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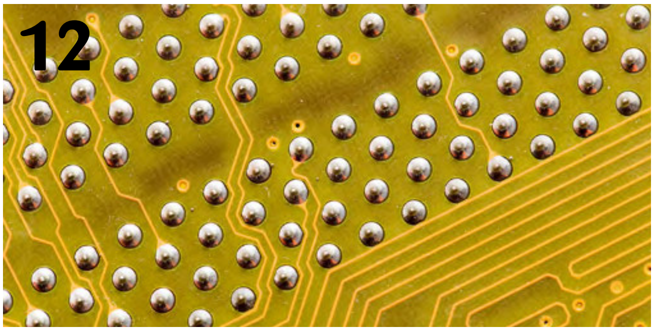

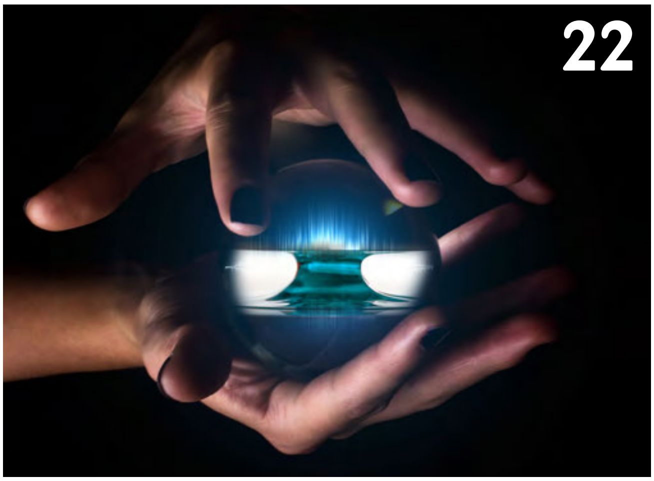

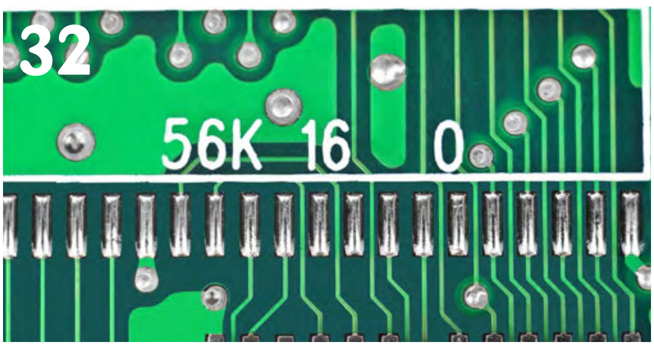

Soldering Excellence: A Tangled Web Indeed!

It is of the utmost importance that the soldering process should be perfect. But soldering is just too complex a process, and further complicating the situation, the requirements and technologies vary between our industry's market segments. This month, *SMT Magazine* looks into some of the different factors and challenges impacting yield when it comes to soldering, and provides strategies on addressing them.

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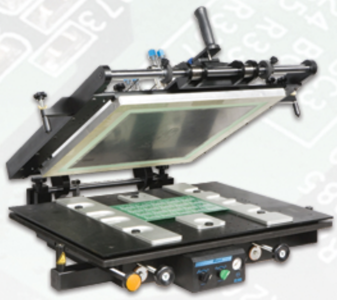

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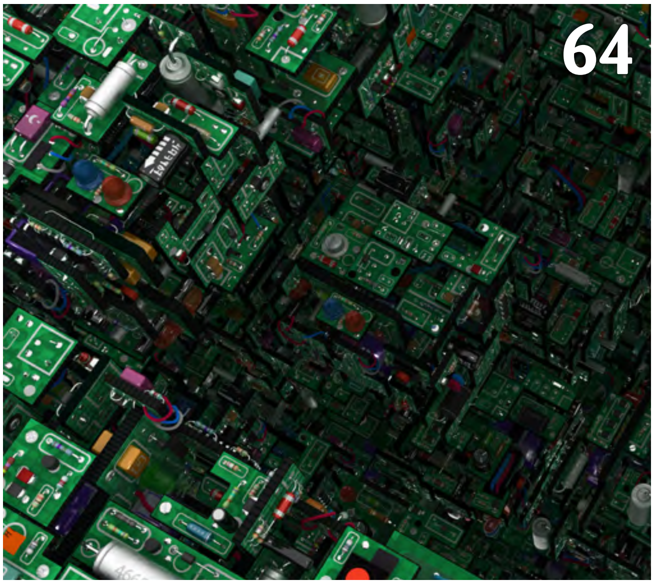

More Content:

What a Tangled (Soldering) Web We Weave!

by Stephen Las Marias
I-CONNECT007

Soldering remains one of the most critical processes in the PCB assembly industry as it "makes or breaks" a finished product—figuratively and literally (for one, cracked solder joints on a circuit board were said to be the main contributor to the fatal crash of Indonesia AirAsia flight QZ8501 on December 28, 2014). The cost of failure is just too high.

Therefore, it is of the utmost importance that the soldering quality should be perfect. But the thing is, soldering is just too complex a process, and further complicating the situation, the process, materials and technologies vary between our industry's market segments. There are just a lot of factors to consider before you put your boards into the reflow and let them run. Soldering for different end-markets or applications—military/aerospace electronics, automotive electronics, medical electronics, or consumer electronics—have their own set of requirements. The military/aerospace sector, for one, still uses leaded solder, while the rest have moved on to lead-free. According to our recent survey on soldering, there are myriad factors to consider based on the different end markets. There's the increased inspection when it comes to high-reliability applications; thermal considerations; solder paste, bar and flux considerations; coating selection; equipment; and the cleaning process, to name a few.

And then there's the issue of solder paste selection or qualification. In our soldering survey, respondents highlighted challenges such as rheology of the paste, consistency, type of solder to use, cleanliness—or ensuring their current cleaning processes can remove the fluxes, printability, and even the "irrational customer preferences." There's a paralysis of choice as there are too many choices and fine differences to account for when selecting a solder paste.

When it comes to their greatest challenges, respondents to the survey highlighted thermal issues, solder selection, reflow profiles, voiding, component size variations, rework, and inspection, among others.

Still, there seems to be a misconception when it comes to no-clean flux, as about 23% of the respondents in our survey believe that using no-clean flux will result in "bright and shiny solder

joints" and will save them from cleaning costs as there should be no residues left on the board. Of course, with no-clean fluxes available for quite a long time now, a third of respondents know that using it doesn't necessarily mean clean boards, but they said they still clean their boards especially when they are used in aerospace applications.

The soldering process offers issues and challenges so wide and complex that it would require a book to discuss in detail. Even then, new market trends will continue to drive the evolution in the soldering process and developments in new solder technologies.

Having said that, this month's issue of SMT Magazine highlights some of the common challenges that manufacturers face when it comes to soldering, and provides strategies to help address those issues.

First, we have an interview with industry veteran Happy Holden and Saline Lectronics' Cathy Cox, who discuss the current soldering landscape and issues that assemblers face, and what they think the industry needs to be successful on this front.

Next, a paper from Alpha Assembly Solutions' Mitch Holtzer, Karen Tellefsen and Westin Bent, explains rheology measurement as a predictive tool for solder paste transfer efficiency and print volume.

We also have an article on voiding control at high-power die-attach preform soldering, contributed by Dr. Ning-Cheng Lee, Dr. Arnab Dasgupta and Elaina Zito of Indium Corporation.

MicroCare Corp.'s Venesia Hurtubise, Elizabeth Norwood and Wells Cunningham, have contributed an article on strategies to remove difficult lead-free and no-clean fluxes from PCB assemblies.

We also have an interview with OK International President and CEO Christopher Larocca, who discusses how their new soldering technology will disrupt the hand soldering world.

Our columnist Rich Heimsch, meanwhile, focuses on solutions for long-term storage of electronic components.

Last, but not least, is the second part of my interview with the EMS firm Virtex. In this interview, Brad Heath and Upinder Singh talk about the company's military and aerospace business and how they are addressing their customers' requirements.

Next month, we will talk about one of the key issues facing the PCB assembly/electronics manufacturing industry: hiring, nurturing and retaining talent. Watch out for it! **SMT**

Stephen Las Marias is managing editor of *SMT Magazine.* He has been a technology editor for more than 12 years covering electronics, components, and industrial automation systems.


