paste B on 2125 [0805] pure tin-coated chip components on OSP, Sn and NiAu board surface finishes with a reduced amount of solder balling with Sn57.6Bi0.4Ag Paste A versus Sn57.6Bi0.4Ag Paste B after reflow as shown in Figure 16.

Head-in-Pillow

Head-in-pillow testing was conducted with Sn57.6Bi0.4Ag Paste A versus Sn57.6Bi0.4Ag Paste B and Sn3Ag0.5Cu Paste C with Sn3Ag0.5Cu ball spheres. The two lead-free Sn57.6Bi0.4Ag pastes had complete merger of the solder sphere after up to 180 seconds ver-

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- A student soldering manual with step-by-step instructions
- Workmanship PCB with components for practical exam

Course Objective:
Upon successfully completing this learning activity, attendee will have received:

- Common Safety Rules for Hand Soldering
- ESD and PCB Handling
- Soldering iron and solder tip maintenance guidelines
- Methods for choosing the correct Tip-Temperature and Size
- HMP Solder and Flux chemistry and why they are used
- Create acceptable solder joints using HMP solder
- Cleaning the PCB
- Inspect work for conformance to the standards
- Rework Techniques

Upon satisfactory completion of the written and practical exam, participants will receive Blackfox certification valid for 24 months.

Prerequisite: Previous Soldering Skills
Class Length: 2 days

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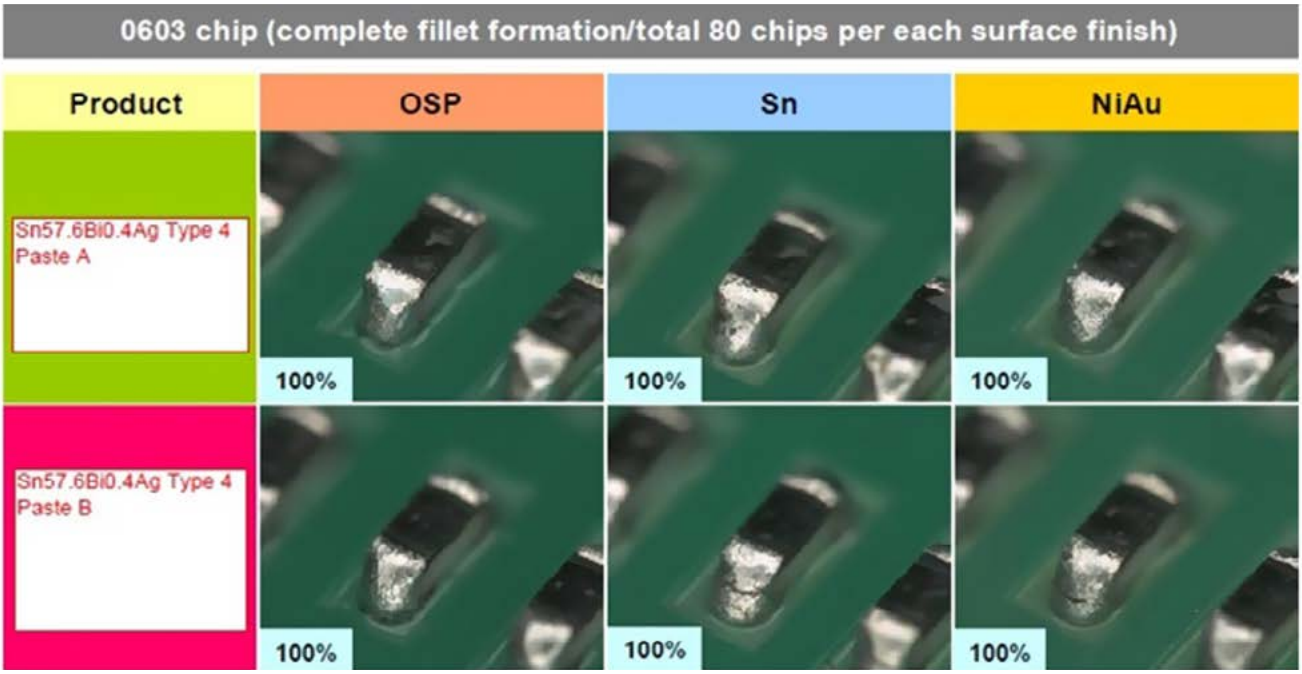

Figure 14: Sn57.6Bi0.4Ag Paste A versus Paste B wetting on 0603 [0201] chip components.

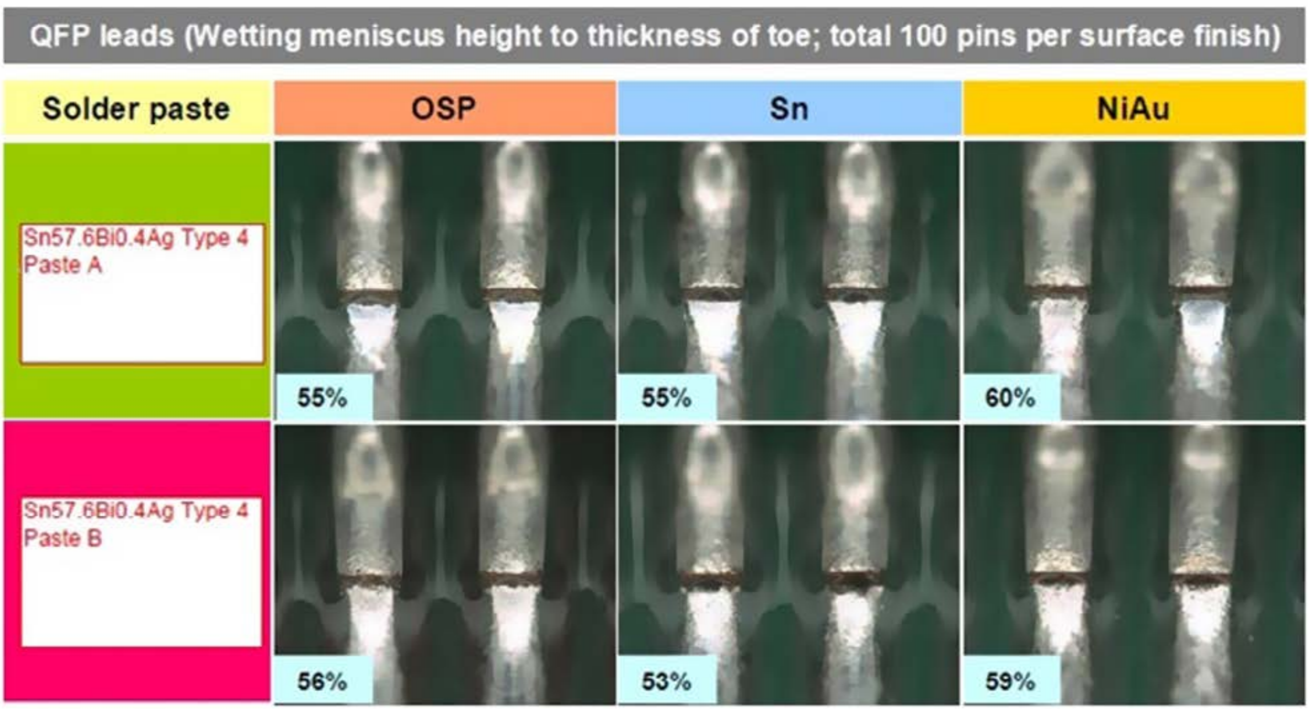

Figure 15: Sn57.6Bi0.4Ag paste wetting versus Paste B wetting on 0.65mm pitch QFP components.

sus 60 seconds with the Sn3Ag0.5Cu paste as shown in Figure 17. The lower hot plate temperature used for the tin-bismuth based pastes compared with the Sn3Ag0.5Cu solder paste meant that the flux was not used up as much with the tin-bismuth based solder pastes with an improvement in head-in-pillow test performance.

Figure 16: Sn57.6Bi0.4Ag Paste A versus Paste B solder balling on 2125 [0805] soldered pure tin-coated chip components.

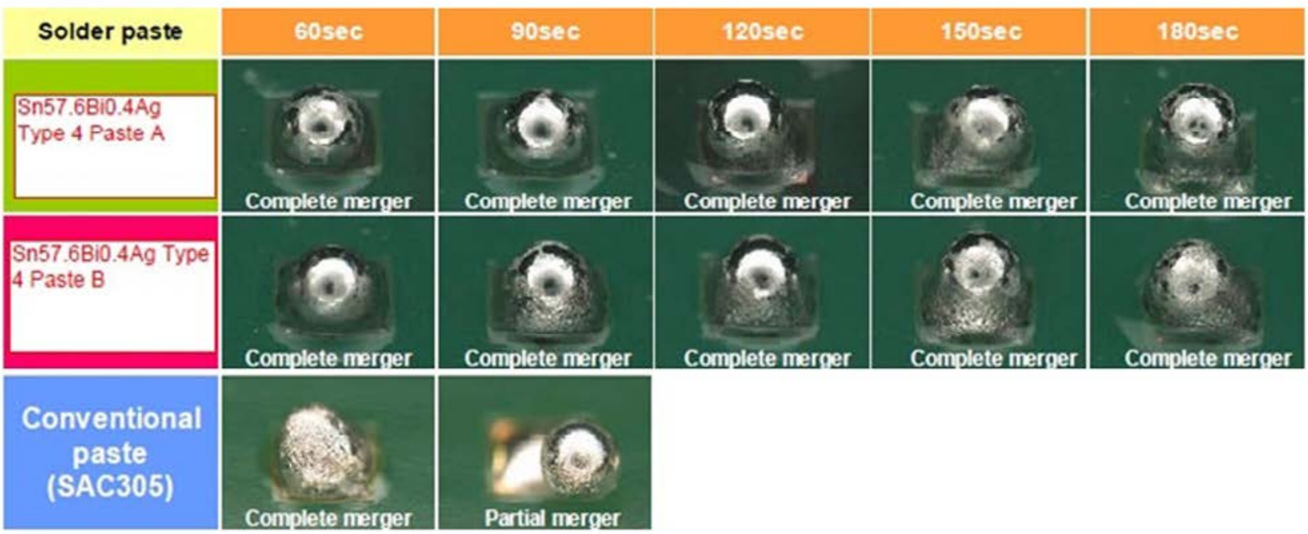

Figure 17: SnBi0.4Ag Type 4 Paste A versus SnBi0.4Ag Type 4 Paste B versus Sn3Ag0.5Cu Paste C head-in-pillow testing.

Pin-in-Paste

Pin-in-Paste testing was conducted with Sn57.6Bi0.4Ag Type 3 Paste A versus Sn57.6Bi0.4Ag Type 3 Paste B. The SnBi0.4Ag Paste A results showed better wetting after reflow versus SnBi0.4Ag Paste B as indicated in Figure 18.

Voiding Studies

Voiding studies were conducted on 6432 [2512] pure tin-coated chip, Sn3Ag0.5Cu 1mm pitch BGA and pure tin-coated power transistor components using Sn58Bi Type 3 Paste A versus SnAgCu Type 3 Paste C which generally showed a lower voiding amount with Sn58Bi

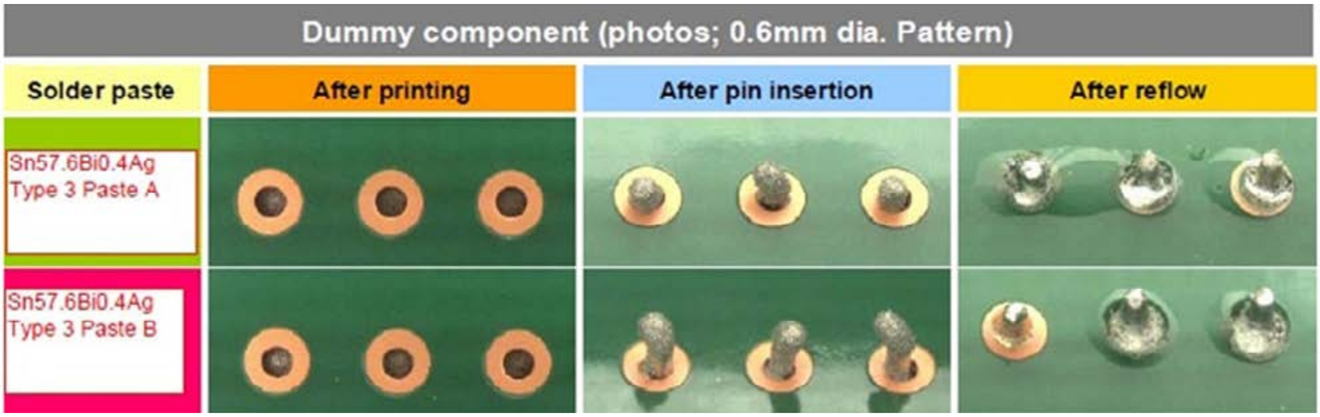

Figure 18: SnBi0.4Ag Paste A versus Paste B pin-in-paste reflow testing.

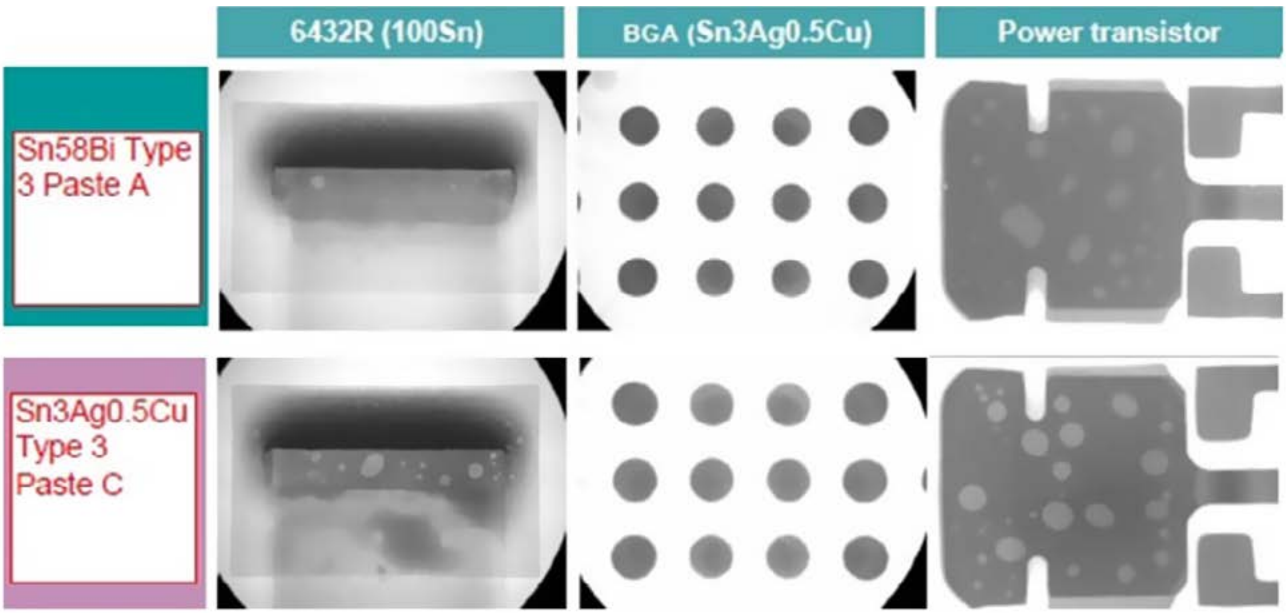

Figure 19: Sn58Bi Paste A versus Sn3Ag0.5Cu Paste C voiding on soldered 6432 [2512] chip, BGA and power transistor components.

Paste A as shown in Figure 19. The surface tension of the Sn58Bi solder paste would be lower than Sn3Ag0.5Cu solder paste during reflow, so it would be easier for the voids to escape with the Sn58Bi solder paste during reflow.

This test was followed by voiding evaluations on Sn57.6Bi0.4Ag Type 4 Paste A versus Sn57.6Bi0.4Ag Type 4 Paste B using the pure tin-coated power transistor component on OSP, Sn and NiAu board surface finishes. Sn57.6Bi0.4Ag Type 4 Paste A showed minimal voiding on all three board surface finishes compared with Sn57.6Bi0.4Ag Type 4 Paste B as shown in Figure 20.

A follow-on study was then conducted to evaluate the affect of silver additions to the tin-bismuth solder on voiding with the power transistor component using Sn58Bi Type 3 Paste A versus Sn57.6Bi0.4Ag Type 4 Paste A versus Sn-57Bi1Ag Type 4 Paste A. There was generally no real difference between the three solder pastes evaluated as shown in Figure 21, which indicated that the voiding was more dependent on the flux type in the paste rather than the silver content in the solder paste.