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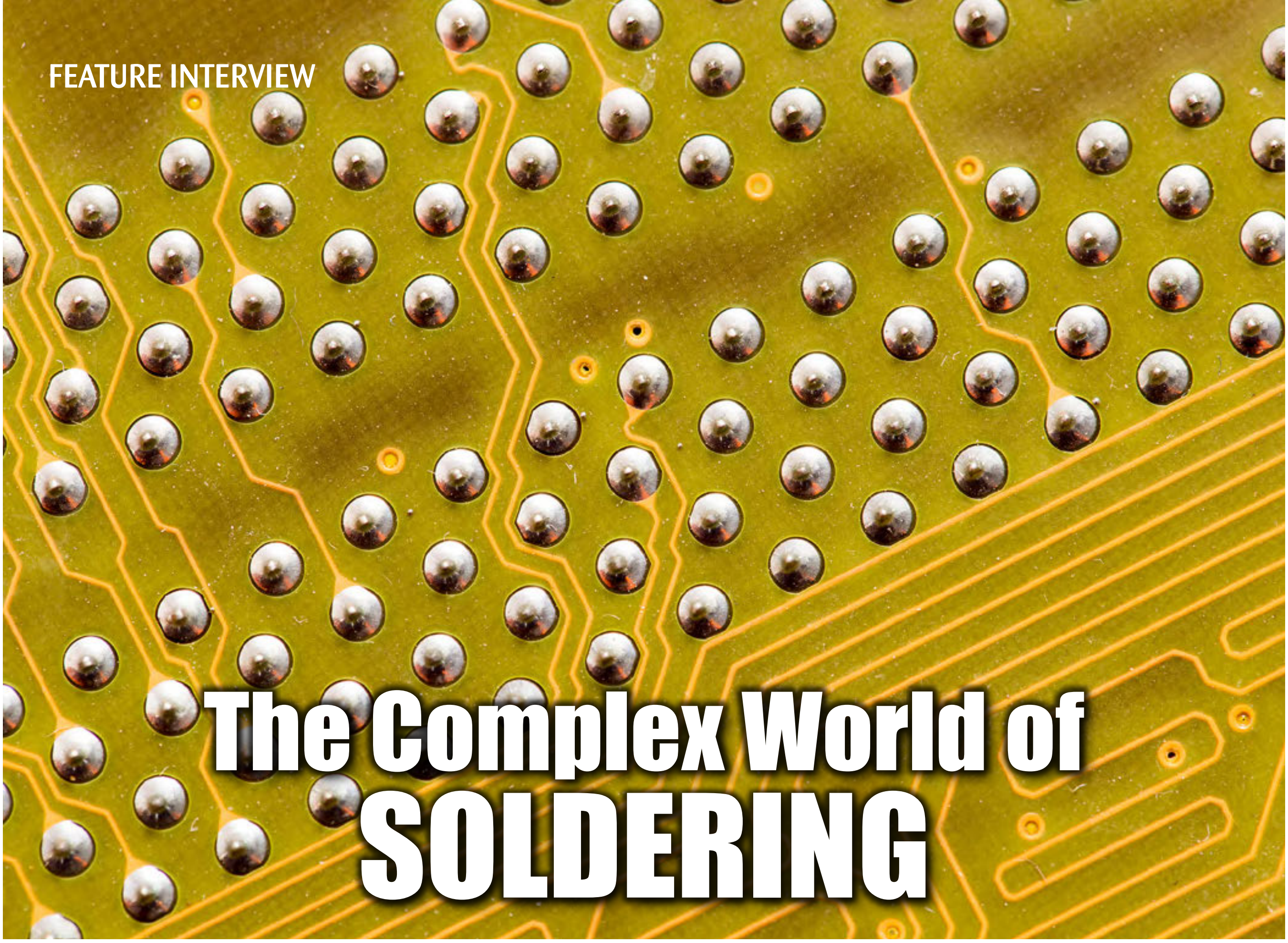


The Complex World of SOLDERING

by Stephen Las Marias
I-CONNECT007

Industry veteran Happy Holden and Saline Lectronics Senior Process Engineer Cathy Cox, discuss the various challenges and issues that users face in soldering, including the lack of a 'one-size-fits-all' approach in the process, and some key factors that the PCB assembly industry should consider when it comes to different applications and markets.

***Stephen Las Marias:** What do you think are the greatest challenges when it comes to soldering in PCB assembly?*

Cathy Cox: I would have to say our challenges are temperature. Temperature is a big problem with the flex boards. With the circuit board being so thin, actually getting the right temperature to be able to run them through a reflow is definitely a challenge.

Happy Holden: Picking a final finish that's compatible with the solder that you picked in the flux. There's no one answer that fits all. So picking that, and then you might say defending it—when people are selling different combinations—is a pretty big challenge, especially when not all the criteria for evaluation and testing is readily available. I've come to learn that the wetting balance really isn't reliable to use that much anymore.

Our end-use applications are so diverse that when you talk about any particular subject, it's tough for people to apply. 'Does this apply to me or is he talking about the other guy over there?' For instance, flex assembly and soldering is a particular challenge; but when I think of soldering, I think of rigid boards and I think of standard size thinner ones. When you get to really thick—over 2 mm—type boards, getting lead-free solder up to a milling temperature is a real challenge. There, you have to worry about the materials you built the boards for. It's a huge industry, and how you carve it up is part of the challenge.

My life for years has been in automotive electronics. The company I work for is one of the highest volume assembler of automotive electronics in the Western hemisphere. Soldering is not really a problem except for new de-

vices, QFNs and things like that that are coming on the market. It's a process that's running extremely smooth.

Las Marias: ***Do you think lead-free soldering continues to be an issue when it comes to reliability?***

Holden: The industry has already moved to lead-free soldering. That was done a long time ago. It's only the military and avionics and a few hold outs that haven't moved to lead-free. I talked to people at the APEX show that were in the military, and they realize that their time is running short because they have fewer and fewer people who support them. If you're going to lead-free then, unlike tin lead where there wasn't much variety, now you've got a whole proliferation of solders and different compatibility with final finishes, and different suitability for reliability life. That's one reason why it's so difficult because depending on what you're assembling for, the answers maybe different.

Happy Holden

Cox: I totally agree with Happy. At Saline Lectronics, the majority of our customers are doing lead-free. Lead-free is definitely more of a challenge with flex boards just due to the temperature. Getting good solder joints is definitely a challenge, but it's a challenge that most companies are up for, so it's good. We need new things in our industry.

Las Marias: ***Do miniaturization, increased board densities, and shrinking component sizes impact the soldering process from your perspective?***

Cox: I don't know if they necessarily affect it from what I can see. We deal with a lot of the 0201s. We're pretty excited to get our hands on 01005s and start playing with them and see if our pick-and-place machines can handle them. We'll need more precise placements to be able to make sure you get a good solder joint. It will be a little bit more challenging for an operator to manually inspect a board with solder joints being so small. But we have our high-tech AOI equipment, so that should not be a problem for us.

Patty Goldman: ***So, you don't see very many of those types of components?***

Cox: We see very small components all the time, but the smaller they get will be a challenge. I don't think it's a challenge that's going to stop us from doing anything. It's just a different way of looking at it; it's a different way of manufacturing it. You have to have more precise placement, make sure the thickness on your solder paste machines are proper, and I think it's going to be awesome.

Goldman: ***What's your biggest bugaboo then?***

Cox: Our biggest with flex boards would actually be our pallets that we use in surface mount to keep our boards flat during the reflow. We can set pallets up for all different types of boards, but getting one to fit completely flat in there every time, and make sure the components are going to sit flat when they go through reflow, is a challenge. Most of the time, it's the bigger components that we see issues with because there's a bigger area to have a bubble in the flex board.

Las Marias: ***Is solder jetting catching up with the paste printing process?***

Holden: My last six years have been in high-volume production, and solder paste printing and the integral AOI machines are going to be tough to match in terms of jetting. Jetting may be much more applicable to high-mix, low-volume, but for the high-volume automobile market, mobile phones, consumer products, paste printing is pretty well defined and highly robust. Jetting maybe coming along, but it will have a hard time matching the fancy step stencils and some of the other techniques developed in stencil printing. But it may be totally adequate for high mix. I've never seen or we've never used any jetting equipment except for

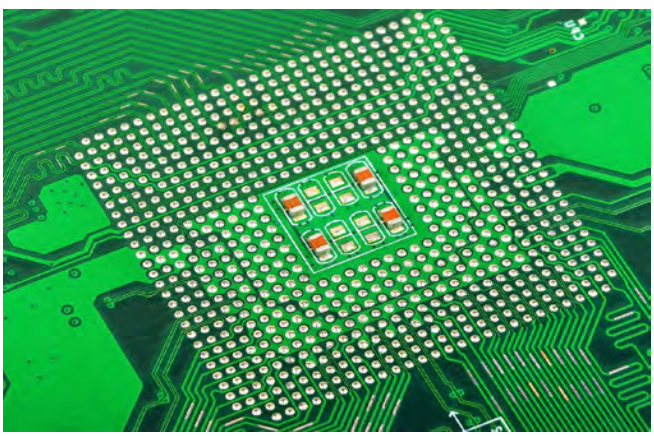
inkjet printing or solder mask printing in the PCB area. I don't have a lot of experience with it, but any kind of jetting like that, be it inkjet, solder mask, or solder, really has not met the needs of volume manufactures to be cost-effective, not yet. It's for the prototype or high mix.

Las Marias: Does solder paste selection or qualification still matter today despite the standard solder types used in certain applications?

Holden: Yes, because they're constantly improving solder paste and things like that. You're kind of always evaluating tweaks and minor improvements to see what it does, especially when one of our focuses in the past has been voiding and the micro-voiding you had with lead free. We haven't rejected products but we'd liked to eliminate it. Those are constantly minor tweaks in the formulation of the solder paste and the refill profile.

Las Marias: I understand solder voiding is still a big issue in the industry. Cathy, how do you tackle voiding?

Cox: We go with Indium solder paste. We have a really good connection with them. They help us through a lot of our issues with incisions, voids, stuff like that. We have been trying a few things here in our shop with changing the amount of paste that we put on a stencil, removing the mask around the pads so that the air can actually escape between the component and the solder pad. We've seen some success with that. The IPC standard keeps getting more and more vague on voiding under QFNs



or even in through-hole components. We took it upon ourselves to kind of set our own standards, making sure that we have anything under 25% under a component or within a barrel fill. With our window pane and with reducing the solder mask around the pads, we've been successful in minimizing voiding to about 25% with our QFNs, BGAs.