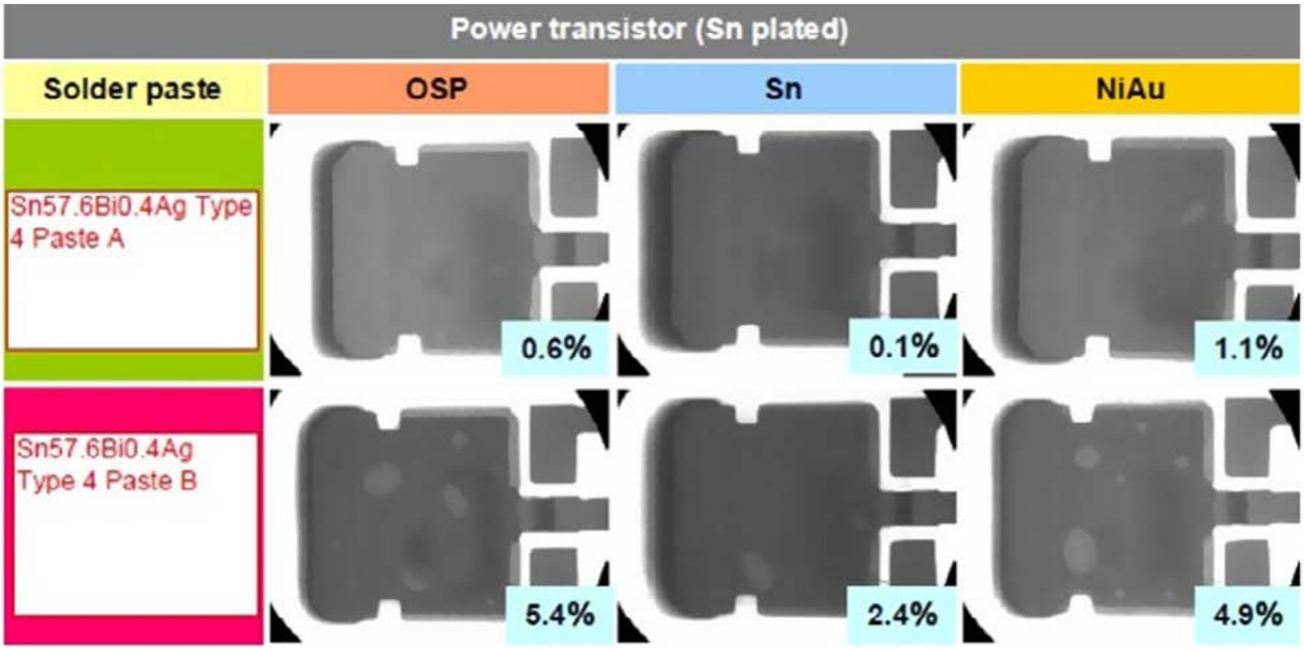

Figure 20: Sn57.6Bi0.4Ag Paste A versus Sn57.6Bi0.4Ag Paste B voiding on soldered power transistor components on OSP, Sn and NiAu board surface finishes.

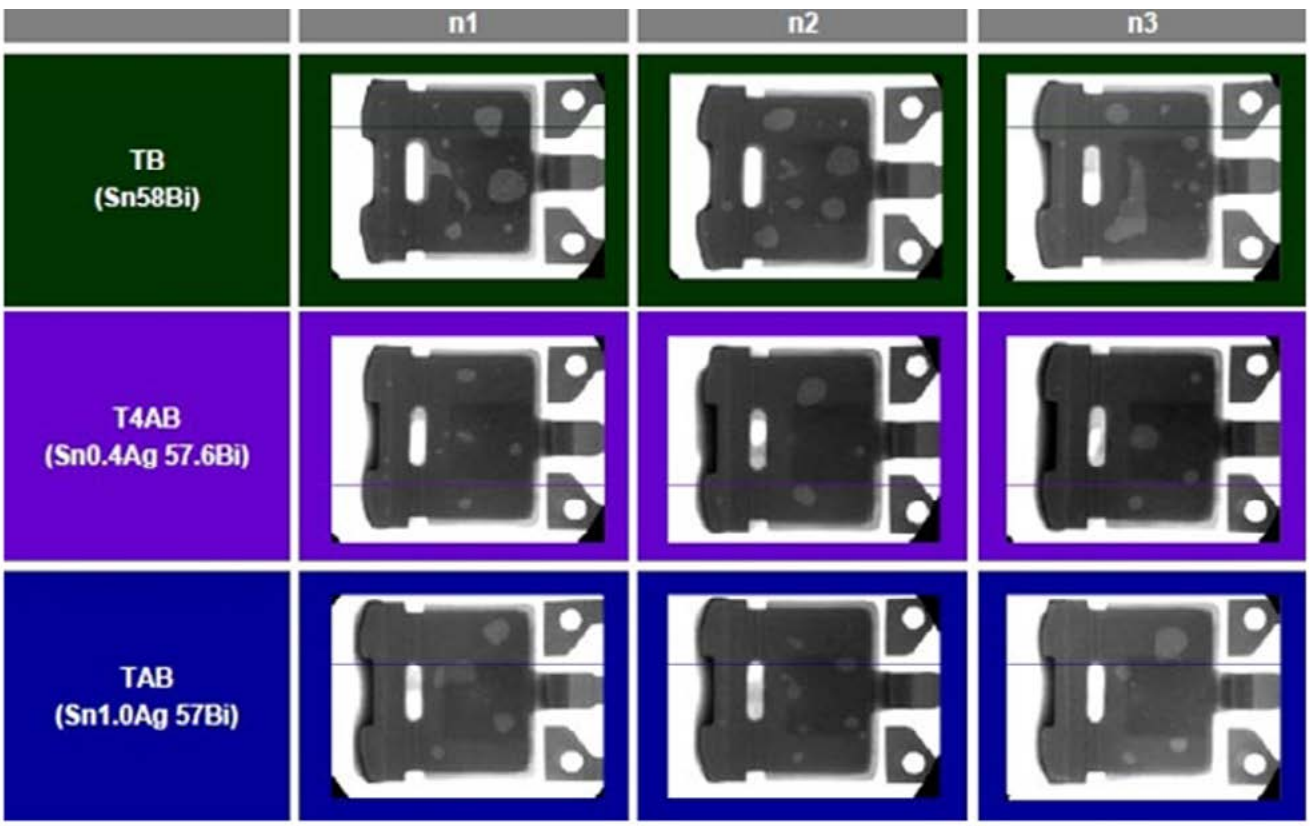

Figure 21: Sn58Bi Paste A versus SnBi0.4Ag Paste A versus SnBi1Ag Paste A voiding with the soldered power transistor component.

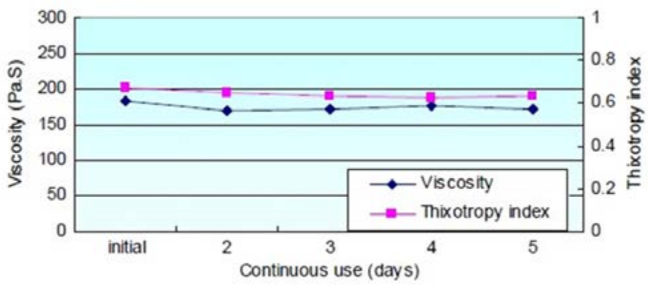

Figure 22: Sn57.6Bi0.4Ag Type 3 Paste A viscosity and thixotrophy index evaluation over five days continuous printing.

Solder Paste Product Durability

Evaluations were conducted on Sn57.6Bi0.4Ag Type 3 Paste A over a period of five days continuous use to understand if there were any variations in viscosity or thixotropic index of the paste. Based on the results shown in Figure 22, there was minimal variation in viscosity or thixotropic index of the paste over the five-day period.

Over the five-day printing study, solder paste print quality on the 0.3mm pitch BGA/CSP and 0.4mm pitch QFP components was assessed and found to be good along with reflow behavior on reflowed soldered 0603 [0201] chip components and large 6330 [2512] board pads as indicated in Figure 23.

There was low Sn57.6Bi0.4Ag Paste A voiding behavior on reflow soldered power transistor components during the continuous print and reflow studies over the five days as indicated in Figure 24.

Bond Strength Data

Initial solder joint bond strength tests were done using 0.65mm pitch QFP, 3216[1206] chip, 2012[0805] chip and 1608[0603] chip components reflowed with Sn58Bi Paste A, Sn3Ag0.5Cu Paste C and Sn37Pb Paste D as shown in Figure 25. The results indicate that the bond strength with Sn58Bi Paste A soldered components was equivalent to or bet-

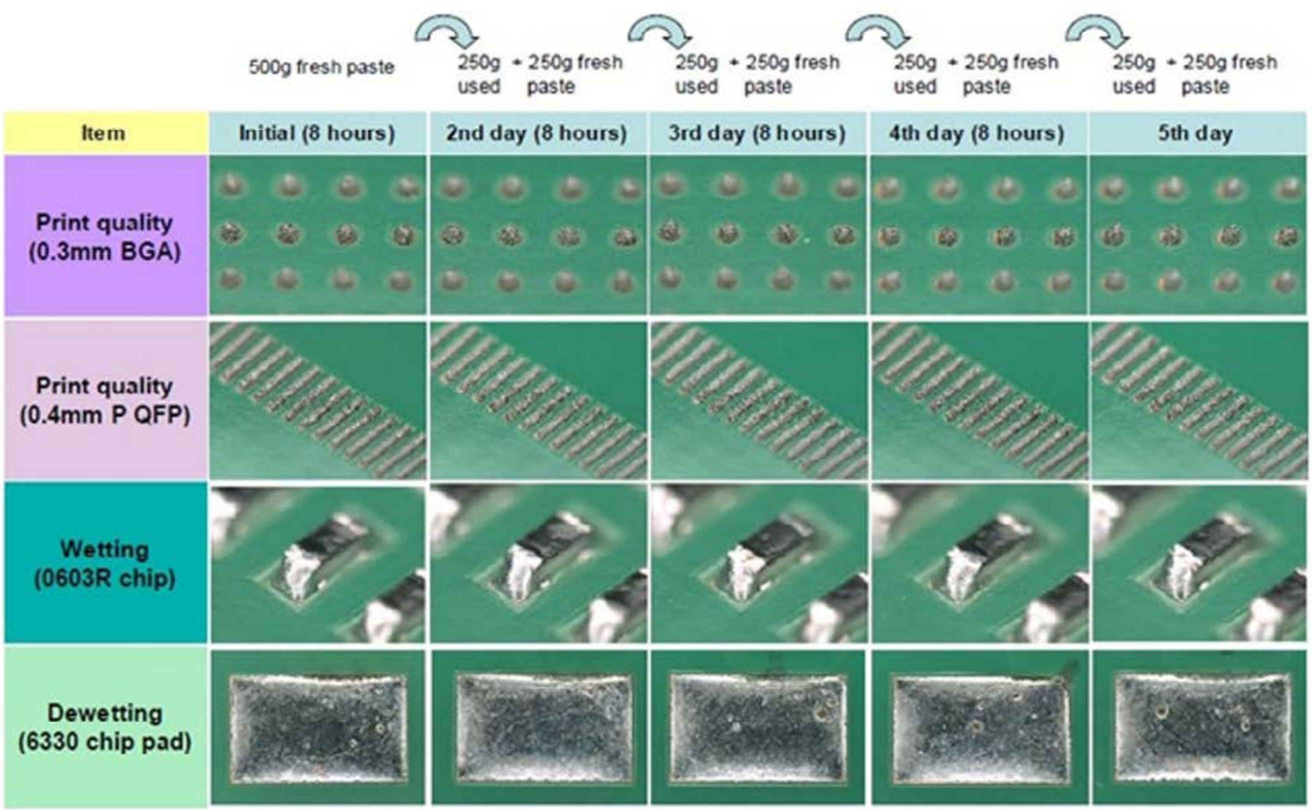

Figure 23: Sn57.6Bi0.4Ag Type 3 Paste A printing and reflow/wetting evaluations over five days of testing.

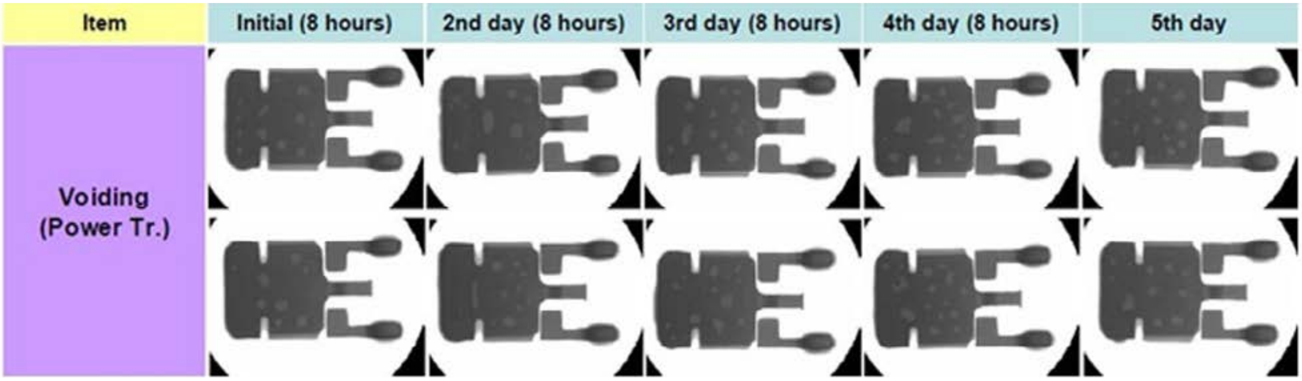

Figure 24: Sn57.6Bi0.4Ag Type 3 Paste A voiding study on soldered power transistor components over five days of testing.

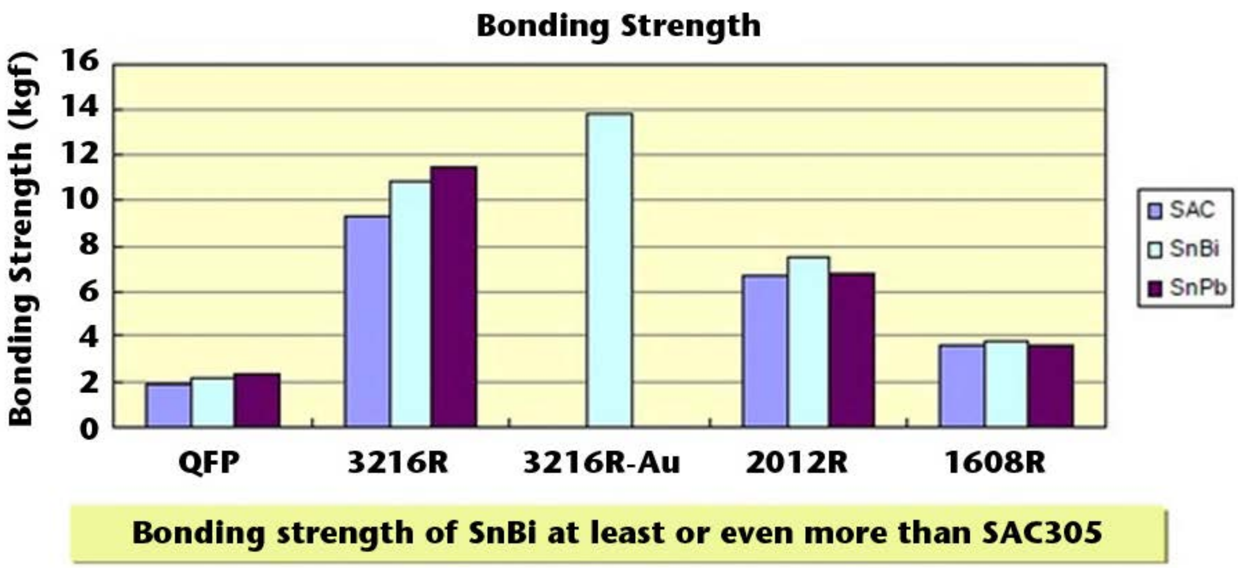

Figure 25: Sn58Bi versus Sn3Ag0.5Cu versus Sn37Pb bond strength results on soldered 0.65mm pitch QFP, 3216[1206] chip, 2012[0805] chip and 1608[0603] chip components.

ter than Sn3Ag0.5Cu or Sn37Pb paste soldered components.

Additional studies looked at the effect of silver additions to tin-bismuth solder on the bond strength results. Pull testing results of 0.65mm pitch pure tin-coated QFP components and shear testing results of 3216[1206] chip and 2012[0805] chip components reflow soldered with Sn58Bi Paste A, Sn57.6Bi0.4Ag Paste A and Sn57Bi1Ag Paste A are shown in Tables 2 and 3. The results indicate minimal differences in pull and shear test data between the Sn58Bi, Sn57.6Bi0.4Ag and Sn57Bi1Ag paste soldered components.

Cross-Sectional Analysis

Cross-sectional analysis was done on 3216 [1206] pure tin-coated chip components soldered with Sn58Bi Paste A, Sn57.6Bi0.4Ag Paste A and Sn57Bi1Ag Paste A. The results indicate good soldering to the chip components and the board for all three solder alloy pastes as shown in Figure 26.

The microstructures shown in Figures 27, 28 and 29 indicate tin and bismuth phases in the


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Unit: Newtons	Sn58Bi	Sn58Bi	Sn57.6Bi0.4Ag	Sn57.6Bi0.4Ag	Sn57Bi1Ag	Sn57Bi1Ag
Component Number	3216 chip	2012 chip	3216 chip	2012 chip	3216 chip	2012 chip
1		67.5		41.3		41.1
2	109.8	45.7	81.6	59.8	95.2	66.0
3	91	76.1	101.0	69.6	92.2	41.6
4	100.1	59.1	83.5	66.2	94.5	58.1
5	104.2	51.6	83.5	56.9	95.6	61.7
Average	101.3	60.0	87.4	58.8	94.4	53.7
Stdev.	7.9	12.2	9.1	11.0	1.5	11.6
Min.	91.0	45.7	81.6	41.3	92.2	41.1
Max.	109.8	76.1	101.0	69.6	95.6	66.0

Table 2: Sn58Bi versus Sn57.6Bi0.4Ag versus Sn57Bi1Ag shear test results on soldered 3216[1206] chip and 2012[0805] chip components from five component tests.

microstructure with some evidence of Cu6Sn5 IMC in the bulk microstructure with good soldering to the board and component interfaces.

Conclusions

Based on the tests conducted during the evaluation the following was determined:

- Sn58Bi, Sn57.6Bi0.4Ag and Sn-57Bi1Ag solder pastes show good printing and reflow performance over the variety of components tested
- The tin-bismuth solder pastes were found to have good head-in-pillow performance and were acceptable for pin-in-paste soldering
- Voiding studies on power transistor components showed low voiding with the developed tin-bismuth pastes with minimal effect on voiding from silver additions to the tin-bismuth pastes
- Paste durability studies showed good results over the five-day print and reflow testing for the developed tin-bismuth paste
- Pull and shear testing data for tin-bismuth soldered components were

Unit: Newtons	Sn58Bi	Sn57.6Bi0.4Ag	Sn57Bi1Ag
Component Number			
1	20.3	18.9	19.9
2	19.6	19.6	19.7
3	19.7	17.2	17.4
4	18.5	20.0	19.6
5	20.7	19.7	20.8
6	21.2	20.6	21.1
7	20.1	19.0	22.1
8	21.8	21.2	21.8
9	19.2	21.6	21.2
10	24.0	22.4	22.6
Average	20.5	20.0	20.6
Stdev.	1.6	1.5	1.5
Min.	18.5	17.2	17.4
Max.	24.0	22.4	22.6

Table 3: Sn58Bi versus Sn57.6Bi0.4Ag versus Sn57Bi1Ag pull testing results on soldered 0.65mm pitch QFP components from 10 component tests.

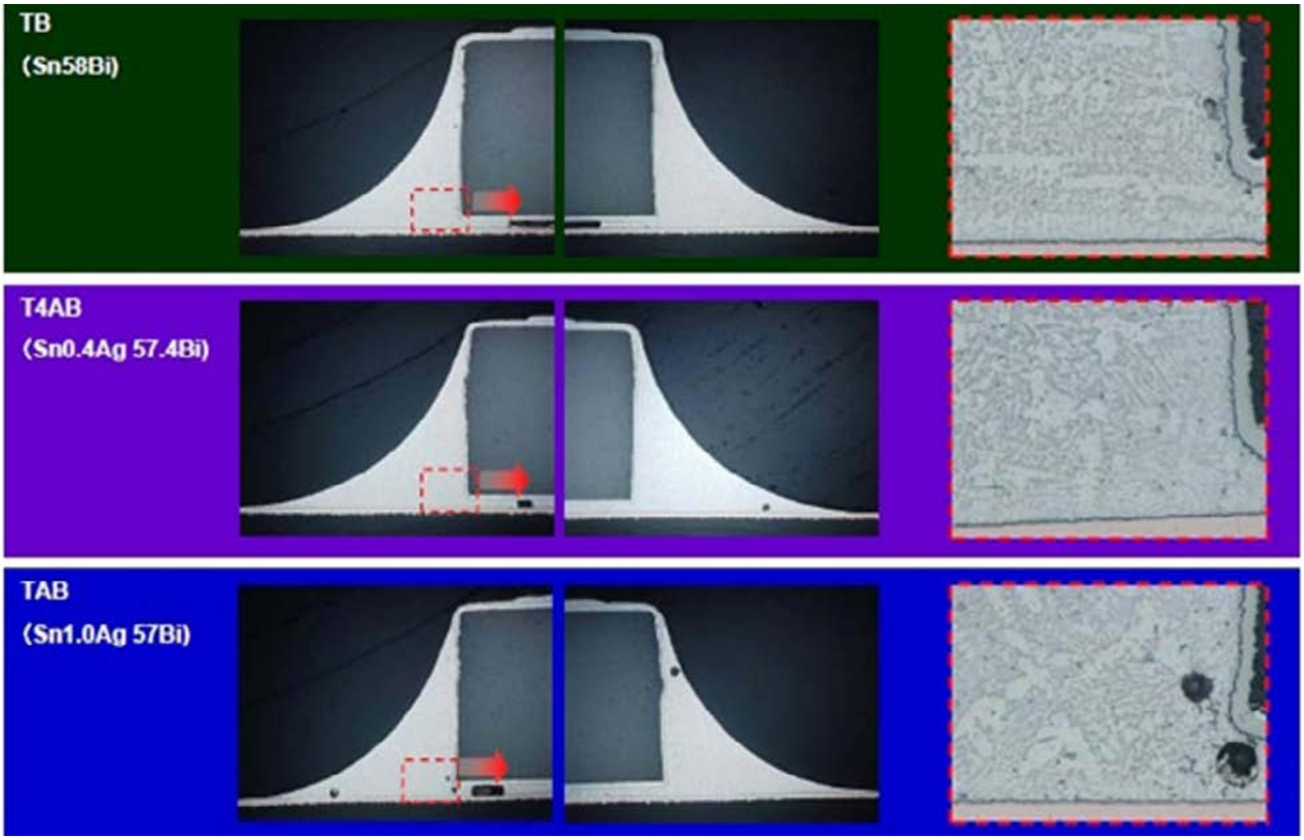


Figure 26: Sn58Bi, Sn57.6Bi0.4Ag and Sn57Bi1Ag soldered 3216 [1206] chip component cross-sections.

equivalent or better than Sn3Ag0.5Cu and Sn-37Pb soldered components

- There were minimal differences in pull and shear testing of Sn58Bi, Sn57.6Bi0.4Ag and Sn57Bi1Ag soldered components
- Cross-sectional analysis of Sn58Bi, Sn57.6Bi0.4Ag and Sn57Bi1Ag soldered components showed good bonding to the board and component interfaces

Future Work

More developments would be accomplished with tin-bismuth based lead-free solder pastes to improve print and reflow performance as well as further work to assess solder joint reliability.

Acknowledgements

The authors would like to thank the research and development engineers at Koki in Japan who conducted the tin-bismuth solder paste development and analysis tests reported in this paper. **SMT**

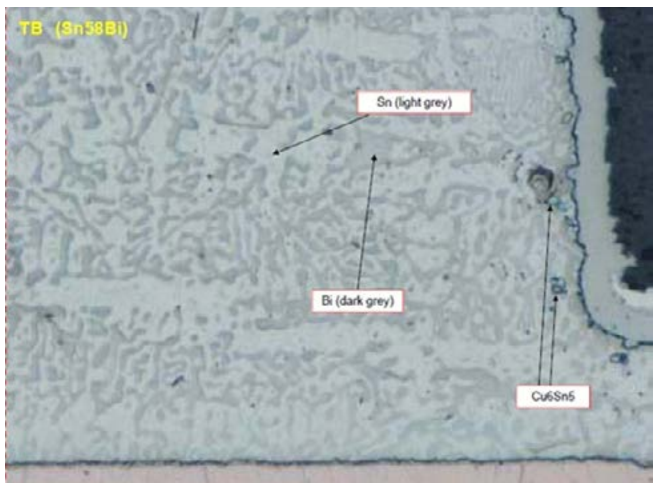


Figure 27: Sn58Bi soldered 3216 [1206] chip component cross-section.

References

1. Jasbir Bath, Manabu Itoh, Gordon Clark, Hajime Takahashi, Kyosuke Yokota, Kentaro

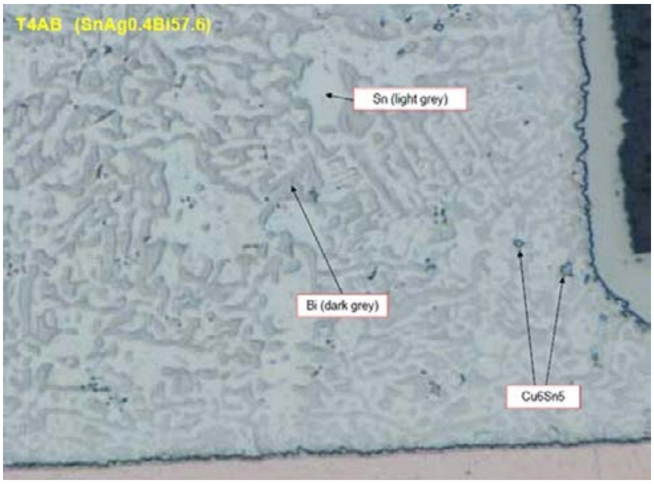


Figure 28: Sn57.6Bi0.4Ag soldered 3216[1206] chip component cross-section.

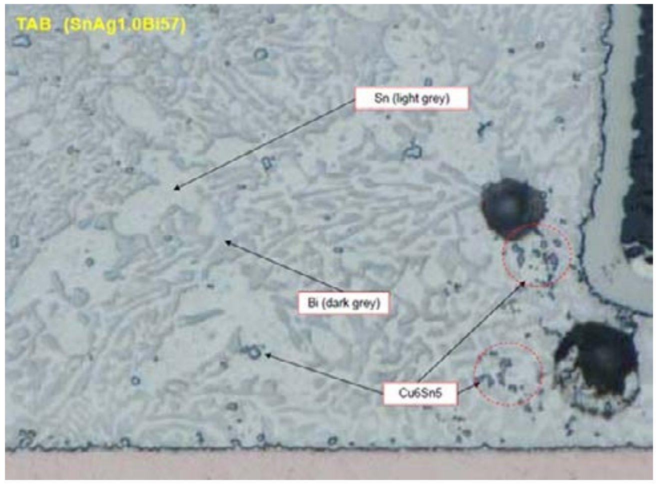
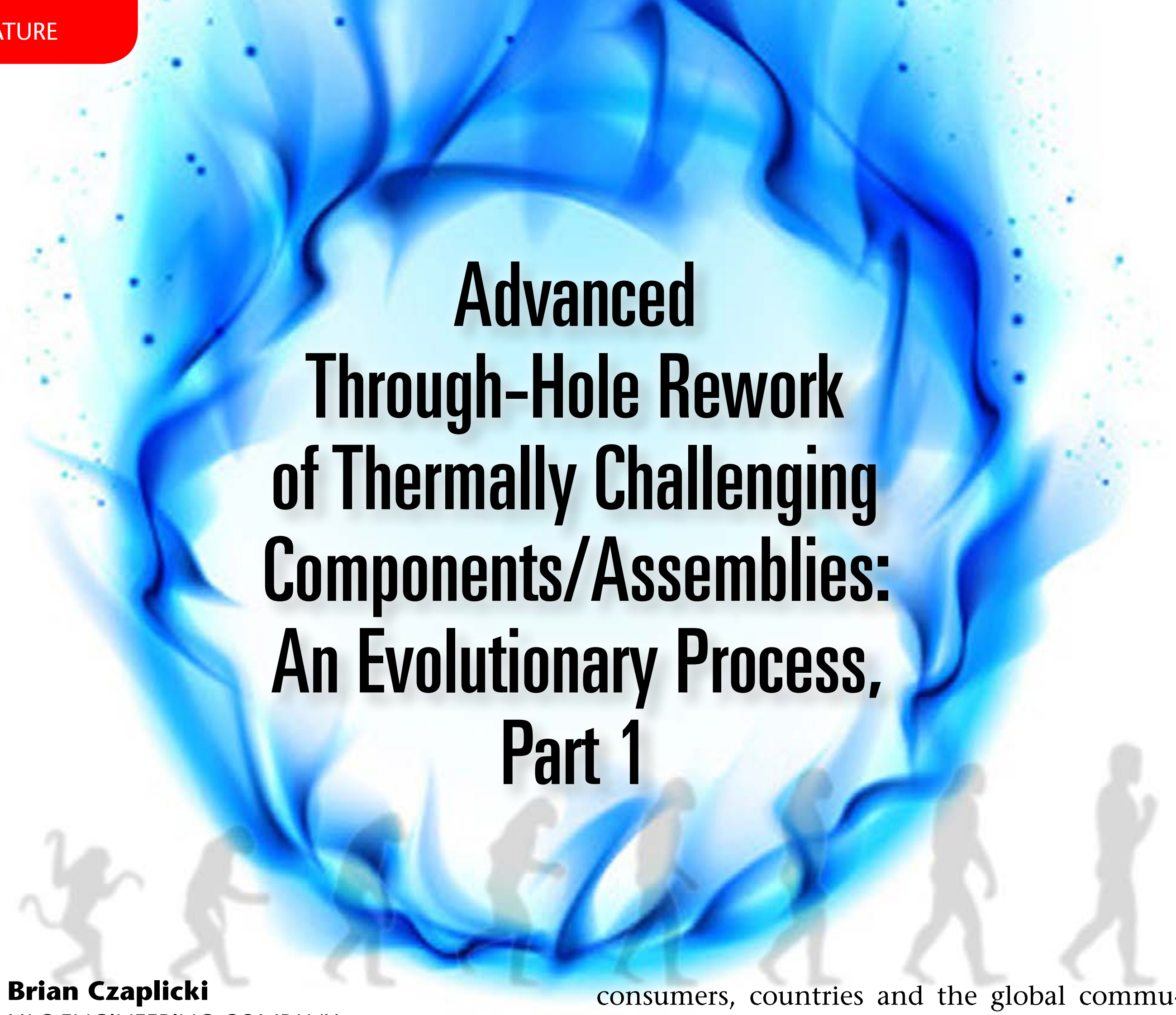


Figure 29: Sn57Bi1Ag soldered 3216[1206] chip component cross-section.

Asai, Atsushi Irisawa, and Kimiaki Mori of Koki Company Limited; and David Rund and Roberto Garcia of Christopher Associates.

2. F. Hua, Z. Mei, J. Glazer and A. Lavagnino, "Eutectic Sn-Bi as an Alternative Pb-Free Solder," IPC Works Conference, 1999.



Advanced Through-Hole Rework of Thermally Challenging Components/Assemblies: An Evolutionary Process, Part 1

by Brian Czaplicki
AIR-VAC ENGINEERING COMPANY

SUMMARY: The conversion of high-end server and network applications to lead-free is being hastened by government regulations and the limited availability of tin-lead components. The successful transition of low-end and mid-range server applications to lead-free has come largely through wave solder process optimization and the use of alternate lead-free alloys for mini-pot rework.

Abstract

Although the vast majority of electronic equipment has made the transition to lead-free without significant issue, some market segments still utilize tin-lead solder. The European Union's RoHS legislation currently exempts server, storage array systems and network infrastructure equipment from the requirement to use lead-free solder (Exemption 7b). The reliability of network infrastructure equipment in finance, health care and national security applications is critical to the health and safety of consumers, countries and the global community and the long-term reliability of these end products using lead-free solder is not completely understood[1].

Figure 1 shows the projected phase out of servers, storage array systems and network infrastructure equipment for switching, signaling and transmission as well as network management for telecommunications over the next few years in the European Union.

In addition to government regulations, the conversion of high-end server and network applications to lead-free is also being hastened by the limited availability of tin-lead components. Although the exact conversion date is unclear, the requirement to ultimately convert these complex products to lead-free is absolutely clear.

The successful transition of low-end and mid-range server applications to lead-free has come largely through wave solder process optimization and the use of alternate lead-free alloys for mini-pot rework.

Copper dissolution has become an industry buzzword, and numerous studies have conclud-

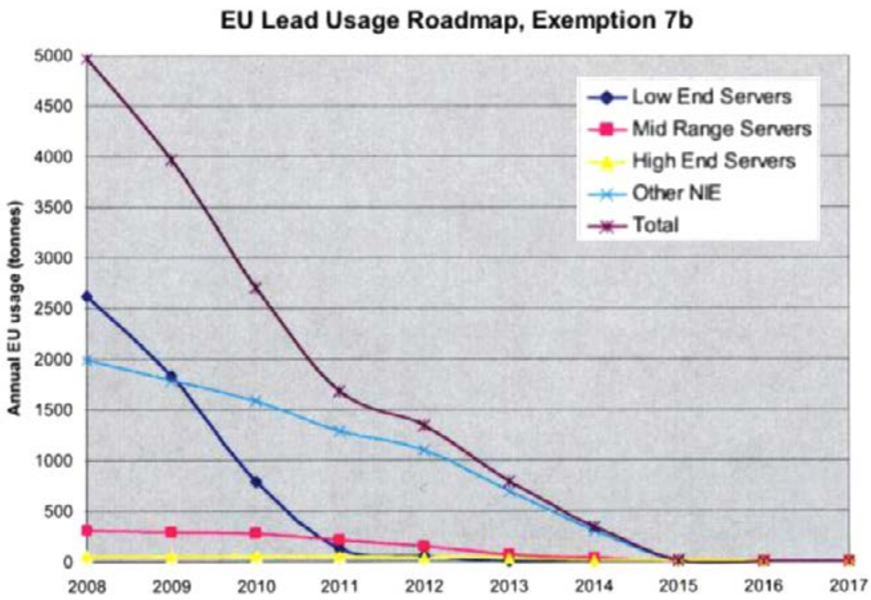


Figure 1: EU Lead Usage Roadmap, Exemption 7b[2].

ed that the current industry standard procedure of using the mini-pot for PTH rework will not provide the capability to rework extremely large, high thermal mass network/server PCBs even when SAC305 is replaced with alternate lead-free alloys such as SN0.7Cu0.05Ni (SN100C) with lower copper dissolution properties. These new rework challenges are reviewed in detail along with potential alternatives to mini-pot rework for these high-end applications.