Our biggest struggle is making sure that if you call a component out, your footprint should actually meet what the manufacturer of the component recommended. We do run into quite a few times here where the customer will call out a part, and it doesn't quite fit, which means that you don't get proper solder joints, you don't get the heel fillet that you want, or the side joints that you want. Then they don't meet IPC standards. It's a struggle to keep going back and forth between the customer and the manufacturer trying to make sure the component still functions. So verifying that you're setting your board up for success with proper pad size would be a good thing for customers to know.

Las Marias: What else do you think should the readers know more about when it comes to soldering?

Holden: Some of the effects that different formulations of lead-free solder paste has when it's reflowed, in terms of interacting with final finish and interacting with land size, is that they don't spread like tin lead, and we find smaller pad sized footprints because it's a stronger joint than tin lead. We've always watched very closely the Japanese and the JPCA standards, because they've been using lead free for 10 years longer than North America. Since a third of all of our output goes to Japanese automakers, we've got a lot of cooperation with Nissan, Honda, and Toyota about what they recommend.

Las Marias: Standardization is still an issue?

Holden: It's all a point of view. Like I said, we're such as big industry that I've been talking about automotive electronics, which were going for a 15-year useful life—and that's a lot different than a mobile phone. We virtually test 100% of every lot because the Japanese or the German

auto companies insist on that. If we ever have a failure, we have to go back into root cause analysis. A lot of my experience deals with reliability because warranty failures and things like that is a big bugaboo in automotive. But depending on which industry you're in, there's a lot of differences. Most mobile phones don't make it past two years before they've been dropped in the toilet, run over, or just that everybody turns them in for the new models.


Cathy Cox

You have to support your customers, and not all customers have the same needs. It's the final performance that our customers required. They weren't dictating a design or a process, only the final performance, whereas if you're an EMS and you have multiple customers, you have to keep shifting it all the time depending on what the requirements are. We still have wave solder machines. They're lead-free, but they're still wave solder.

Cox: We do too. We do a lot of military and oil and gas that we build predominantly through-hole. We have a lead one and a lead-free.

Holden: Lead-free is a lot tougher than the tin lead.

Cox: Yes. I was thinking about it and a lot of what I've experienced here in the last couple of years is our customers will sometimes call out to use a lead-free no clean solder on their boards. Then they are upset with us that their boards do not look clean and the solder looks to be disturbed. Really, the industry needs to know having a lead-free solder is going to look more grimy than using leaded solder. They look different. A no-clean solder doesn't necessarily mean that it's going to be clean. You're going to have residue there, but it's not active flux residue. The different types of solder that you run into along the way, whoever you use should talk to you about the way your solder is going to look before you actually put it on the boards. I think that's a big thing. Our customers come back and say the boards are dirty, but they're not. They meet IPC standards and they use a no-clean flux, which will leave slight residue on their boards.

Holden: That's one thing I can't ever remember reading or seeing: a breakdown of the soldering industry by what all of the different types of solders look like, in terms of a picture, whether clean or no clean. Then, their interaction with final finishes, and then what industries they are preferred by in terms of a matrix. A lot of people tend to get confused, because if you're talking about the communications industry, that may not apply to the consumer industry; or when we're talking about automotive, that might not apply to medical. You haven't always seen these things. Nobody's ever come out and given us matrix of what they're supposed to look like, and maybe what the estimated life is in terms of their interaction with land patterns, with final finishes, and with percent of voiding. That chart or definitive explanation has not been out there.

Cox: I agree. A lot of customers I know say, 'Oh, if I have the choice between the no clean or the aqueous, I want to go with the no clean because that means my board will be clean.' But in reality, it means that you don't need to clean the board because the residue that's left isn't active. You will actually have a cleaner board, appearance-wise, if you use an aqueous flux. Then you can wash it and there is nothing left behind. That's something we struggle with over here a lot with our customers. It's just a miscommunication of what they're actually using, what the product is doing, and how it's going to look.

Las Marias: Cathy and Happy, thank you so much again for your time and your insights.

Cox: Thank you.

Holden: Sure. **SMT**

MilAero007 Highlights

Jabil Adds Aerospace and Defense Precision Machining Capabilities

Jabil Circuit Inc. has acquired the assets of Lewis Engineering, a contract engineering and precision machine shop for rapid prototyping and manufacturing aerospace products, turbine engine components and industrial pumps.

Kitron Gets Communications Order from Kongsberg

Kitron has received a NOK 120 million order from Kongsberg Defence Systems (Kongsberg) for military communications equipment. The equipment to be supplied is related to a contract for deliveries to KONGSBERG portfolio of projects in communication equipment.

Nortech Systems Reports Modest Sales Drop in Q4 FY 2016

Nortech Systems Inc. reported net sales of $29 million for the fourth quarter ended December 31, 2016, compared with net sales of $31.4 million for the fourth quarter of 2015. Net sales for the 2016 fiscal year rose 1% to $116.6 million, compared with $115.2 million reported for fiscal 2015.

ERAPSCO Awarded $64.6M U.S. Navy Sonobuoy Contract

ERAPSCO, a joint venture between Ultra Electronics Holdings plc and Sparton Corp., has received subcontracts valued at $64.6 million for the manufacture of sonobuoys for the United States Navy.

Kyzen Hosts Successful Aerospace Solvent Seminar

Leaders in the aerospace industry recently gathered at Kyzen corporate headquarters for in-depth training on chemistry benefits. Kyzen hosted an educational seminar on Wednesday, February 22, 2017 at its headquarters in Nashville for the aerospace industry.

Etek Europe Celebrates 10th Anniversary

Etek Europe recently celebrated its 10th anniversary last month. The event was honored with the presentation of a crystal decanter, and a cake replica of Etek's Technology Center.

Cicor Posts Record Order Intake and Successful Turnaround in 2016

Cicor was able to get back on track again in the second half of the year after a difficult first six months. Turnover in the last financial year was CHF189.5 million, 4.9% above the previous year.

ACDi Moves to New Facility in Maryland

EMS firm American Computer Development Inc. (ACDi) recently moved to a new, more streamlined facility in Frederick, Maryland. The modernization and efficiency of the new facility positions ACDi for Industry 4.0 improvements, helping them evolve into a smart factory.

Riptide Integrates Sparton's AHRS Technology into UUVs

Sparton Corp. has integrated its industry-leading Attitude Heading Reference System (AHRS) products on Riptide Autonomous Solutions unmanned undersea vehicles (UUVs). Riptide chose Sparton's revolutionary AHRS M-series due to the product's ability to deliver another level of navigation precision in a very small form factor at low cost.

Libra Industries Embarks on Continuous Improvements in 2016

EMS firm Libra Industries has spent more than $636,000 on continuous improvements in 2016 as part of the company's ongoing quality efforts.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Predicting Solder Paste Transfer Efficiency and Print Volume

by Mitch Holtzer, Karen Tellefsen and Westin Bent
ALPHA ASSEMBLY SOLUTIONS

Industry standards such as J-STD-005 and JIS Z 3284-1994 call for the use of viscosity measurement(s) as a quality assurance test method for solder paste. Almost all solder paste produced and sold use a viscosity range at a single shear rate as part of the pass-fail criteria for shipment and customer acceptance respectively.

As had been reported many times, an estimated 80% of the defects associated with the surface mount technology process involve defects created during the printing process. Viscosity at a single shear rate could predict a fatal flaw in the printability of a solder paste sample. However, false positive single shear rate viscosity readings are not unknown.

Intuitively, solder paste is subjected to several shear rates during the printing process. A squeegee forcing paste into an aperture may be the highest, and most critical strain rate applied to solder paste during the process. Separation of the stencil from the printed circuit card may be the second most important. Paste interaction with the squeegee is also a critical step for a high yield process. Very low shear force behavior may be an indicator of the potential for slumping. Using a cone and plate fixture on a variable speed rheometer, this study will examine the correlation between rheology and print volume and print volume repeatability of the pastes. The goal is to determine if a specific set of viscosity vs. shear strain rate curves can predict the defect rate of a solder paste, and possibly create a more accurate prediction of the solder pastes value in use to users. The expectation is that this work will lead to a rich sequence of further valuable studies.

Introduction

Being able to predict the transfer efficiency and print volume reproducibility of solder paste are valuable data points for any circuit assembly process. Knowing how many good boards that can be expected from a jar of solder paste is critical for a contract manufacturer working on paper thin margins. Tier 1 automotive suppliers who in most cases, cannot re-work defective assemblies, pay dearly for defects. Defective assemblies must be discarded, and production lines are stopped until the root cause of the defect is determined and corrected.

Commercially available solder pastes use an upper and lower limit for viscosity. Generally, this viscosity is measured at one shear rate, typically the shear associated with a spiral viscometer rotating at 10 revolutions per minute (RPM). If the powder contained in solder paste is dissolved by the acid activator in the solder paste flux, the viscosity of the solder paste will quickly increase. If the viscosity increases more than 20 to 30% above the upper limit of the specification, poor printing results will be highly likely. The solder paste will not roll evenly over the stencil and apertures in the stencil will remain unfilled, causing skips in the paste printing pattern.

The purpose of the study was to determine if there is a correlation between print yields and rheology. The ultimate goal would be to use rheological measurements to better predict the print volume and print volume repeatability of any sample of solder paste.

Another benefit of this test method is the reduction in wasted solder paste. Using a spiral viscometer requires an entire 500-g jar of paste. Because of the lengthy exposure to relatively high shear, this 500-g sample is no longer suitable for use in an assembly process. Only a very few grams of solder paste are used in the cone and plate rheology measurement.

This study was limited to one no-clean paste flux, SAC 305 lead-free powder and three particle size distributions. It should be noted that water soluble solder paste also can increase in viscosity and become unprintable due to the same mechanism. In fact, water soluble pastes may tend to do this more quickly when exposed to elevated temperatures. They also can increase in viscosity in the presence of very low humidity. Evaluating water soluble paste behavior is beyond the scope of this study.

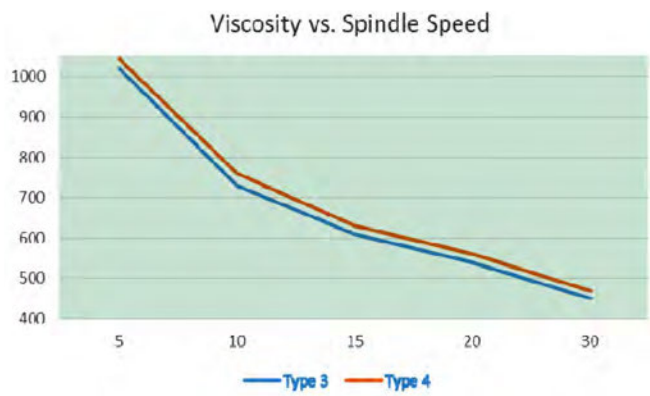

Figure 1: Viscosity (Y-axis) vs. viscometer rotational velocity (RPM X-axis).

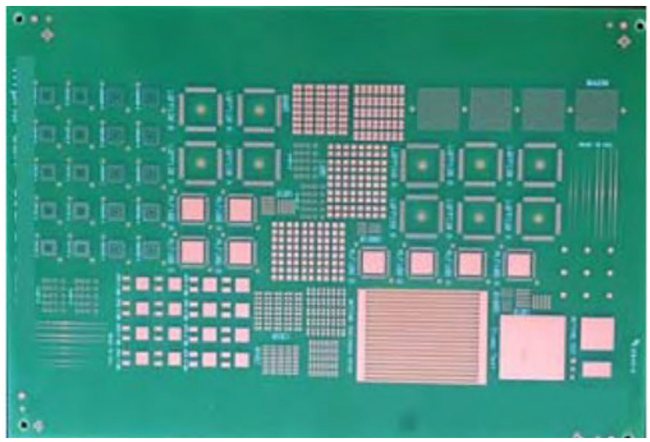

Figure 2: Print volume test vehicle.

Experimental Conditions

Three solder pastes were manufactured for the experiment using commercial scale equipment. There have been multiple examples of lab size solder paste batches showing differing rheological properties versus commercial scale batches. In this experiment the same batch of flux was used to make all three pastes.

Note that using a given lot of paste flux, varying the particle size distribution at a fixed metal loading will lead to different viscosity results. A Type 3 powder at 89% metal loading will have a lower viscosity than a Type 4 powder at the same metal loading. These differences in viscosity are more pronounced at lower shear rates. Figure 1 shows one lot of flux with two PSDs of SAC 305 powder at one metal loading.

The three pastes were also subjected to a standard print volume and print volume repeatability evaluation. A standard test vehicle was used. (Figure 2), using an uncoated .004 in. (100µ) thick, laser cut stainless steel stencil. Print volumes were measured using a Koh Young Aspire solder paste inspection (SPI) device. These measurements were then exported to Minitab statistical analysis software program and process capability was reported.


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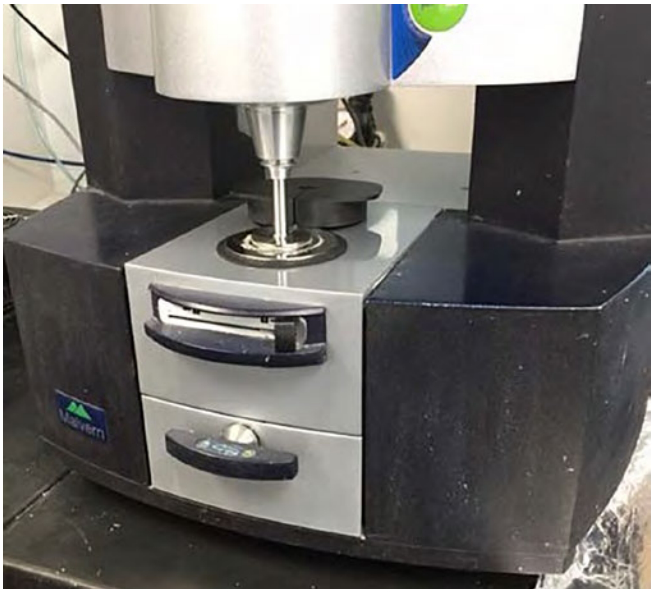

Figure 3: Cone and plate rheometer.

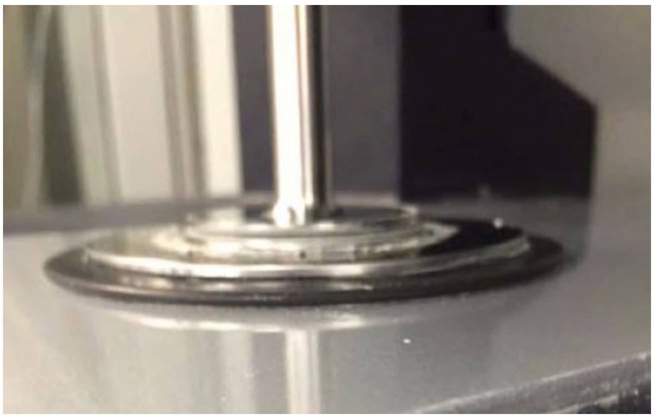

Figure 4: Close-up of the cone and plate mechanism.

RHEOLOGY MEASUREMENT

Cone and Plate Rheometer

A Malvern Kinexus rheometer fitted with a cone and plate probe was used to measure rheology. The device among many other things, is capable of creating a continuum of shear rates, while measuring the viscosity of the solder paste at each shear rate. Figure 3 is a photo of the device.

Figure 4 is a close-up of the cone and plate mechanism. Because of the heat that is developed from the friction of the solder paste trapped between the cone and plate, a cooling unit is connected to the base plate. A water bath maintained at 25°C is adjacent to the device, and a continuous stream of 25°C water flows under the bottom plate, maintaining an isothermal condition for the viscosity measurement.

Shear viscosity was measured while shear rate was continuously logarithmically ramped from 0.1 to 100 s-1 for a total measurement time of 2 minutes. 10 measurements were made per decade of shear viscosity.

	Type 3	Type 4	Type 5
Metal Loading	88.73	88.32	88.22
10RPM Viscosity	1373	1373	1388

Table 1: Metal Loading and Viscosity of 3 Pastes Used.

Results and Discussion

Table 1 details the metal loading and initial viscosities of the three pastes at room temperature (25°C). As mentioned above, the metal loading needs to be decreased as powder size distribution decreases in order to obtain the same 10 RPM Malcolm measured viscosity.

It is interesting to note that the divergence in viscosities tends to be greater at lower shear rates. Conversely, the viscosities converged at the higher shear rates.

The print volume reproducibility (CpK) of the pastes made with Type 3, 4 and 5 powders when the area ratio was 0.79 was 2.89 ±0.14 (Figure 5). This converts to an expected defect rate of less than 0.6 parts per trillion.

The performance of the three pastes diverged at a 0.54 aspect ratio (Figure 6). In other words, a 210 µ (.008”) square aperture in a 100µ (.004”) thick stencil. The paste made with Type 3 powder showed a CpK of 1.23. This translates in an estimated defect rate of greater than 100 per million opportunities. The paste using Type 4 powder showed a CpK of 1.82, translating to an expected defect rate of approximately 50 per billion opportunities.

Finally, the paste that used the type 5 powder showed a CpK of 3.48, translating to an in-

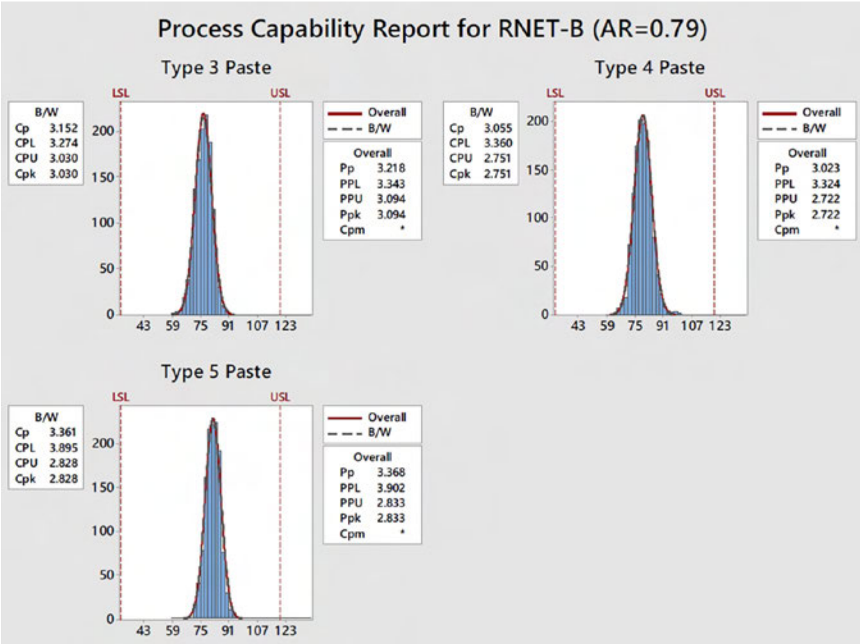

Figure 5: Histogram of deposits @ AR=0.79.