Introduction

A logical question to ask before reading this article: Why are we even concerned about plated through-hole (PTH) technology? After all, isn't it being replaced by surface mount technology? The short answer is that even though we have been in high-volume SMT production for over two decades, PTH technology still exists and is not expected to go away for a long time to come[3]. As long as we humans have to touch it, switches, connectors and other mechanical devices are better attached to the circuit board with through-hole connections. This is also true for devices which may encounter high forces such as military, aerospace and automotive applications[4].

iNEMI's (International Electronics Manufacturing Initiative) strategic methodology provides an overview of how and why technology changes. Two major factors include the government and disruptive technology[5]. Certainly, these two factors combined to create an industry upheaval during the transition from tin-lead to lead-free beginning in 2000.

PTH rework was extremely straightforward prior to the transition to lead-free. The solder fountain or "mini-pot" was the technology of choice and "copper dissolution" was a largely irrelevant technical term. Mini-pot operators simply flowed solder against the component lead pattern for as long as was required to remove or replace a component. In extreme cases, a high thermal mass assembly was preheated in an oven prior to rework to reduce thermal shock and to minimize solder contact time. Today if you Google "copper dissolution during lead-free PTH rework," you will find page after page of information and technical studies involving the once obscure mini-pot.

Objectives

The main objectives of this article:

1) To outline the reasons why the mini-pot is receiving so much attention and technical analysis in regard to lead-free PTH rework.

2) To outline the evolution of the mini-pot including identifying the lead-free PTH rework it is capable of performing as well as its technical limitations.

3) To communicate the gaps and challenges identified in the PTH Rework and Repair section of the 2013 iNEMI Technology Roadmap and to discuss efforts to date to resolve these gaps including an assessment of alternative rework technologies, an overview of a next-generation mini-pot system and a lead-free PTH rework study.

The Solder Fountain and Lead-Free Solder

Although solder fountain and mini-pot are generic terms, they most often refer to one par-

Figure 2: A typical mini-pot.

Figure 3: Solder wave on mini-pot.

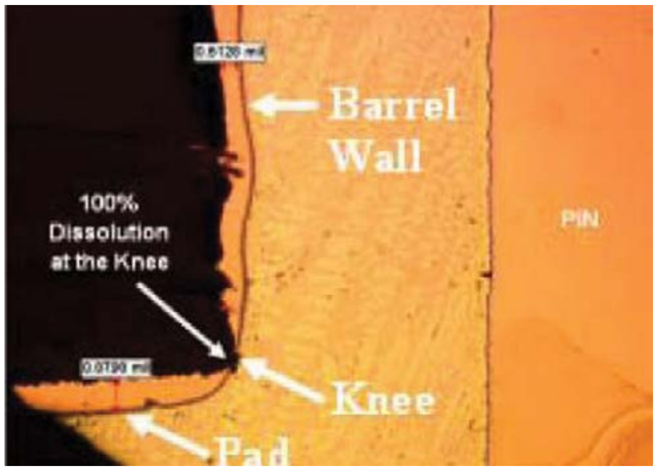


Figure 4: Hidden defect[6].

ticular machine, which is the machine we will be referring to throughout this paper (Figure 2). The solder pot and pump housing on this machine are both cast iron which is resistant to the corrosive nature of lead-free solders. However, two changes to the mini-pot were required to provide lead-free capability. First, all pump components such as the impeller, screws and solder baffle were changed from stainless steel to titanium and second, the flow wells which direct the solder flow were changed from plated steel to titanium (Figure 3). No coatings of any kind are used due to user concerns regarding coating wear/scratching and contamination.

The main issue with lead-free PTH rework on the solder fountain is easily described in two words: copper dissolution. Copper dissolution is a two-stage process whereby copper on the PTH knee, barrel and annular ring is dissolved by tin and forms an intermetallic compound which in turn is dissolved in solder.

Copper dissolution is often a hidden defect, as shown in Figure 4. Multiple studies have shown that copper at the PTH knee erodes at a much faster rate than at either the annular ring or barrel. Therefore it is possible for pads to appear to be perfectly acceptable while the knee, which is hidden from view, can have significant or even complete dissolution.

There are two reasons why copper dissolution, which was a non-issue for tin-lead rework, is now a significant issue for lead-free PTH rework. First, the higher tin content in lead-free solder significantly increases the dissolution rate as shown in Figure 5. Second, the higher melt temperature of lead-free solder requires increased contact time and/or increased solder temperature to reflow the component, both of which lead to increased dissolution.

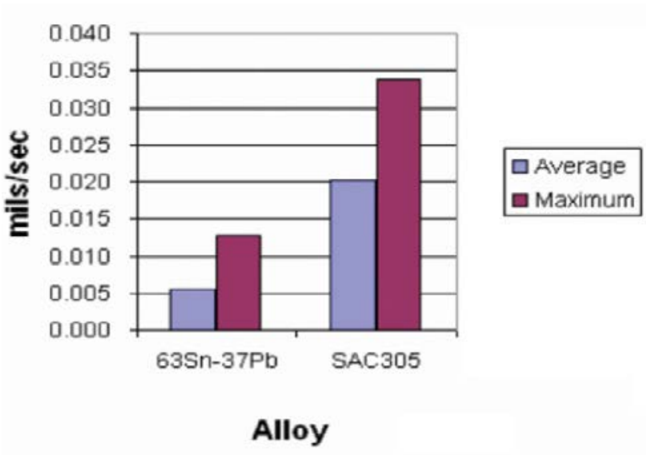


Figure 5: Dissolution rates by alloy[7].

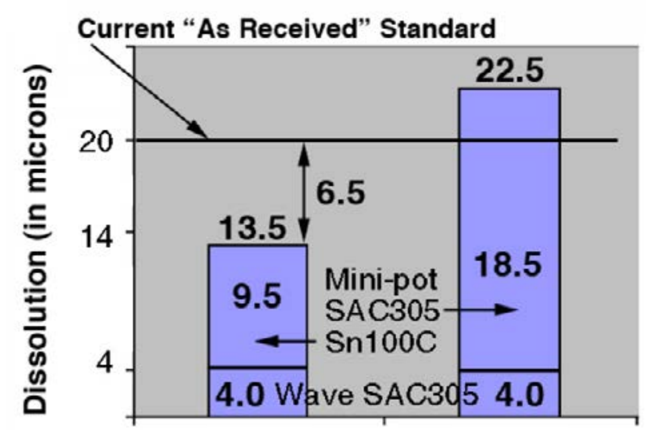


Figure 6: As-received Cu minimum thickness standard (20µm).

The higher dissolution rate of lead-free solder combined with higher solder melt temperature significantly reduces the rework process window on the mini-pot.

The extremely narrow PTH rework process window that SAC305 provides is being addressed today largely through the use of alternate solder alloys such as SN-0.7Cu-0.05 Ni which contain a small amount of nickel that retards dissolution.

However even the use of lower-dissolution solder in the mini-pot rework process is not the end-all solution for successful lead-free PTH rework, especially for mid-range applications where significant (45+ seconds) total solder contact time is required to remove and replace a component. A previous study of copper dissolution on the PTH knee using a mid-range server board which required 45 seconds total contact time to remove and replace the component yielded these results regarding copper dissolution[8].

Alloy	Process	Cu Dissolution
SAC305	Wave Solder Process	2-6 microns (4.0 Avg)
SAC305	Mini-Pot Process	15-22 microns (18.5 Avg)
SN100C	Mini-Pot Process	7-12 microns (9.5 Avg)

IPC Standard 6012-B specifies an "as-received" copper minimum thickness average of 20 microns for Class 1 and 2 PCBs[9]. In addition, previous studies on copper dissolution and solder joint reliability have demonstrated that when copper at the PTH knee falls below 12.7 microns, cracks may form during reliability testing[10]. As a result, 12.7 microns has become the industry minimum acceptable copper thickness standard.

Figure 6 shows the importance that the as-received copper thickness plays in regards to having acceptable copper thickness levels remaining after the wave and mini-pot processes. Although a mini-pot rework process using low-dissolution solder would reduce dissolution almost 50% on average (9.5 vs. 18.5 microns), the remaining copper thickness after wave solder and rework would be 6.5 microns if the as received thickness was 20 microns (minimum as received thickness standard). This value of 6.5 microns is approximately 50% below the current post-rework minimum standard thickness of 12.7 microns.

Rather than hope that the actual as-received copper thickness exceeds the 20 micron minimum standard, one possible solution is to increase the standard itself. In fact, iNEMI is now proposing that the as-received standard be increased from the current 20 microns to 33 microns. A SAC305 wave solder process followed by a SN100C mini-pot rework process would yield successful results with a new as-received standard of 33 microns as shown in Figure 7. If the as-received copper thickness was 33 microns and the total wave and mini-pot dissolution was 13.5 microns, the post-rework thickness would be 19.5 microns which is well above the 12.7 micron minimum.

Regardless of whether the as-received copper thickness standard is increased or not, every possible effort should be explored and if prac-

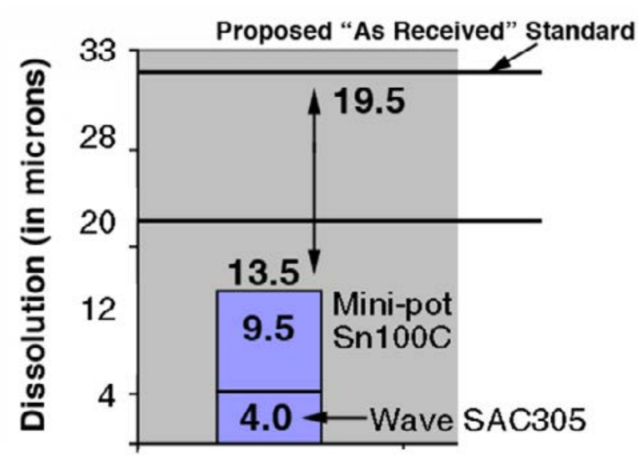


Figure 7: Proposed as-received standard (33µm).

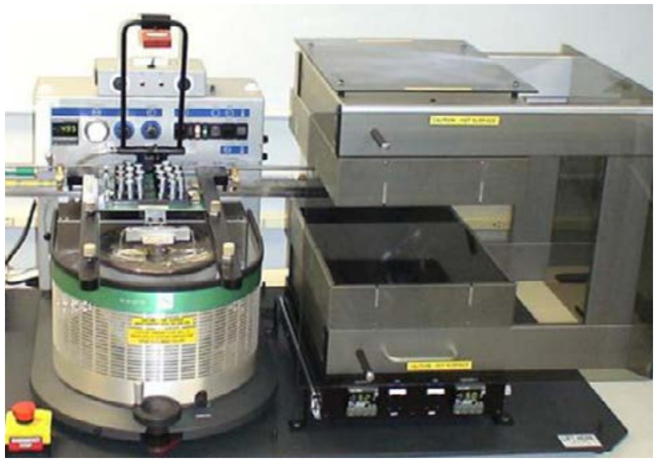


Figure 8: Mini-pot with IR preheater.

tical, implemented to expand the mini-pot rework process window.

Expanding the Mini-Pot Process Window

Virtually every mini-pot study uses a remote oven to preheat the PCB prior to mini-pot rework. Although the concept of preheating the PCB to minimize solder contact time is valid, the unintegrated approach results in significant heat loss prior to solder contact. Alternatively, a mini-pot configuration with an integrated top and bottom IR preheater provides rapid transfer of the PCB from the preheater to the solder wave with virtually no heat loss as seen in Figure 8. In addition, several studies preheat the board to relatively low levels (100-125°C) remotely due to concerns regarding temperature sensitive component on the board. In one previous study where the board was preheated remotely to 125°C, the board temperature during actual rework had dropped 35° to 90°C. Maximizing the board preheat temperature will minimize the required solder contact time which is critical for minimizing copper dissolution. Current studies have shown that bottom-side preheating of high thermal mass assemblies allow the topside board temperature to reach 150°C while topside temperature-sensitive components such as electrolytic capacitors reach only 85-105°C.

Another way to further increase the process window for lead-free PTH rework is to remove the component using a combination of convective and IR heating.

In 2009, the New England Lead-Free Consortium conducted an extensive long-term reliability study of lead-free and halogen-free electronic assemblies. Of particular interest was a rework process that compared initial installation, removal and replacement of a 200-pin lead-free connector on a high thermal mass PCB using a large solder fountain system compared to a process where the large solder fountain system was used for initial connector installation and replacement, however a DRS25 BGA rework system with topside convective heating and bottom side IR heating was used to remove the connector (Figure 9).

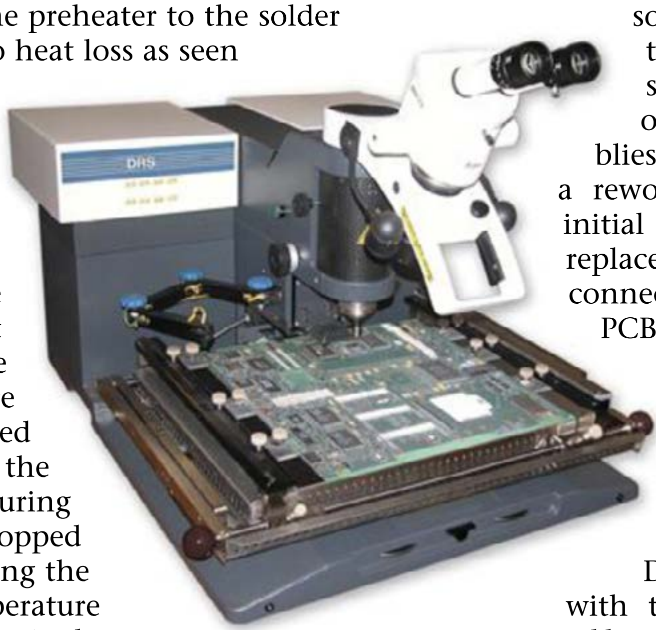


Figure 9: BGA rework station.

The consortium found that the convective removal process reduced copper dissolution by 43%[11]. The only downside to the convective removal process on a BGA rework system is that it is not integrated with the mini-pot and therefore requires two separate pieces of equipment to be used. In addition, the capability to remove and replace a component in a single cycle which is desired by many users due to its timesaving nature is impractical with a separate convective removal process.

Summary of Recommendations for Increasing the Process Window for Lead-Free PTH Rework on Low to Mid-Level Complexity PCBs

1) Use SN-0.7Cu-0.05 Ni solder as the nickel acts to retard copper dissolution.

2) Add an integrated top and bottom IR preheater to the mini-pot to maximize the core temperature of the PCB during rework and to minimize solder contact time.

3) If #1 and #2 do not provide the process window required for a particular application, use a BGA rework machine with combined convective/IR heating for component removal.

Lead-Free PTH Rework of High Thermal Mass Components on Large, High Thermal Mass PCBs

Discussions in the previous sections focused on optimizing the capability of the mini-pot to provide the ability to rework lead-free PTH components on low to mid-complexity assemblies.

However, the current leaded solder exemption for servers, storage array systems and network infrastructure equipment is scheduled to expire in July 2014. The Rework and Repair section of the 2013 iNEMI Technology Roadmap has identified several challenges and gaps related to lead-free PTH rework of high thermal mass components on very large, high thermal mass PCBs, including meeting IPC standards for copper dissolution and barrel fill, addressing the significant challenge of reworking PTH connectors with body temperature ratings of only 240°C, increasing the process window to allow removal and replacement of a PTH component in a single step, selecting a common industry lead-free solder alloy for PTH rework and determining the impact of mixing different lead-free solder alloys during wave soldering and rework. Contamination of the mini-pot is also a concern as well as the use of fluxes that are electrically reliable even if not sufficiently heated[12].

Due to the fact that mini-pot optimization is required to provide the capability to rework lead-free PTH components on low- to mid-complexity assemblies, previous studies have concluded that alternative solutions are required for reworking high thermal mass, lead-free PTH components on very large, high complexity PCBs for server, network and storage applications. These assemblies will typically exceed 0.120 inches in thickness, have 14 or more layers, seven or more ground layers, and ten ounces or more of copper[13]. iNEMI mentions convection, IR, laser and vapor phase technologies as possible alternative solutions to the mini-pot for lead-free PTH rework of high-complexity assemblies[14].

Convection has been proven to be a viable technology for lead-free PTH component removal and barrel cleaning although issues related to board discoloration and resin recession exist. Vapor phase is in use for removing large, high thermal mass surface mount connectors on high complexity assemblies[15]. It would seem logical to assume that vapor phase could also effectively remove high thermal mass lead-free PTH components on high complexity assemblies. However, vapor phase subjects the entire assembly to an additional reflow cycle and the cost of Galden, the liquid that is boiled to transfer energy through the heat of condensation, which is extremely expensive.