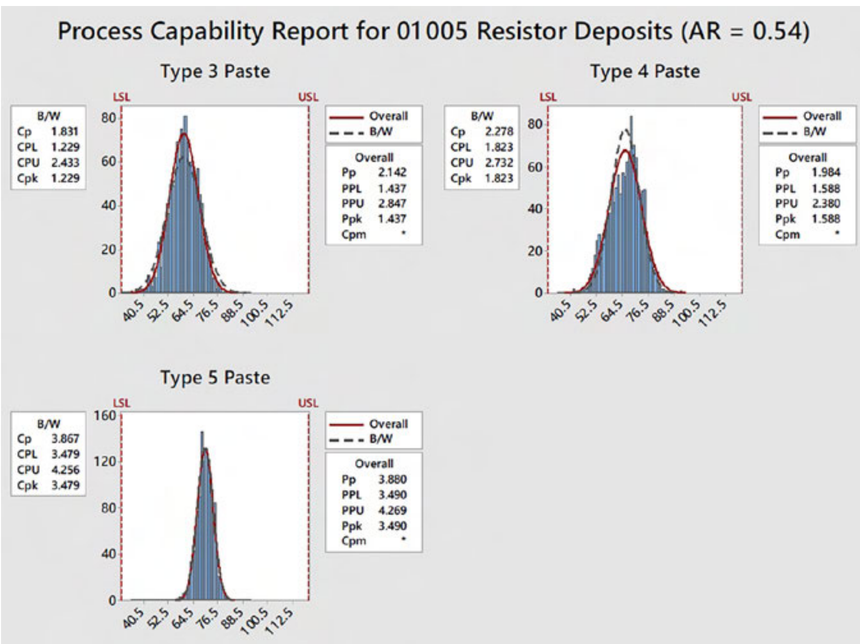

Figure 6: Histogram of print deposits @ AR=0.54.

finitesimally small expected defect rate of 1 in 2.56 x 10-17 opportunities.

The results are three rheology profiles that are different at low and medium shear rates, and three different print performance levels at an area ratio of 0.54. The question is whether or not there is a cause and effect between these two observations.

A second type of rheology test that may be more relevant to the print process is the shear stress sweep. In this measurement, the shear stress is cycled from low to high and back to low. Intuitively, this is similar to a set of squeegee blades pushing a bead of paste back and forth. Figure 7 shows the results of the three test pastes. Again, there is a consistent pattern between the Type 3, 4 and 5 pastes. This is another indication that a rheological footprint may be a predictor of print quality.

There is a distinct hysteresis between the high to low stress sweep and the low to high sweep. At high stress, the solder paste behaves mostly like a viscous liquid and shows shear thinning, but as the stress decreases and viscosity increases, a discontinuity occurs at about 100, 75 and 65 Pa for types 3, 4 and 5 powder respectively. The discontinuity viscosity is lower for the type 5 powder than the types 3 and 4. After the discontinuity, the viscosity decreases somewhat with decreasing shear stress.

During the low stress to high stress sweep, the viscosity increases with shear stress until another discontinuity occurs at about 4 Pa for all three pastes, after which the viscosity decreases slowly showing a quasi-solid behavior until the stress is about 100 Pa when shear thinning starts.

Figure 7c shows the normal force measured during the shear sweep measurements. The normal force is perpendicular to the direction of the shear stress. The data is rather noisy, but

distinct differences between the pastes made with the three types of powder are observed. All of the pastes show high normal force at high shear rates, which decrease with decreasing stress. However, the type 3 paste increases with decreasing stress below 100 Pa until and discontinuity is reached at about 20 Pa. In addition, there is a strong hysteresis observed in the reverse sweep. The normal force remains almost constant with stress, until about 100 Pa, when it decreases slightly with stress until a minimum occurs at about 250 Pa and the normal force increases with stress. The paste made with type 5 powder shows similar increases of normal force between 100 and 1000 Pa, but almost constant normal force at stresses less than 50 Pa, the decreasing stress having high normal force than the increasing stress. The normal force behavior for the type 4 paste is between that of the type 3 and type 5 pastes.

Oscillation sweeps can also be used to look at the properties of solder pastes. During these measurements, the truncated cone rotates clockwise and counterclockwise sinusoidally. By making oscillatory measurements, the solid-like (elastic, in phase with displacement) and liquid-like (viscous, out of phase with displacement) behavior of materials can be separated. Figure 8 shows frequency sweep measurement data. Here a stepwise sweep of frequencies between 10 and 0.1 Hz was made at a constant complex shear stress of about 10 Pa. Figure 8a shows complex modulus vs. frequency, and in Figure 8b, the complex modulus is divided into its in phase (elastic, solid-like) and out of phase (viscous, liquidlike) components. For all three pastes, the elastic modulus reaches a steady value at about 10 Hz, but the viscous modulus continues to increase with frequency. Likewise, Figure 8c shows viscosity decreasing with frequency. The T5 paste has the highest viscosity at low frequency and T3 the lowest viscosity, with T4 being somewhere in between.

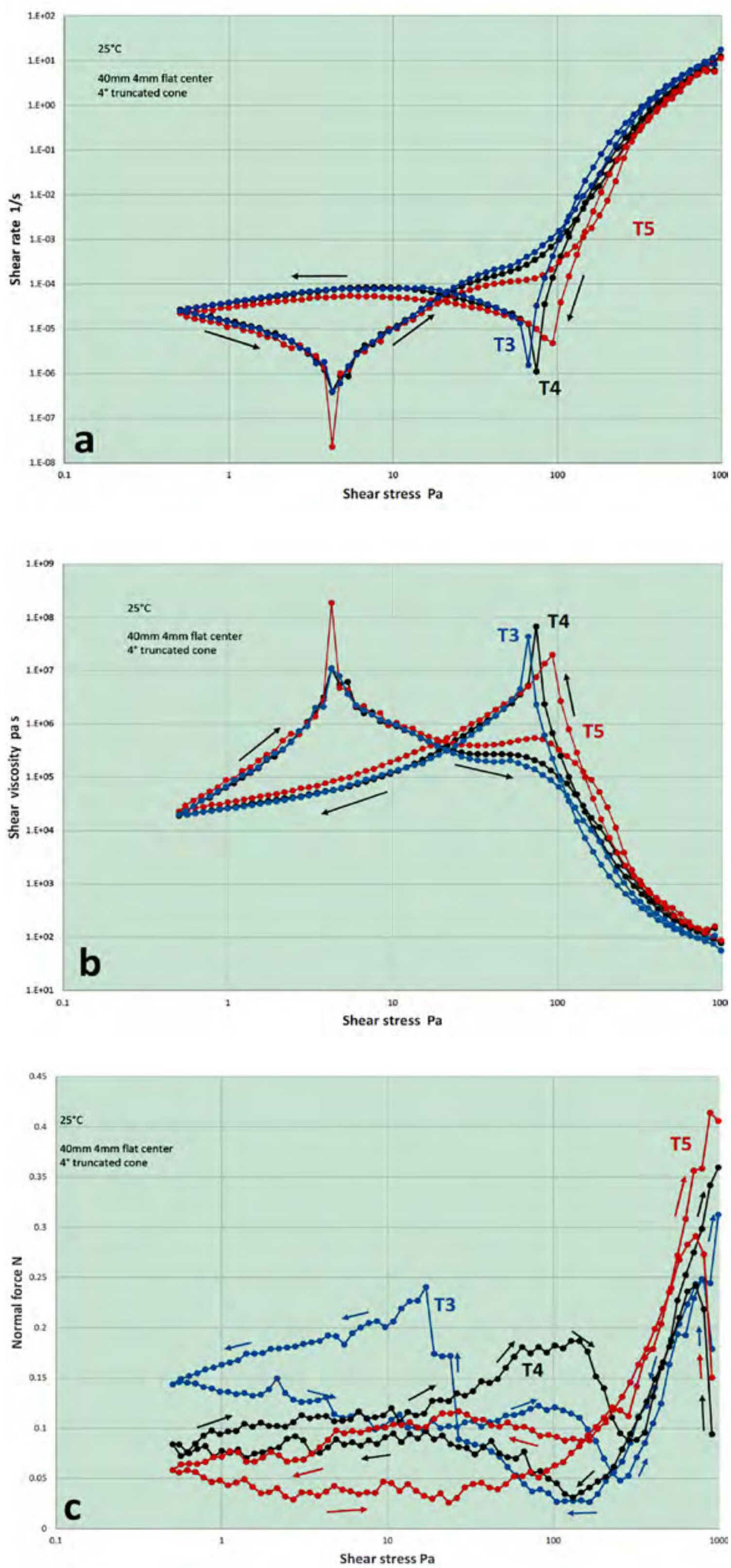

Figure 7: Shear stress sweep: (a) shear rate vs. shear stress; (b) shear viscosity vs. shear stress; (c) normal force vs. shear stress.

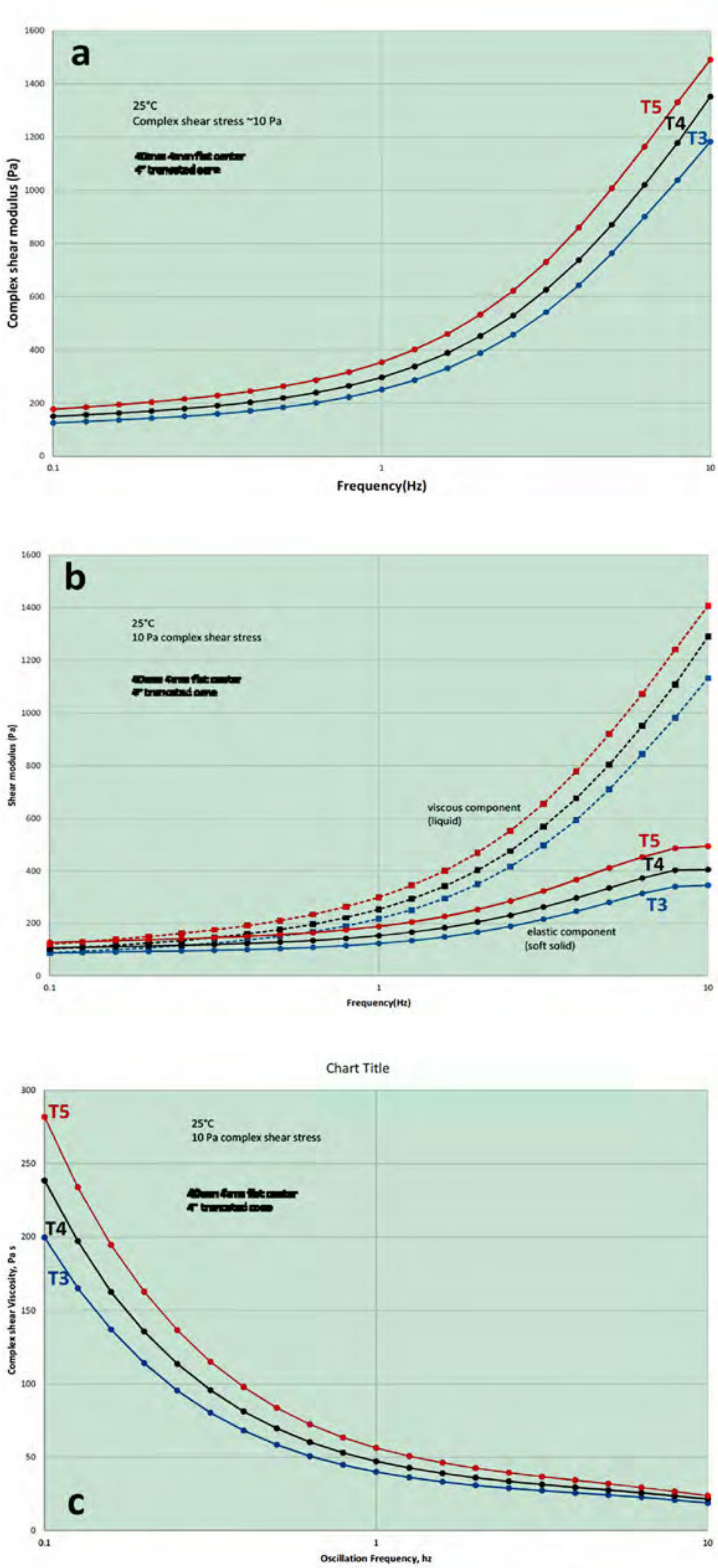

Figure 8: Oscillation frequency sweep: (a) complex modulus vs. frequency; (b) elastic and viscous modulus vs. frequency; (c) complex viscosity vs. frequency.

Conclusions

The three types of rheology measurements studied here all show trends that mirror the print volume and volume reproduceability for the three pastes used in this study. A low area ratio, 0.54 amplified the correlation of the rheology measurements to the print deposit reproduceability.

The paste sample size required for rheological testing is an order of magnitude lower than what is required for spiral viscosity testing. Both suppliers and users could see a significant reduction in wasted material if rheology would become the standard for solder paste inspection.

Obviously, more testing, including a round robin test by the IPC-JSTD-005 would be required before this type of test method could be elevated to an industry standard.

Acknowledgements

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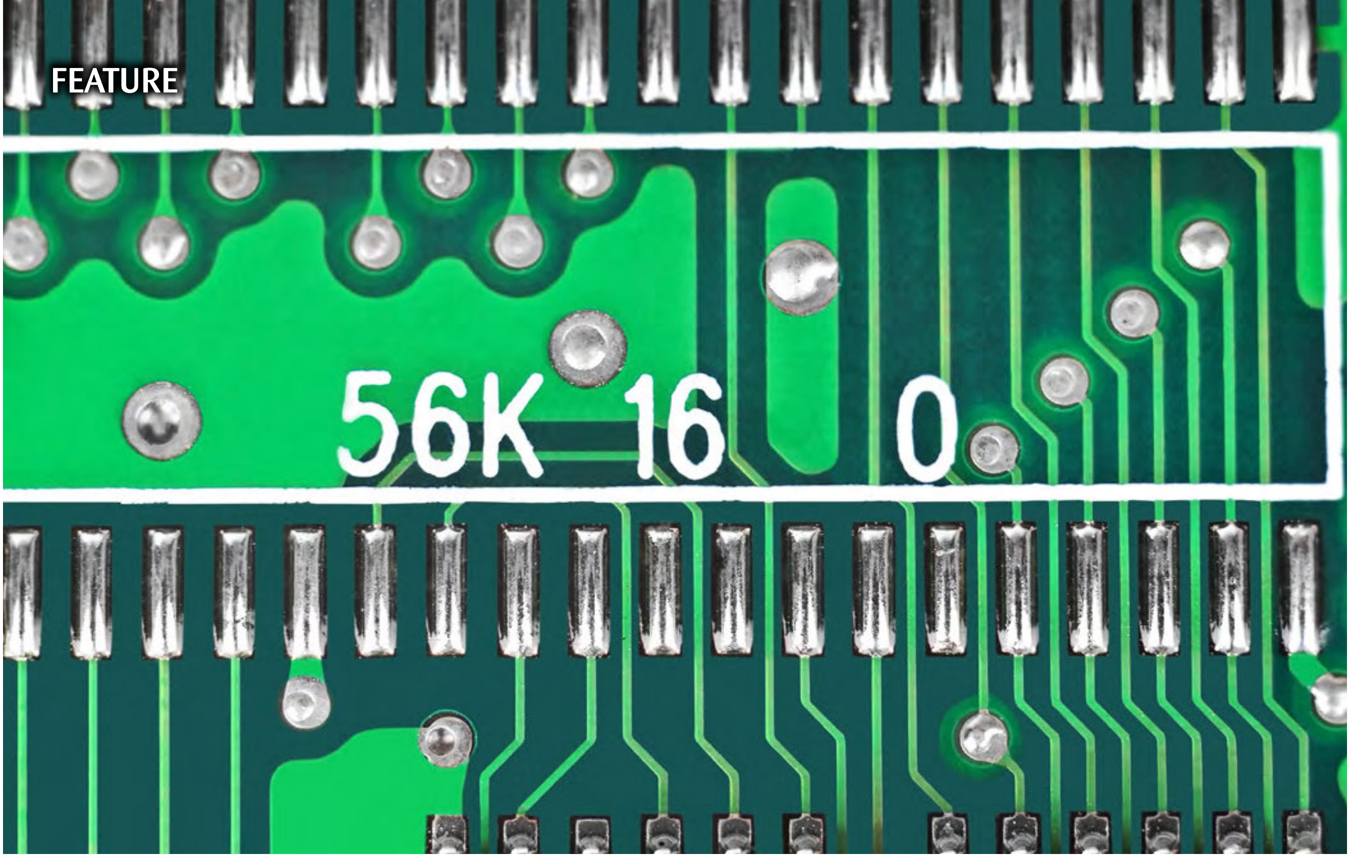

Voiding Control at High-Power Die-Attach Preform Soldering

by Dr. Arnab Dasgupta, Elaina Zito, and Dr. Ning-Cheng Lee
INDIUM CORPORATION

Assembly of components with large pads, such as high-brightness LEDs or high-power dies, often is soldered with preforms. Solder preforms are used to lower voiding and to lower flux fumes that can be generated by solder paste. The use of solder preforms also result in better thermal and electrical conductivity compared to Ag epoxy. This is particularly true when the joints are to be formed within a cavity. Voiding in the solder joint is a concern for high-reliability and high-performance devices. In this study, voiding behavior of large pad high-power devices was simulated with copper (Cu) coupon to Cu coupon sandwiches. A flux-coated preform was studied in this assembly, with variation in solder alloy type, quantity of solid flux coated on solder preform, Cu coupon pre-oxidation extent, reflow temperature, and pressure exerted onto the sandwich during reflow.

Experiment

1. Solder Alloy Type

Preforms of three solder alloys were tested: 96.5Sn/3Ag/0.5Cu (SAC305), 63Sn/37Pb, and 57Bi/42Sn/1Ag. The preform diameter was 0.906-inch, and 0.006-inch thick.