In addition, neither convection nor vapor phase offer practical solutions for replacing lead-free PTH components as both methods involve the use of solder paste and solder performs or screen printing which add complexity and significantly increase cycle times. Some IR rework systems designed primarily for BGA rework claim to have PTH component rework capability; however, these systems appear to lack the capability to handle high thermal mass PTH components on high complexity assemblies and also lack the ability to effectively clean the barrels and replace the component. Information on laser technology typically focuses on SMT rework and selective soldering.

Continued Evolution of the Mini-Pot

None of the alternative technologies discussed above appear to be well suited as a mini-pot replacement for lead-free PTH rework of high thermal mass components on large, high-complexity assemblies. The reason for this lies in the fact that none of these technologies were designed with this objective in mind. At best, we are trying to utilize existing technology that was designed for other purposes.

Rather than try to force-fit an existing technology as a possible solution, what is needed is the "clean sheet of paper" design approach. As Ray Prasad once wrote in *SMT Magazine:*

What is really needed is an alternative rework system for through-hole that does not exist today. Anyone who can come up with a rework system that can reflow and remove through-hole components quickly without causing internal barrel or trace cracking can truly claim an advantage. Does such a system exist today in the market place? No. Can such a system be developed? Yes, but it requires engineering and financial resources of users and equipment suppliers.[16]

Because the mini-pot has been the technology of choice for tin-lead rework for over 20 years and it is able to provide rework capability for lead-free PTH components on low-to-mid-complexity assemblies, it seems logical to develop a system that utilizes the strengths of the mini-pot and to address its weaknesses. In fact, this concept has already been in development and beta site testing for over three years. The PCBRM100 is a next-generation mini-pot technology designed specifically for rework of lead-free PTH components on large, high-thermal-mass assemblies. Compared to the mini-pot, the 100 is a large machine with a footprint measuring 3050mm long by 1320mm wide by 1955mm high (120 x 52 x 77"). (Figure 10).

The 610 x 660mm (24 x 26") board carrier includes a pull-out feature to provide ergonomic loading/unloading of heavy boards and a tilt frame to allow operator access to the bottom of the board for fluxing and positioning bottom side supports. The carrier is programmable in the "x" and "z" axes and uses linear encoders for accuracy and repeatability. Spring-loaded carrier arms allow for thermal expansion of the board during rework.

The EZ-Line alignment system features a down-looking digital camera with zoom lens mounted on a programmable "y" axis that superimposes the image of the solder stack over the top of the board. X/Y joystick-based controls are used to quickly and accurately align the component with the solder stack (Figure 11).

A 711 x 711mm (28 x 28") quartz composite top and bottom IR preheater (16Kw) with 25 watts per square inch heating density and independent temperature control provides rapid, uniform preheating of even the largest, most thermally challenging PCBs. The preheater panels have an extremely high radiant efficiency

Figure 10: The PCBRM 100 mini-pot.

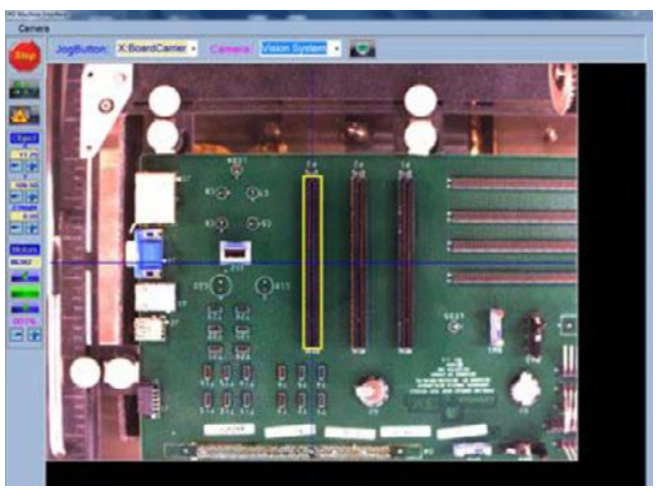


Figure 11: EZ-Line alignment system.

and do not depend on external reflectors. The top preheater panel has a programmable "z" axis which allows the preheater to "sandwich" the PCB based on its topside topography, thereby creating a high-efficiency oven-like preheating effect. A thermocouple attached to the PCB provides temperature-based preheating control for process repeatability.

The heart of the 100 is a cast iron solder pot with titanium pump components. No coatings of any kind are used to handle the aggressive nature of lead-free solder alloys. The pot has a solder capacity of 90 pounds and is nitrogen inerted. An internal chambering system along with a servo-motor driven pump creates a laminar solder flow with extreme thermal uniformity across the wave (+/- 2°C). Quick-change titanium solder stacks direct a flow of solder against the lead pattern of the component to be reworked, as shown in Figure 12. The solder pot is programmable in the "y" axis and has quick electrical disconnects so that the existing pot can be removed and replaced by a spare pot with a different solder alloy.

What makes the 100 unique is the integrated focused convective top and bottom heating systems (FCH). After the entire board is preheated, the PCB is moved to a position just above solder contact position. The programmable hot gas head brings the nozzle down and over the topside of the component to be reworked. The nozzle is fed by a 2Kw heater so it has the power needed to heat virtually any component regardless of size or thermal mass. Two seven-inch convective heating blades focus heat on the bottom side leads. Each blade is fed by a 3.5Kw heating element and has a quick slide baffle that allows the heat from the blades to be sized to match the size of the lead pattern (Figure 13). Other key features include a laser distance sensor which provides automatic squaring of the convective heating nozzle and eight traveling TCs which provide on-machine profiling capability.

A typical removal process would be to preheat the entire board to 150°C followed by a focused convective heating (FCH) stage until all joints reach approximately 200°C (as per the thermal profile), at which time the bottom side pins are immersed in solder for 10-20 seconds depending on the thermal mass of the component and PCB. Top and bottom side focused convective heating continues during solder immersion. Solder contact combined with focused convective heating provides the maximum thermal transfer in the shortest possible time. The nozzle lifts automatically and the operator removes the component. This hybrid heating approach eliminates the requirement for 100% convective/IR heating found with BGA rework machines, thus reducing potential issues such as exceeding the maximum package temperature specifications, resin recession and board discoloration.

The PTH barrels can be cleaned immediately after the component is removed and the solder flow stops. The PCB remains in place over the solder stack with the bottom convective heating blades on. The component nozzle is replaced by the barrel cleaning nozzle

Figure 12: Solder pot with titanium solder stack.

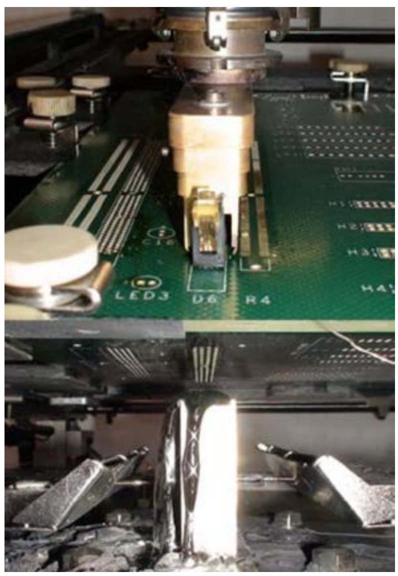


Figure 13: Focused convective heating.

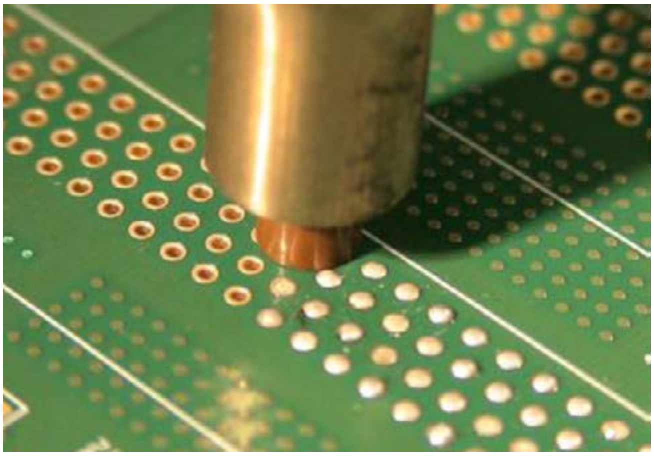


Figure 14: Barrel cleaning.

which provides heat and vacuum to remove the solder in the barrels. The vacuum tip is made of a high-temperature composite to prevent any abrasion of the pads or laminate. A precision force sensor controls the initial touch off of the vacuum tip on the board. A vacuum sensor automatically and continuously adjusts the tip height providing non-contact barrel cleaning. Dual digital cameras provide the operator with multiple viewing angles during the cleaning process. The operator uses the x/y/z joystick to move the vacuum tip as desired (Figure 14).

The replacement process typically duplicates the removal process where FCH occurs until the joints reach 200°C at which time the bottom side leads are immersed in solder. However, instead of the nozzle lifting and the operator removing the component, the nozzle remains in place over the component while it is soldered in place. Using FCH in this fashion eliminates the solder contact time typically required to bring the component through an extended soak stage during both the removal and replacement processes. The reduction in solder contact time results in reduced copper dissolution. In addition, topside FCH during the replacement process improves barrel fill by providing a heated upward path for the solder to follow. **SMT**

To view Part 2 of this article, click here.

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Brian Czaplicki is the director of technical marketing programs at Air-Vac Engineering. In 2012, Czaplicki participated in the development of the Rework and Repair Section of the 2013 iNEMI Technology Roadmap, which identified the key future rework and repair challenges facing the electronics industry. This article is one result of that research.

Beating the Heat:
A Review of Thermal Management Challenges

by Joe Fjelstad
VERDANT ELECTRONICS

SUMMARY: Over the last few years, a number of '90s-era solutions have been brought down off the shelf, dusted off, and pressed into service to once again get the heat out of electronic devices and systems. A wide range of solutions have since been developed operating on various principles.

Heat is a by-product of the operation of every electronic device, be it large or small. The amount of heat produced by some devices, such as digital watches and small calculators, may be nearly immeasurable, but where there is resistance, there is also heat. For larger and more powerful electronic devices, heat is much more apparent, as anyone who has actually used a laptop on their lap can attest.

With the industry's unceasing effort to increase product performance by shrinking transistors and circuits, an unfortunate increase in thermal energy densities on ICs has occurred. Today, the matter of elevated temperatures on the chip is an increasingly important issue for chip, package, and system designers for a very important reason: the inverse relationship between long-term reliability and higher temperatures. Stated more simply, as the chip gets hotter and/or spends more time at an elevated temperature, the reliability of the die, and thus the product in which it is used, tends to worsen.

Armed with this knowledge, technologists have directed significantly more attention toward thermal management of electronic systems, beginning with the IC. Interestingly, this is not the first time the issue has arisen. Back in the late '80s and early '90s, the industry was facing a similar problem when bipolar chip design and manufacturing technology dominated. At that time, numerous thermal management solutions were being developed and offered to address the problem of high thermal loads on the chip and in the system. However, relatively few of those solutions were put to use because CMOS technology took over as the process of choice for semiconductor design and manufacture, especially for microprocessors and other high-transistor-density devices. CMOS was a much more efficient and cooler operating approach for IC chips. Figure 1 offers a graphical representation of what was happening back then and the dramatic and immediate effect the changeover had. The graph also shows that the challenges of the past are returning.

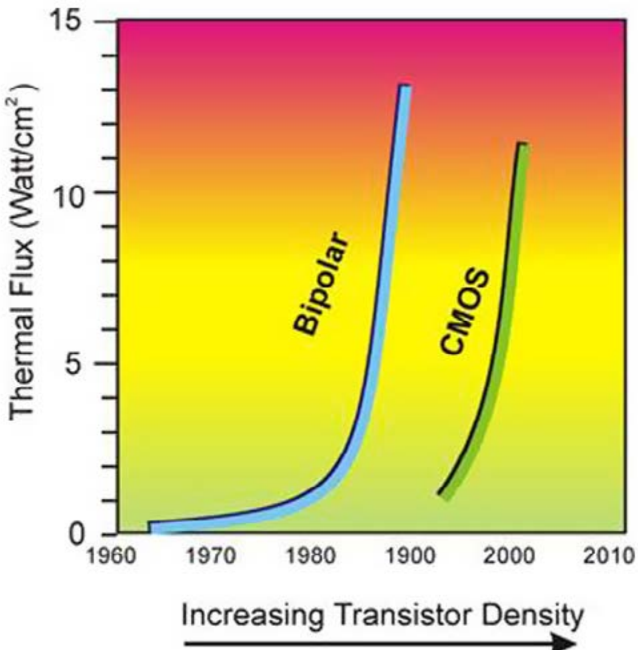

Figure 1: The challenge of cooling electronic devices, especially high-end microprocessors, was being addressed with intensity in the late '80s, but was delayed by the introduction of CMOS technology. Concerns are on the rise again as thermal densities rise and transistors shrink to potentially create a perfect storm relative to reliability[1].

Over the course of the last few years, a number of '90s shelved solutions are being brought down, dusted off, and pressed into service to once again get the heat out of electronic devices and systems. A wide range of solutions has since been developed, operating on various principles. However, as thermal engineers have been heard to say relative to the management of the heat generated by any device, "Ultimately it all goes back to air." This statement is accurate because air is the most omnipresent and versatile thermal transfer medium on Earth. When you think about it, it is the convection currents in the atmosphere that allows the earth to get the heat out (but as climatologists note, it could as well help to keep a greater amount of heat in if the CO_2 content gets too high).

When it comes to the task of cooling, two modes of thermal transfer are generally considered: Primary thermal transfer modes and secondary thermal transfer modes. The primary modes are generally based on conduction, the first of which is direct thermal transfer normally through a solid material such as a metal, as metals are generally good thermal conductors. The efficacy of conduction depends on the conductivity of the solid employed. Metals, as was mentioned, are normally good thermal transfer materials, but they can vary widely in terms of thermal conductivity. The other primary method of thermal transfer is via convection. In an actual cooling system, convection typically works in concert with conduction and is facilitated by the involvement of the other common states matter, liquids, and/or gasses. Obviously, for convection to work, the temperature of the liquid or gas passing over a surface must be cooler than what is being cooled and the faster the flow rate, the better the cooling.

The most familiar secondary thermal transfer mode is the one used by the sun to get rid of its heat: radiation. Radiation, simply stated, is the thermal transfer of energy from one body to another through space without a transfer medium. An infrared lamp is a good practical example. Another secondary method is phase change, which is something that is also experienced on a daily basis. Phase change examples include evaporation and condensation as well as freezing, melting, and sublimation. The cooling effect we get from the evaporation of perspiration from a passing breeze on a hot day is, again, something to which everyone can relate. All of these effects occur through either a loss or gain of thermal energy.

Given these fundamental modalities of thermal transfer, one might think there would be limits to the number of solutions; however, a surprising number exist. The most fundamental way to achieve rapid thermal transfer is by immersion liquid cooling. Again, this is something that should be familiar to everyone in daily life. Think, for example, of cooling a hot frying pan by dipping it in a sink filled with cool water.

Other common methods effecting thermal transfer revolve around spraying methods. Spray cooling, either with a jet of cool vapor or gas impingement cooling, has the advantage of obviating concern about overspray, as is the case with liquid spray cooling. Liquid spray cooling systems are typically based on the use of a closed loop system with an evaporative cooling cycle—the coolant is evaporated when it strikes the hot surface, condenses in a chiller, and is reused.

A popular thermal transfer technology developed around this method is the heat pipe, a sealed system with micro-channels and a fluid. When one end of the heat pipe is placed on a hot surface (e.g., an IC chip) there is evaporation of the internal liquid at the interface with the chip and cooling and condensation at the distal end. Heat pipe offers much better thermal performance than solid metal and can be very low profile (~0.5 mm).

The last of the methods in this brief discussion is thermoelectric cooling. Thermoelectric cooling is based on the Peltier effect, named in honor of Jean-Charles Peltier, a French physicist who in 1834 discovered the heat effect of an electric current at the junction of two different metals. Peltier observed that when an electric current passed across the junction of two dissimilar conductors (i.e., a thermocouple) there was a heating effect not accountable by Joule heating alone. When the effect was eventually applied in a real-world application, the result was a solid state cooling system that can actively cool by drawing heat away from the device of interest (the IC chip) passing it to heat sink or head spreader. The biggest concern with the method is that it requires an additional energy budget to operate. Keep this in mind when considering any type of cooling solution.

A very important aspect of thermal management is assuring that one is providing and achieving the best possible solution at the interface between the heated device and thermal management solution being applied. One way of accomplishing this goal is to use a thermal interface material (TIM), a somewhat disparate family of materials including everything from conductive foams to various greases filled with conductive materials. The function of the material is to help assure the efficient and even transfer of heat from the device being cooled to the thermal management device which is used to spread and/or dissipate the source of the heat. Moreover, TIMs need to accomplish this basic objective while not imparting any stress at the thermal interface. This can be a daunting challenge given that substantial differences in material properties between the thermal management device (i.e., heat spreader, heat pipe, or fan) and the IC chip can be substantial and perhaps the most important difference in this regard is the difference in coefficient of thermal expansion (CTE).