2. Flux Coating

The preform was pre-coated with a solid flux film using liquid flux at 0.5, 1.0, and 2% flux concentrations in isopropyl alcohol upon application.

3. Cu Coupon Oxidation Pre-treatment

The copper coupon (0.906-inch diameter, 0.020-inch thick) was used to simulate both die and substrate. It was pre-cleaned by soaking in a diluted HBF4 aqueous solution, followed by deionized water rinsing, and air drying. These cleaned Cu coupons were then oxidized by placing them on a 230°C hot plate for 0, 30, and 60 seconds, and five minutes prior to the soldering process.

4. Die-Attach Sandwich Setup

The high-power die-attach setup was simulated with the use of two Cu coupons, which were to be joined with a flux-coated solder preform. A 3-inch x 3-inch ceramic plate was used as a carrier. The simulated die-attach sandwich (Cu coupon on a solder preform, then placed on another Cu coupon) was placed on the carrier. At die-attach with solder preforms, many manufacturing processes use fixtures with some weight on the die to secure the sandwich. In this study, metal weight varying from 0 to 100 grams was placed on the top of the sandwich to simulate the fixture weight. Paper cardboard was placed on top of the die for heat insulation, if a weight was used.

5. Reflow Peak Temperature

The sandwich on the carrier was placed on a 5-zone, in-line contact reflow oven, and then sent through the reflow oven with various peak temperatures as follows:

- SAC305: 240°C, 250°C, and 260°C
- 63Sn/37Pb: 205°C, 215°C, and 225°C
- 57Bi/42Sn/1Ag: 160°C, 170°C, and 180°C

6. Reflow Under Various Pressures

For SAC305, various weights were placed on top of the sandwiches at reflow: 0, 10, 30, and 100 grams. For this set of assembly, freshly cleaned Cu coupons, 0.5% flux concentration, and a peak temperature of 240°C were used. Ten sandwiches were reflowed for each condition. For 63Sn/37Pb and 57Bi/42Sn/1Ag, 0, 10, 20, and 30 grams of weight were used for the pressure study.

7. Assessment

After reflow, the sandwiches were examined under X-ray to determine the voiding area percentage. For SAC305, three sandwiches for each weight condition were cross-sectioned to determine the bondline thickness under various weights.

Results

Effect of Weight on SAC305 System Using X-ray Images

Figure 1 shows the X-ray images of SAC305 sandwiches under various weights. Here, the flux concentration was 0.5%, the peak temperature was 240°C, and the coupons were etch-cleaned prior to use. Although 10 samples were prepared for each combination of conditions, three sandwiches were removed due to large opens in the solder joints because the image analysis software was unable to determine the voiding percentage properly. Most of the samples showed full wetting to the perimeter of coupons, and only a few showed a small fraction of non-wetting near the edge of the joints.

Most of the voids showed plain vacancy, except for a few samples where some spotty light-

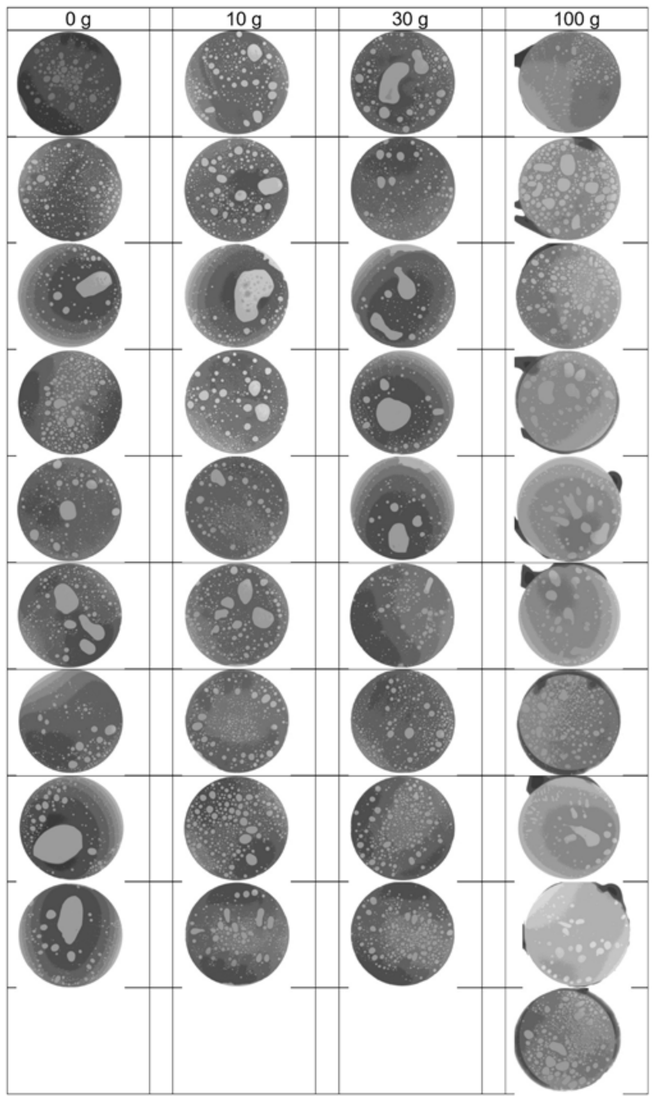

Figure 1: X-ray images for SAC305 soldered sandwiches processed with various weights on top of samples.


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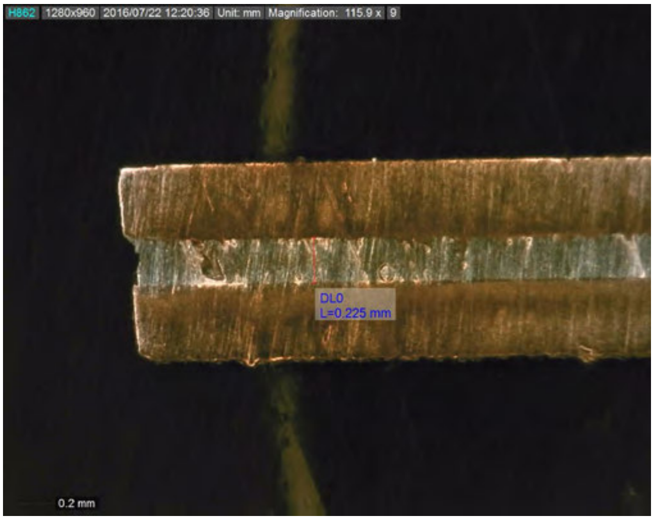


Figure 2: Edge view of cross-sectioned samples under 30 grams of weight.

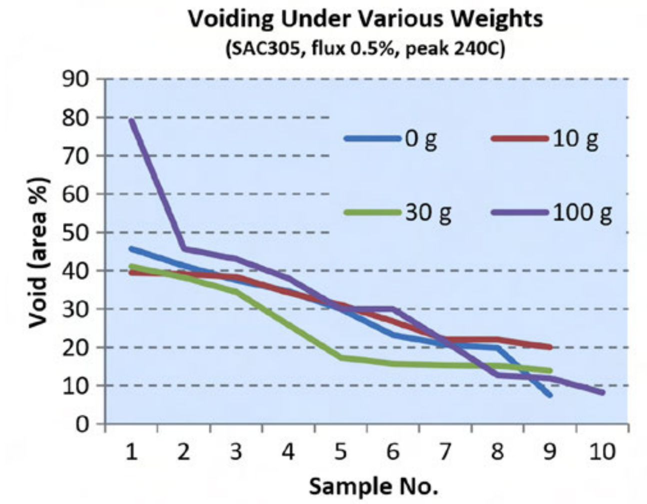


Figure 3: Actual voiding data of SAC305 under various weights.

colored solder were seen within the voids, such as in the third image of the 10-gram series and the first image of the 30-gram series. The spotty solder islands were attributed to the once-formed liquid joints, but were wiped out partially by expanding voids.

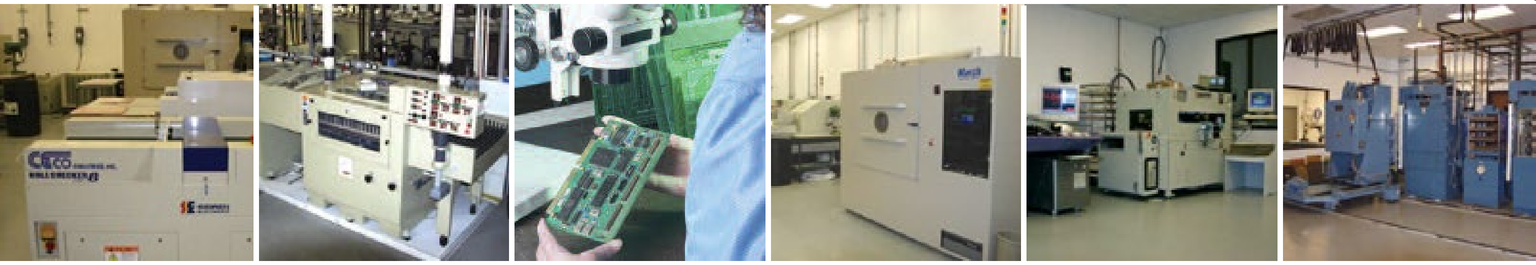
In most images, concentric ring textures can be seen clearly, indicating the Cu coupons may be warped. Also, the joint appeared to be thicker toward the center, and the solidification may have been developed stepwise from the edge toward the center.