While many different components are used in electronic assemblies, those that command the greatest attention are typically the CPU or microprocessors along with certain high-power transistors. The reason for the focused attention and cooling demand for these devices, especially CPUs is driven by both the increase in overall power on the chip and, equally important in the case of the CPU, the local power densities on the die during cooperation, commonly referred to as "hot spots." These hot spots will become sites of failure on the chip if not addressed and are a fundamental reason why thermal interface materials are becoming key design elements of many electronic products.

> **"The importance of the thermal interface material cannot be overstated as it is a critical element in improving thermal conductance between components, especially since virtually components have imperfect contact surfaces."**

The importance of the thermal interface material cannot be overstated as it is a critical element in improving thermal conductance between components, especially since virtually components have imperfect contact surfaces. The role of the TIM is to provide an interface medium which is used to transfer heat from an electronic device to the cooling element with a minimum of thermal resistance. A key factor in thermal interface material selection and use is managing the important relationship between bond line thickness (BLT) and thermal resistance. BLT reduction is an important goal of any thermal design. The thickness of the bond line is influenced by various parameters, but most important are the pressures applied to bring the mating surfaces together and the size, volume, and distribution of thermal particles in the TIM.

Among TIMs, several basic types and some newer solutions are being rolled out. First are thermal greases which are normally a silicone grease-based matrix loaded with conductive particles (e.g., aluminum nitride) to enhance thermal conductivity. They offer fairly high-bulk thermal conductivity and can achieve a thin bond line with minimal pressure due to the low viscosity of the material which fills surfaces; however, the grease can flow and migrate. Another family of TIM material is phase change materials, organic resins filled with alumina or boron nitride. Their higher viscosity makes application easier and provides increased stability and less migration; however, more pressure is required and the thermal conductivity is generally lower than greases.

The third type of TIMs are gels, a mix of conductive particles in a silicone or olefin matrices that require curing. Because they are cured, migration is not a concern. The last is adhesives filled with conductive particles such as silver. These, again, are of limited concern relative to migration; however, the choice of adhesive is important as epoxies when cured can have high post-cure modulus resulting in a CTE mismatch which can induce stress. In the case of all TIM products requiring cure, delamination is a potential concern. At the end of the day, however, it has been suggested by thermal engineers steeped in the technology that, when using a TIM, inadequate mounting pressure is more important than almost any other factor, including the material choice.

“At the end of the day, however, it has been suggested by thermal engineers steeped in the technology that, when using a TIM, inadequate mounting pressure is more important than almost any other factor, including the material choice.”

Interesting advances in TIM alternatives are taking place. For example, Semiconductor Research Corporation (SRC) and researchers from Stanford University have developed TIM foam-like material with conductivity comparable to copper in the form of a nanostructured carbon thermal tape that conducts heat like a metal, yet allows the thermally connected materials to expand and contract with temperature changes. In another example, Georgia Tech is attempting to create a TIM material comprised of mixture of diamond, the most thermally conductive natural material (~2,000 watts per meter Kelvin) and silver, which is among the most thermally conductive metals at 400 watts per meter K, but still significantly lower than diamond. According to developers, the highly-malleable silver matrix completely surrounds the diamond particles and can be formed in thin sheet, which allows the composite material to be cut to the precision required to conform components and serve as thermal shims. In addition, developers state that the silver allows those components to bond readily to other surfaces, including semiconductor chips.

Thermal management has returned to the forefront of the design process, and understanding this problem, and some prospective solutions, is an increasingly important part of product development. **SMT**

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Verdant Electronics Founder and President Joseph (Joe) Fjelstad is a four-decade veteran of the electronics industry and an international authority and innovator in the field of electronic interconnection and packaging technologies. To contact Fjelstad, or read past articles, click click here.

Video Interview

DEK's Stencil Printing Solution Evolution

by Real Time with...
IPC APEX EXPO 2013

DEK's future technologist, Clive Ashmore, provides an overview of the evolution of stencil printing from just a year ago and describes what it means to provide value-added technology solutions.

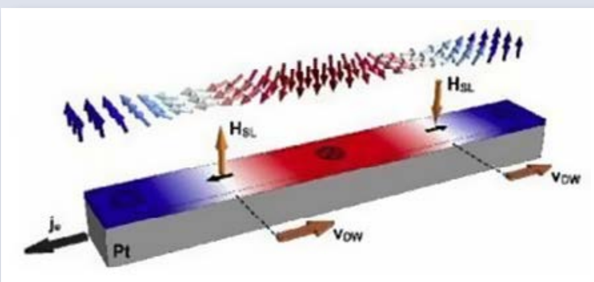
realtimewith.com

New Magnetic Phenomenon Leads to Better Data Storage

A magnetic phenomenon discovered by MIT researchers could lead to faster, denser and more energy-efficient chips.

The findings, reported in the journal Nature Materials, could reduce the energy needed to store and retrieve one bit of data by a factor of 10,000, says the paper's senior author, Geoffrey Beach, an assistant professor of materials science and engineering at MIT.

Beach says that hints of the new phenomenon have been reported for years, but had remained unexplained. It turns out the key to this phenomenon lies not in the magnetic materials themselves, but in what's next to them: In this case, the team used thin films of a ferromagnetic material, deposited on a metal base, with a layer of an oxide material on top--a ferromagnet sandwich. The behavior of the ferromagnetic layer, it turns out, depends on the metal that layer rests upon.



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Ferromagnetic materials, including bar magnets, have a north and a south pole. When such materials are used for data storage, such as on a computer's hard disk, separate tiny "domains" on their surface can have these poles pointing either up or down, representing ones and zeros. Normally, when a ferromagnetic material is exposed to a current, these domains are pushed along the surface in the same direction as the electron flow.

In these ferromagnetic sandwiches, the forces pushing the domains are 100 times greater than in conventional ferromagnetic storage systems. Since the power needed to move the domains varies with the square of these forces, Beach says, such a system could be 10,000 times more efficient than existing technology.

SMTonline Supplier/New Product News Highlights

XJTAG Workshop Gives Introduction to Boundary Scan

The free workshop aims to provide engineers with an introduction to boundary scan and to show how this innovative debug, test, and programming process can improve designs and reduce respins and to enhance test coverage, fault diagnosis, and production yields on complex BGA-populated circuits.

JUKI, Sony, and Sony EMCS Form Joint Venture

Juki Corp., Sony Corp., and Sony EMCS Corp. announce that based on an intention to strengthen the competitiveness of the SMT equipment and related businesses each company operates, the three companies have concluded a formal agreement to integrate the aforementioned businesses under Juki Automation Systems Corporation, to be established August 1, 2013, as a joint venture company.

New Semblant Process Prevents Tin Whiskers, Vapor Damage

Nano-materials company Semblant Ltd. has launched the PlasmaShield™ plasma conformal coat process to deliver best-in-class environmental protection without the expense associated with material costs or manufacturing complexity. The PlasmaShield conformal coat process prevents solids and liquids from contacting electronics, protects against vapor damage (moisture, pollutant gasses, salts), and can mitigate tin whiskers.

Cirtech Invests in Aegis Software

Circuit Technology Inc. (Cirtech), a New Hampshire-based CEM, has been investing in Aegis software—and it's an investment that has been growing steadily alongside the business as the company seeks to profit further from the software's benefits. Aegis is now being used for new product introduction (NPI) and to manage a paperless shop floor environment throughout its PCB and electromechanical assembly operation.

H.B. Fuller Enters Electronic & Assembly Materials Market

H.B. Fuller Company announced that the company is entering the growing electronics and assembly materials market with a total solutions "eco-system" approach that includes materials, processes, and equipment support from the concept phase to the consumer's hands.

Essemtec Develops Integrated PCB Identification System

A traceability solution should be able to assign assembly data to products without any doubt. Many systems, however, are likely to fail if there is manual intervention. Essemtec has now invented the integrated PCB identification system that no longer can be bypassed.

3CEMS Receives Best Partner Award from ASUS

"We are very proud of our long-term partnership with ASUS since 2009," said Su Ching Ma, vice president of 3CEMS Group. "We are honored to have received the recognition from ASUS for delivering the high level of customers' satisfaction."

Electrolube Releases Aromatic-free Polyurethane Coating

Electrolube has announced the addition of a new aromatic-free polyurethane conformal coating (PUCAF) to their product range. PUCAF has been specifically designed for the protection of electronic circuitry for optimum reliability and increased performance of devices.

Avnet to Acquire Assets of Seamless Technologies

Avnet, Inc. has agreed to acquire substantially all assets of Seamless Technologies, an IT private cloud and data center automation service provider. Seamless Technologies provides expertise and services in IT infrastructure software technologies, automation, cloud, virtualization, integration, and Information Technology Infrastructure Library (ITIL) best practices.

Northwest CM Invests in FCT's DEK VectorGuard

FCT Assembly has secured an order from a fast-growing contract manufacturer (CM) in the Northwest. After thorough evaluations, an order was placed for FCT's DEK VectorGuard® stencil system and NL932 no-clean, lead-free, halide-free solder paste.


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SMT PERSPECTIVES AND PROSPECTS

Cyber Security: From Boardroom to Factory Floor

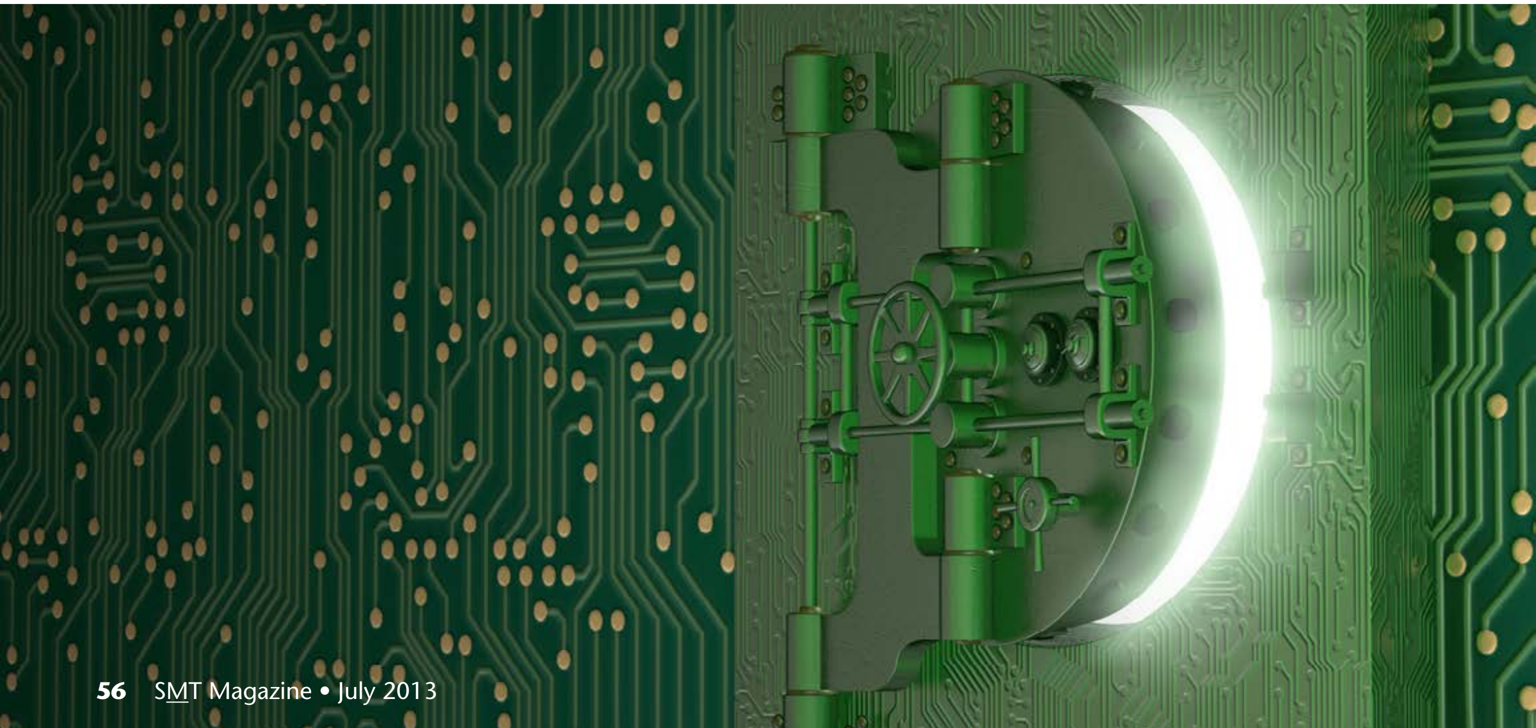
by Dr. Jennie S. Hwang
CEO, H-TECHNOLOGIES GROUP

We are living in a digital world. The digital world is characterized by big data, social media, mobile-gaming, Internet communication, cloud computing and ultra-connectivity. As a result, we benefit immensely from various new tools and vast information flow, which were not available as recent as just 25 years ago. Regardless of which industry we serve and which capacity we hold, we are now working in the cyberspace. Cyberspace is changing the way we do business and every aspect of our lives. Living in this global network of computers also comes with new demands and challenges.

As data has become a new asset of the digital world, various incidents of cyber attacks and extortion attempting to take data as hostage have occurred. For example, when a company's computer system is broken into, its access codes and passwords are then changed and its customers are locked out of its own system, and a ransom is demanded. This could be triggered by an insider (employee) or an outsider (hacker in any locale). Futher, a cyber thief could just simply steal the corporate secrets or confidential and proprietary information, and then demand a ransom.

Cyber attacks are and will continue to be a huge concern to U.S. corporations in the foreseeable future. It's a matter of when, not if. It is not industry-specific and every company will have to deal with this challenge. The earlier preparation is made, the better a company is positioned to fend off the attack. The most insidious nature of cyber attack is that it could happen with ease anywhere, anytime, without physical boundaries and across national borders.

In the recent decade, there have been an increasing number of computers being compromised with malware and corporate IT systems being breached. A company from the boardroom to the factory floor including each of the employees must work in tandem. For corporate directors, this creates a new dimension in board-



room oversight. So how do we tackle this new dimension and what is the proper board oversight so that the company can prevent, mitigate and detect the risks of cyber attacks and cyber extortion? What should employees be aware of and how do they execute each of the tactics to avoid becoming a victim individually or collectively?

As digital technology continues to advance and the cyber landscape is still evolving, IT operating systems, firewalls and security software are not perfect at any point in time. Hackers of every nationality are working relentlessly to attack their targets and poke holes.

Avoiding Victimization: As a Company or an Individual Employee

In my view, there is not a panacea. Nonetheless, a company needs to establish a robust system coupled with good cyber practice through a two-prong strategy, which should be embedded with multiple lines of defense and deterrents. The following two-prong strategy intently embraces both mitigation and crisis management:

- Mitigating strategy is to avoid becoming a victim
- Crisis management strategy is to react and manage the attack if it occurs

A company must cultivate what I call a cyber culture. The effort is to make a cyber attack as difficult and strenuous as can be so that the corporate operating and network system is far away from being the low-hanging fruit.

Under a savvy and diligent board oversight, a cyber culture can be cultivated over time with persistent and pervasive effort by considering the following 20 actionable items.

1. Implement clear and consistent written policies and rules in the use of company computer and data systems
2. Provide employee awareness training
3. Establish a well-informed workforce
4. Encourage employees to observe and detect unusual attempts to gain access
5. Monitor unusual attempts by artificial intelligence detect system (in-house or via a third party)
6. Install quality and current antivirus and malware software
7. Update browsers and operating systems
8. Understand the likely "holes" of software
9. Pay attention to both software and its configuration
10. Perform firewall, antivirus, network vulnerability testing
11. Perform regular computer security review
12. Perform security audits
13. Implement computer access control
14. Implement physical access deterrents
15. Consider, when appropriate, cyber security insurance against sensitive data breaches, hacking, sabotage, and other cyber-vulnerable incidents
16. Observe cyber security standards when applicable
17. Exercise a need-to-know policy
18. Nurture a positive working environment
19. Practice a company-wide, performance-based reward system
20. Keep pace with emerging technologies

How about the incurring cost? Yes, we should be mindful about the cost related to upkeep cyber security. It takes an astute balancing act to implement sufficient control with acceptable cost while avoiding operational impediments. Under today's environment, lack of awareness and unpreparedness is the most precarious position a company can put itself in.

In short, be prepared with current knowledge, updated know-how and a living strategy to counter this insidious corporate risk. **SMT**

Dr. Jennie Hwang is CEO of H-Technology Group and a pioneer and long-standing contributor to SMT manufacturing since its inception. She is the author of 350+ publications and several textbooks, and an international speaker and author on trade, business, education, and social issues. To read past columns or contact Dr. Hwang, click here, or phone (216) 577-3284.

Mil/Aero007 News Highlights

DuLaney to Keynote SMTAI; Presents F-35 Lightning II

The opening keynote session and annual meeting at SMTAI, October 15, 2013, will feature Bob D. DuLaney, Lockheed Martin and U.S. Air Force Major General (Ret), as keynote speaker. He will present "F-35 Lightning II: The Centerpiece for 21st Century Global Security," providing an overview of the program and detailing the importance of the aircraft, current progress, economic impact.

TT electronics-IMS Expands Aero & Defense Offering

Global provider of EMS for the aerospace and defence markets, TT electronics integrated manufacturing services is expanding its cable harness capabilities with the announcement that New Chapel Electronics Ltd. is now part of its business in Europe. The transfer of business operations and technology should be completed by the second quarter of this year.

ZESTRON Renews ITAR Registration

ZESTRON, the globally leading provider of high-precision cleaning products, services, and training solutions, is pleased to announce its renewal of the International Traffic in Arms Regulations (ITAR) registration with the U.S Department of State, Directorate of Defense Trade Controls.

Power Design Services Earns ITAR Certification

As 30% of the company's revenue comes from government- and military-related projects, PDS recently pursued and received ITAR certification. Vice President Tuan Tran explained, "We want our customers to know that when they send us data we will make sure all documents are properly stored and protected."

API Nets $1M Follow-on Order for Defense Assemblies

API Technologies Corporation, a provider of RF/microwave, microelectronics, and security solutions for critical and high-reliability applications, has won a follow-on order, valued at $1.0 million, to provide critical electronic assemblies for a major electronic defense platform.

Sparton, USSI Secure $8.8M Subcontracts for Sonobuoys

Sparton Corporation and USSI, a subsidiary of Ultra Electronics Holdings plc (ULE) announce the award of subcontracts valued at $8.8 million from their ERAPSCO/SonobuoyTech Systems joint venture, for the manufacture of multiple passive and active sonobuoys to the South Korean Government.

API Secures $6.2M Contract for Defense Assemblies

API Technologies Corporation, a provider of RF/microwave, microelectronics, and security solutions for critical and high-reliability applications, has competitively won a $6.2 million order from a leading prime contractor to provide critical electronic assemblies for a major electronic defense platform.

Unmanned Aerial Vehicle Market to See CAGR of 3.3% 2013-2018

According to a new market research report "Unmanned Ae rial Vehicle (UAV) Market (2013-2018)," authored by MarketsandMarkets, the total global UAV Market (2013-2018) is expected to reach $8,351.1 million by 2018 with a CAGR of 3.30%

Ground Robot Market to Reach $12.0 Billion by 2019

Military ground robot market growth comes from the device marketing experts inventing a new role as technology poised to be effective at the forefront of fighting terrorism. Markets at $4.5 billion in 2013 reach $12.0 billion by 2019.

Global Military Radar Systems Market to Hit $8.6B in 2013

In 2013, the global military radar systems market is evaluated at nearly US $8.6 billion. Developed countries lead the overall market in terms of radar technological developments.

Clash of Clans—The New Expansion of PCB Assembly Equipment

by Eric Klaver
ASSEMBLEON

"Smaller, cheaper, faster, more accurate" are the traditional words used to describe new PCB pick-and-place machines. However, these words are mainly used to describe the placement of standard SMD components.

Miniaturization technology is very much driven by the mobile (smartphones, tablets) industry. Key factors are data processing speeds, lower cost prices and thinner devices. Manufacturing and assembly of the phones themselves consists of several overlapping sectors.

Most assembly sectors are (or actually, were) pretty much defined by their own unique equipment, with equipment manufacturers competing only with manufacturers of similar equipment. Everybody kept to their own world. But the combined drive for speed, accuracy, reliability and mounting complexity has opened up the other segments to traditional PCBA equipment, which is at the center of all these segments. Technology and standardization have made equipment more accurate and reliable, still serving a market that has low cost price as a main target. A large portion of the cost price is driven by the speed of the pick-and-place equipment, as it is typically a very high-volume market.

And this speed is exactly what the other markets are currently lacking. They are either very accurate or have extremely high forces (or another variable), but most of these dedicated pieces of

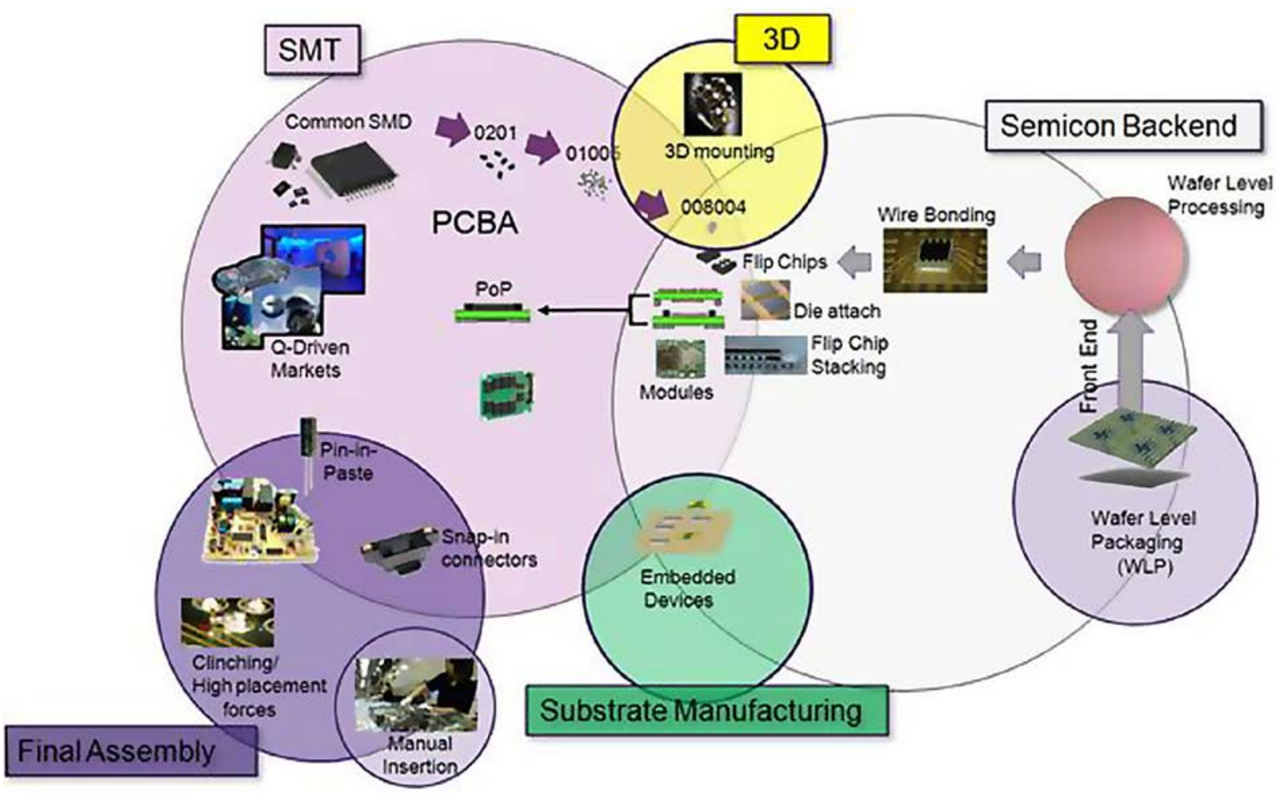


Figure 1.

CLASH OF CLANS—THE NEW EXPANSION OF PCB ASSEMBLY EQUIPMENT *continues*

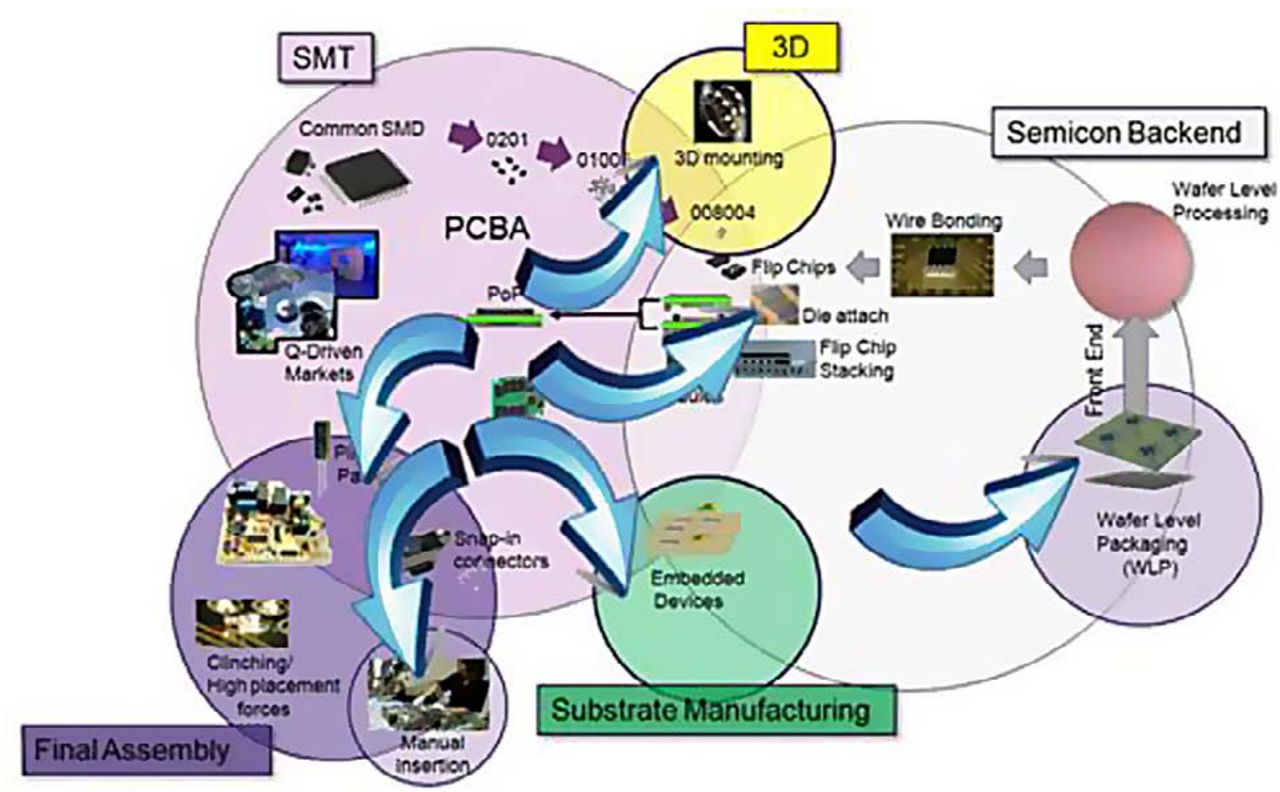


Figure 2.

equipment lack the very high volumes of traditional pick-and-place equipment. And while traditional pick-and-place machines cannot, at least for a while, replace all processes, they are slowly moving into the other segments. That takes time, of course, and it does not make sense to move into even a part of a segment if the market size is too small and investments are too high to make the equipment adjustments.

The second sector is final assembly or manual mounting. Miniaturization is not overly critical here, but reliability and component handling definitely are. There are also different requirements like higher (snap-in) forces. Here, forces are already controllable up to 70N, have pin-in-paste techniques, grippers and odd-form handling. The steps towards final assembly have therefore already been made, and in some cases, pick-and-place equipment can also replace manual insertion.

Reducing repeatability and accuracy below 10 microns (@ Six Sigma) has also made it possible for pick-and-place machines to break into backend manufacture. While wire bonders still do have their place here, flip chip bonding is growing at wire bonding's expense. Flip chip bonders are traditionally slow, however, and they are themselves now increasingly being replaced by PCBA equipment. The improved accuracies are also making it possible for pick-and-place equipment to move into wafer level packaging fabrication.

While not able to manufacture substrates, pick-and-place machines can already embed passive (ultra low-profile capacitors and resistors) and active (ultra flip chip) components into to the substrates. This means that the equipment has also made its move into substrate manufacturing—a new market, as there was no existing SMT equipment.

So existing processes are consolidating, and new markets are emerging. Meanwhile the pick-and-place segment is itself developing. Although equipment is now highly capable of mounting on various levels (2.5D mounting: in cavities, stack-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ing, package on package etc), the next step is real 3D mounting, where components are required to be placed at an angle. That demands an extra dimension on top of the existing X, Y, Z and R movements. While 3D mounting still needs special actions (placement still uses X, Y, Z and R, but the board rotates), it won't be long until standard SMT equipment will do that as standard and at very high speeds.

While some pick-and-place vendors will stay concentrated on the traditional PCBA segment, equipment manufacturers are already moving towards the other segments, making use of the existing technology and high placement speeds. It will be interesting to see how the equipment manufacturers of these different segments will develop new strategies in response to being challenged by a whole new set of competitors arriving on their turf. **SMT**

Eric Klaver has been with Assembleon since 1998. Klaver specializes in vision technology and feeding and is currently the chairman of IEC work group TC40WG36, which specializes in component packaging. To contact Klaver, click here.

Semiconductor Inventory Down to $37.6 Billion in Q1

Total inventory held by semiconductor suppliers declined significantly in the first quarter as excess stockpiles created during the global economic malaise of 2012 were cleared away, done in anticipation of a resurgence in consumer demand for electronic products expected by the second half of 2013.

Semiconductor makers' inventory in the first quarter declined to $37.6 billion, down 4.6% from $38.4 billion in the fourth quarter of 2012, according to a Supply Chain Inventory Brief from information and analytics provider IHS. The graph presents the IHS estimate of inventory held by semiconductor suppliers in terms of revenue.

The decline in inventory paralleled the contraction in semiconductor revenues, which fell 5.1% sequentially, following the normal seasonal demand pattern.

"While overall chip revenue declined in the first quarter, falling inventories among chip suppliers—combined with expanding stockpiles at distributors, contract manufacturers and original equipment manufacturers (OEM)—indicate that consumer demand for electronics rose during the period," said Sharon Stiefel, analyst for semiconductor market intelligence for IHS. "This contributed to a decline in chip inventories. At the same time, semiconductor companies maintained tight control over their manufacturing capacity, contributing to the decline in inventory."

Signs of Strength from PC and Cellphone OEMs

Throughout the electronics supply chain, the largest increases in inventory were posted by cellphone and PC OEMs. Cellphone makers expanded their inventories—including finished smartphones—by 7.2% during the quarter. For their part, PC OEMs expanded their stockpiles of items including notebook and desktop computers by 6%.

The increase in OEM, contract manufacturing and distributor inventories during the first three months of the year contrasted sharply with the fourth quarter of 2012 when these segments trimmed their stockpiles.

"The rise in inventories among the various segments of the supply chain indicates the electronics industry is preparing for an increase in demand during the second half of 2013," Stiefel said.

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August 27–29, 2013
IPC APEX India™
Bangalore, India

September 10–12, 2013
IPC Conference on Component Technology: Closing the Gap in the Chip to PCB Process
Sponsored by Amkor Technology, Inc.
Chandler, AZ

September 24–26, 2013
IPC Technology Market Research Conference & Management Meetings
Chicago, IL

October 12–17, 2013
IPC Fall Standards Development Committee Meetings
Co-located with SMTA International
Fort Worth, TX

October 16, 2013
IPC Conference on Assembly and Reliability
Bangkok, Thailand

November 12–13, 2013
7th International Symposium on Tin Whiskers
Hosted by IPC and CALCE
Sponsored by Lockheed Martin
Costa Mesa, CA

November 13–14, 2013
IPC Conference on Solder and Reliability: Materials, Processes and Test
Costa Mesa, CA

December 4–6, 2013
HKPCA International Printed Circuit and IPC APEX South China Fair
Shenzhen, China

More Information
www.ipc.org/events

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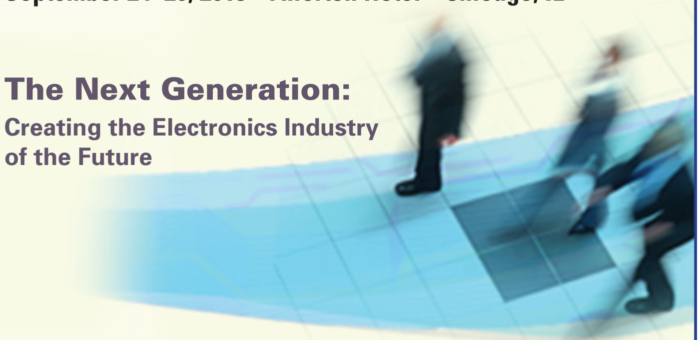
IPC Technology Market Research Conference & IPC Management Meetings
September 24–26, 2013 • Allerton Hotel • Chicago, IL

The Next Generation:
Creating the Electronics Industry of the Future



The IPC Technology Market Research Conference (TMRC) & IPC Management Meetings are the only events of their kind in the electronics industry that provide a high-level perspective on technology, market trends and management issues for senior-level decision-makers. Geared for the executive, these events will give you a unique view of the industry so you can take action. It's the one venue where you can:

- Discover how key technology drivers will impact your industry segment.
- Get a preview of emerging market trends … and what they will mean for your business.
- Hear from leading technologists on new advancements and their impact on industry needs.
- Meet with other decision-makers from the supply chain and work on solutions to industry challenges.
- Network with potential customers and suppliers who can provide the answers you need.

No other event will provide you with this type of information or allow you such access to other industry executives.

Management Meetings — September 24
TMRC — September 25–26

For more information, visit www.ipc.org/tmrc-mm
or contact Susan Filz, IPC director of industry programs.

Questions? Contact IPC registration staff at +1 847-597-2861 or registration@ipc.org.

SMTonline Market News Highlights

Promising Future for U.S. Semiconductor Manufacturing Market

Six years ago, the outlook for U.S. semiconductor manufacturing was dim and dimmer. At the time, Intel was building their Dalian fab, AMD was ramping up their Dresden facilities, TI was transitioning to a fab-lite model, and the U.S.-based fabless giants were growing their business through foundries based in Asia. It was common for people to see semiconductors like other manufactured goods, inevitably moving to Asia, just another example of merciless globalization.

Printed Electronics to Become Integral Part of Our Lives

CETEMMSA's study reveals that in 2020 printed electronics will become part of our lives with products like electronic skin, electronic human tissues and organs, or architectural urban elements which react to external stimuli. By 2030, we will have digital food and will regularly use aerospace commercial transport thanks to the use of printed electronics in different sectors. The printed electronics industry will reach EUR 60 billion turnover in 2020. The aim of printed electronics is to make electronics flexible by printing different components, including sensors, circuits, batteries, or LEDs.

3D Printing Poised to Grow Across All Markets by 2025

3D printing has come of age, surpassing $1B in revenues during 2012 and with growth expected to continue across all target markets to 2025. Across the board printer manufacturers are reporting a surge in sales, some cannot meet demand, as awareness of the technologies and what they offer grows.

Data Science to Impact Medicine More Than Drugs

"In the next 10 years, data science will have more to do with improving medicine than anything you will ever learn in medical school or anything currently being researched in the laboratory," said Frost & Sullivan Partner Reenita Das during her keynote presentation at the 12th International BIOtech Exhibition and Conference.

Global Mobile Memory Revenue Down 5.2% in Q1

According to DRAMeXchange, a division of global research firm TrendForce, total 4Q12 revenue for the mobile DRAM industry grew 21.4% from the third quarter and reached US $2.74 billion, boosted by climbing shipments of low to mid-end smartphones as well as seasonality. In the first quarter of 2013, however, revenue fell to US $2.6 billion, a quarterly decrease of 5.2%, due to the effects of the off-peak quarter.

Indicators Suggest Weakening Business Activity

Manufacturing firms responding to the monthly Business Outlook Survey suggest that regional manufacturing activity weakened this month. All of the survey's broadest current indicators were negative this month, indicating weaker conditions compared with April.

Global Automotive Electronics Market to Reach $314.4B by 2020

The global market for Automotive Electronics, estimated at US$191.3 billion in 2013 and forecast to be US$204.6 billion in 2014, is further projected to reach US$314.4 billion by 2020, thereby maintaining a CAGR of 7.3% between 2012 and 2020.

Global Semiconductors Sales Hit $23.62B in April

The Semiconductor Industry Association has announced that worldwide sales of semiconductors reached $23.62 billion for the month of April 2013, a 0.6% increase from the previous month when sales were $23.48 billion, but down slightly from the April 2012 total of 24.06 billion.

Digital X-ray Market to Hit $4.82 Billion in 2018

The digital X-ray market is driven by technological advances in automation, growing numbers of elderly people, and need for improved and faster imaging methods. The growing incidence of chronic disease like tuberculosis, pneumonia, and other gastrointestinal disorders are propelling the market in both developed and developing countries.

DRAM Industry to Witness Steady Growth in 2014

According to TrendForce, a global market research firm, PC DRAM prices have shown noticeable signs of rebounding in 2013, following two years of financial losses and declining output value. The prices of mainstream products like 4GB modules rose by nearly 60%, which helped to ease the declining ASP of both server and mobile DRAM.

EVOLUTIONARY SOLUTIONS

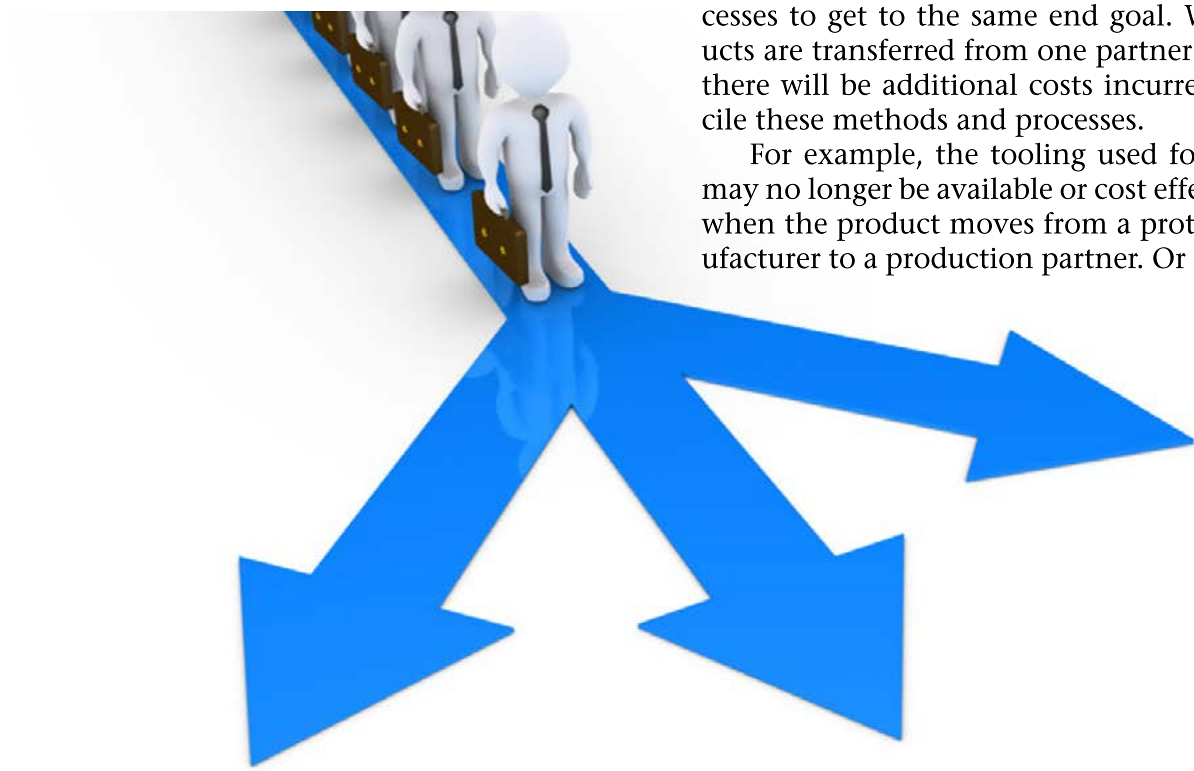
Choice Solutions

by Karla Osorno
EE TECHNOLOGIES, INC.

Electronics are the lifeblood of modern society (SMT Magazine, December 2012). But if you want to make products that depend on this lifeblood to function, then you face a lot of challenges. Often, you need to work with different partners for design, prototyping, and manufacturing of electronic assemblies—all of which slows your time to market. If you have to send your manufacturing operations to the Far East to keep them cost-competitive, it complicates your logistics and also puts you at risk for suffering losses through foreign counterfeiting. And changing manufacturers can quickly get prohibitively complicated and expensive. As an OEM, understanding these challenges will help you to navigate through them and choose the right partner.

Different Partners

OEMs looking to outsource manufacturing to EMS providers do so for financial and logistical reasons. They are looking for a partner to take over the daily management and activities of manufacturing operations.



Many OEMs choose to focus on their core competencies and outsource design, prototyping and manufacturing of electronic assemblies. If the OEM has to outsource to three different partners—one for design, one for prototyping, and one for manufacturing—then it becomes more challenging. Now you are dealing with three different teams with different management, policies, and capabilities.

Another major factor is the costs related to transferring from design to prototyping and from prototyping to manufacturing. Some of these costs relate to tooling, manufacturability design changes, documentation and communication. Adding to the challenge, many are duplicate costs, meaning the OEM pays for each partner who incurs the costs and builds it in to overhead rates or direct bills the OEM.

Each partner has unique methods and processes to get to the same end goal. When products are transferred from one partner to another, there will be additional costs incurred to reconcile these methods and processes.

For example, the tooling used for a product may no longer be available or cost effective to use when the product moves from a prototype manufacturer to a production partner. Or it may have

been developed for small runs rather than for long-term use. Or it may be heavy and impractical to transfer the tooling to the new partner.

There will also likely be design improvements based on manufacturability that may not make it back to the original customer documentation. The changes may be customer approved and updated at the contract manufacturer location, but due to cost and organizational restraints, the customer chooses not to update the original documentation. Thus, the prior revisions that are no longer current get sent to the new partner. This is unfortunate and costly since the OEM paid for the changes and will ultimately pay again.

Verbal instructions and internal manufacturing documents would not be transferred either. So the new partner must learn from production experience the same lessons learned by the previous manufacturer—and the OEM has again paid twice for the same information.

Communication methods and styles are developed during regular communications between OEM and its partners. When partners change then this communication has to be developed between the OEM and the new partner. Again, the duplication of costs will often show up in additional time and production delays.

This duplication of effort has a price and the OEM ultimately has to pay it.

Offshoring

Some products are perfect candidates for sending offshore to be manufactured in low cost regions of the world. OEMs that make this decision have typically counted the cost and determined that offshore is the best option. However, this practice carries risks and often uncalculated qualitative costs.

Logistics get significantly more complicated when the product is being manufactured overseas. Many factors including language, time zones, culture, communication styles, communication barriers, and transit times add to the complexity and therefore, the costs.

Collaboration is a challenge because of geographic distances and time zones. The size and weight of the product is a major factor in both shipping methods and costs. Access to raw materials is another consideration. And cost advantages have to be enough to offset slower delivery times and less responsiveness.

Risks of counterfeiting also exist. Management oversight to help protect intellectual property is more challenging with overseas production. And protection of proprietary designs takes on a whole new meaning when dealing with another country and its unique and foreign legal systems.

Some OEM companies are choosing to reshore their products to avoid this challenge (SMT Magazine, May 2013). Definitely, choosing the right partner can minimize the risks and costs associated with offshoring.

Changing Manufacturers

Mistakes will happen. However, when complete breakdowns in controls, communication, or results occur then drastic action is needed. The partnership is not going well and it is necessary to make a change. This change may be qualifying a second source or it may mean completely changing to a new supplier. The challenges of changing manufacturers to an OEM will be similar to the challenges of having different partners, but significantly magnified.

Costs related to tooling, design for manufacturability changes, documentation and communication will be incurred. Additionally, there will be other challenges including maintaining production during the transition. Customers still need to be served regardless of supply chain issues.

Some other challenges include making decisions about the timing of the transition and about the number of products to transfer. Many factors will impact this decision. Definitely the severity of the quality issues from the previous partner will have the largest impact. The options and timing for qualifying a new supplier have a large impact also.

When possible, OEMs will want to transfer small runs of the most critical products to the new partner after qualification has been finalized. When these specific final products are deemed qualified, more production can be transferred. At times, multiple products will be transferred at the same time. Generally, there is a schedule of product transfer created and communicated to the new partner.

The previous partner may or may not be told of the schedule depending on whether the communication will be detrimental to product deliveries. If the manufacturer is aware that they are losing the business they may cut ties and leave the OEM in a critical position. This assessment must be made and is an example of an OEM challenge when changing manufacturers.

Solutions

If you really want to achieve quick time to market you need a partner with extensive manufacturing capacity who you can also turn to for custom design expertise as well as turn-key product development that is based on your specifications. A single integrated design engineering and manufacturing partner you can depend on for high-quality, cost-effective and on-time product delivery. OEMs want to choose a proven and experienced partner to minimize these challenges.

One solution is to choose an industry-leading electronics manufacturing and development firm that specializes in full-service circuit board design and assembly for your segment. Choose a company that provides the strictest process and quality controls. Choose a company that offers in-house engineering and prototyping services, which will drastically reduce your development time and expense. Choose a company with extensive experience helping you switch manufacturers. In fact, choose a company that can handle most all the details for rapidly transitioning multiple product lines so you can quickly optimize all of your manufacturing operations to reduce costs and improve quality. Choose the company that offers solutions instead of more problems. Whatever you do, choose well. **SMT**

Karla Osorno is business development officer for EE Technologies, Inc., an EMS provider delivering complete engineering and manufacturing services with locations in Nevada and Mexico. To read past columns or contact Osorno, click here.

TOP TEN

News Highlights from SMTonline this Month

① GE Invests $4.3M in New PCBA Facility in Nevada

GE's Measurement & Control business has opened a printed circuit board assembly (PCBA) center to provide prototypes and testing for all measurement & control products. Located in GE's Bently Nevada facility in Minden, Nevada, the center's state-of-the-art surface-mount assembly line represents a $4.3 million investment in quality and productivity.

② North American EMS Market Forecast: $69 Billion in 2013

IPC findings indicate that EMS market growth has been volatile in response to economic trends. It is expected to continue growing slightly faster than most other segments of the electronics supply chain due to increasing OEM outsourcing, with modest growth expected to continue this year.

③ Celestica Names Winners of 2012 TCOO Supplier Award

Celestica Inc., a global leader in the delivery of end-to-end product life cycle solutions, has announced the winners of its 2012 Total Cost of Ownership Supplier Awards. The awards honour suppliers who provide the best TCOO performance to Celestica and its customers by demonstrating excellence in quality, delivery, technology, service, pricing, and flexibility.

④ Creation Technologies Achieves FDA Registration Approval

"Requirements for the medical devices that Creation designs and builds are becoming increasingly complex," said Creation-Mississauga General Manager Mark Krzyczkowski. "More and more of our customers are taking advantage of the full suite of services that we offer, and so our grasp of their needs has had to become very sophisticated."

5 Walt Hussey New COO of OnCore Manufacturing

OnCore Manufacturing, LLC, a global supplier of EMS, has appointed Walt Hussey chief operating officer. He joins the executive staff and will lead the extended global operations organization encompassing eight manufacturing sites in the U.S., Mexico, and China.

6 Medical EMS Market Benefits from Rise in OEM Outsourcing

The medical EMS market is benefitting from an increase in OEM outsourcing. Increases in electronic content, costs, wireless connectivity, and convergence have encouraged OEMs to view EMS providers as strategic partners. This research service discusses the trends for growth, challenges, services, and products. Analyses are included for forecasts, geography, the competitive environment, and vertical markets.

7 CTS Aims for Future Growth; Restructures, Repatriates Funds

To improve capacity utilization and operating profit on a go-forward basis, CTS Corporation will simplify its global footprint by consolidating manufacturing facilities into existing locations. This process has already begun in Singapore. The company will also repatriate approximately $30 million to the U.S. from Singapore.

8 CBA Report Evaluates EMS Industry's People Skills

"In the EMS industry, with its low barriers to entry and where many companies were started by engineers, there is an even greater need for attention to 'people skills' to find competitive advantage," explained Eric Miscoll, Ph.D. and SPHR, lead researcher on the project.

9 Efore's Q2 Sales Down; Rest of Year Looks Strong

Efore's president and CEO comments, "Profitability and efficiency improvement measures are progressing well and, after full implementation, we estimate reaching positive results from operating activities with approximately EUR 15 million net sales per quarter."

10 SMTAI 2013 Program Finalized; 18 Courses to be Offered

SMTA International will be held at the Fort Worth Convention Center October 13-17, 2013. This year's program allows attendees to choose from 18 courses, 130 technical papers, four focused symposia, and numerous free offerings throughout the conference and exhibition. New this year, IPC will co-locate its Fall Standards Development Committee Meetings October 12-17.

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 of events, check out *SMT Magazine's* full events calendar here.

Micromachine/MEMS
July 3-5, 2013
Tokyo Big Sight, Tokyo, Japan

Thermotec 2013
July 3-5, 2013
Tokyo, Japan

NANOTEXNOLOGY 2013
July 6-13, 2013
Thessaloniki, Greece

6th International Symposium on Flexible Organic Electronics (ISFOE13)
July 8-11, 2013
Thessaloniki, Greece

Printed Electronics Asia 2013
July 9-10, 2013
Tokyo, Japan

Semicon West
July 9-11, 2013
San Francisco, California, USA

ITAR and EAR: How Will Export Control Reform Impact Your Business?
July 9, 2013
Webinar

Ohio Valley Expo & Tech Forum
July 11, 2013
Cleveland, Ohio, USA

Surface Mount Rework of BGA, PoP, CSP & QFN Components
July 11, 2013
Dublin, Ireland

Techno-Frontier 2013
July 17-19, 2013
Tokyo, Japan

ISMSE 2013
July 27-29, 2013
Singapore

Microscopy & Microanalysis 2013
August 4-8, 2013
Indianapolis, Indiana, USA

Philadelphia Expo & Tech Forum
August 15, 2013
Cherry Hill, New Jersey, USA

IPCA EXPO-2013
August 29-31, 2013
Gujarat, India

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Next Month in *SMT Magazine*

High-Density Packaging

The August issue of *SMT Magazine* brings you the low-down on high-density packaging :

- Assembly challenges associated with new leadless packages
- Package-on-package (PoP) techniques
- Flip-chip techniques
- Embedded active components
- Packages for mobile devices
- New packaging trends and strategies

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