1. Bondline Thickness (BLT): The 100-gram weight samples showed a much lighter shade of color than the other three weight samples, suggesting much thinner solder BLT data for SAC305 joints under various weights. The sandwich samples were cross-sectioned, as exemplified in Figure 2, with the BLT measured at both the edges and the center. The average value was calculated to represent the BLT of a given weight condition, as shown in Table 1.

Weight (g)	Sample	BLT-left (mm)	BLT-Center (mm)	BLT-right (mm)	Average (mm)	Overall Average (mm)
0	B	0.060	0.120	0.095	0.092	
0	F	0.221	0.214	0.217	0.217	0.163
0	G	0.177	0.226	0.138	0.180	
10	K	0.208	0.223	0.140	0.190	
10	N	0.162	0.101	0.138	0.134	0.179
10	L	0.237	0.126	0.280	0.214	
30	R	0.225	0.099	0.318	0.214	
30	E	0.124	0.152	0.240	0.172	0.191
30	N	0.225	0.196	0.136	0.186	
100	Y	0.022	0.033	0.055	0.037	0.037

Table 1.

2. Voiding vs. Weight Analysis: The actual voiding data of SAC305 under various weights are presented in Figure 3 and Figure 4. Other than the 100-gram condition showing a wider voiding distribution, no clear trend can be concluded. The lack of an obvious trend could be attributed to data scattering. It might also be possible that weight may not be a direct governing parameter. Similar to all other liquids, liquid solder is expected to follow fluid dynamics, with a greater difficulty to have lamellar flow under a small clearance. Since voiding involves void coalescence and escaping, and a higher BLT will facilitate both, it makes sense to investigate voiding behavior around the bondline thickness. Figure 5 shows that with increasing weight, the BLT maintained constant around 0.18 mm at first, then decreased at a weight higher than 50 grams, and then reached 0.04 mm at 100 grams of weight.



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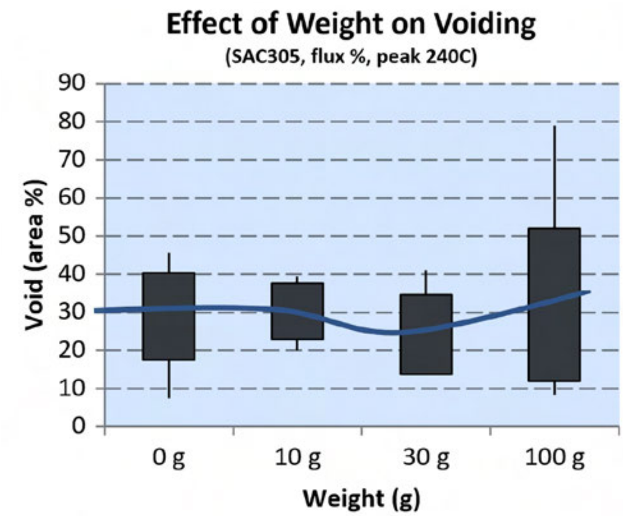

Figure 4: Voiding data of SAC305 under various weights.

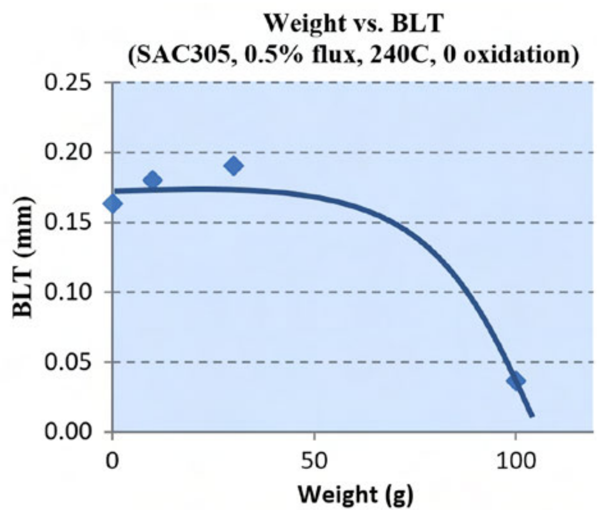

Figure 5: Relationship between weight and BLT for SAC305.

3. Radius of Curvature: The relationship observed between BLT and weight can be understood by reviewing the radius of curvature effect. For a curved surface, any point on the surface can be specified by two principal radii of curvature, as shown in Figure 6. R1 is the radius of curvature in the plane of the paper and R2 is the radius of curvature perpendicular to the plane of the paper.

$$\Delta P = \gamma \left(\frac{1}{R_1} + \frac{1}{R_2} \right) \quad \text{Equation 1}$$

This equation describes the pressure difference across a curved interface (DP) in terms of the surface tension of the interface (g) and the two principal radii of curvature at a point on the surface [1].

The surface tension of SAC305 has been reported to be 0.568 N/m [2]. In the sandwich structure discussed here, R2 was the Cu coupon radius, 0.906 inch (0.0115 m). By setting an R1 value being half of the BLT, or 0.003 inch (0.000076 m), the pressure difference across the liquid solder surface is 765,000 g-f/m2. The Cu coupon area used in this study should be able to maintain a constant BLT with a weight placed on top of the sandwich up to 318 g-f.

In this study, liquid solder was squeezed out at 100 g, lower than the calculated 318 g-f.

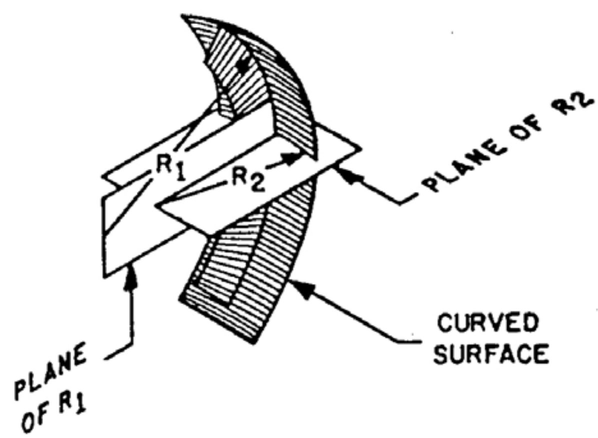

Figure 6: Radius of curvature [1].

This was probably attributed to the uneven BLT caused by warpage of the Cu coupon, as shown in Table 1.

4. Lamellar Flow Effect: Voiding is a function of BLT thickness (Figure 7), where the voiding maintained at about 32% area ratio at the thin bondline, then decreased gradually when the BLT was greater than 0.15 mm. However, if the voiding was expressed as volume by multiplying the voiding area % with BLT, the relationship between voiding and BLT can be seen in Table 2 and Figure 8. Here, all void shapes were approximated as pancake, and the volume was expressed as an arbitrary unit.

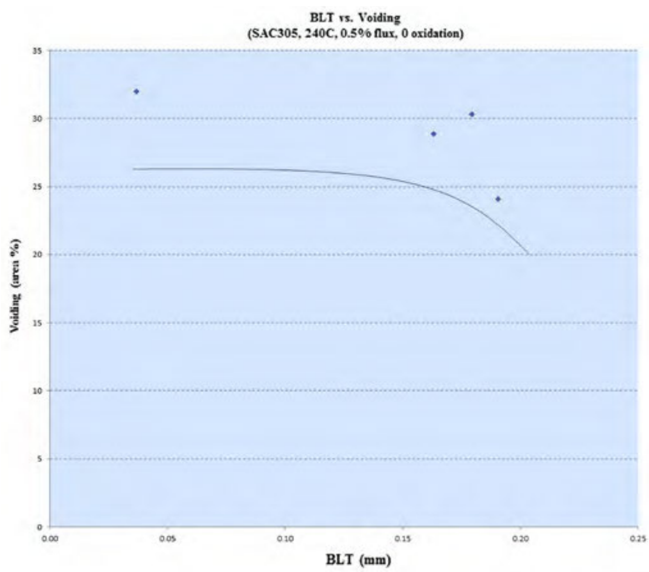

Figure 7: Relationship between BLT and voiding for SAC305.

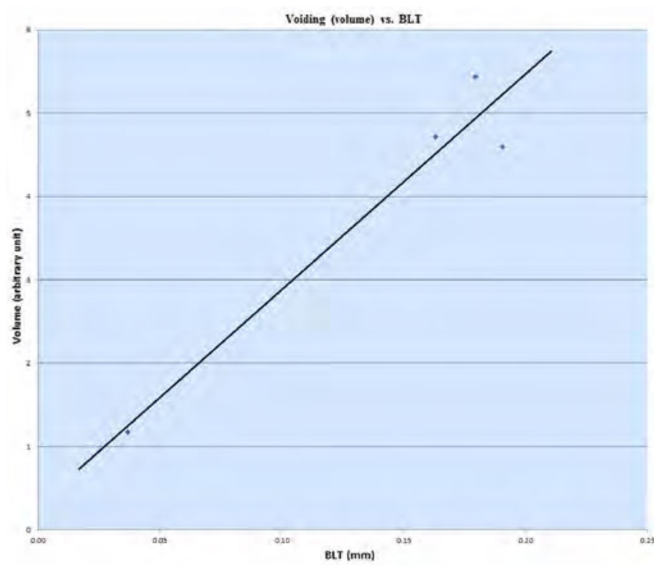

Figure 8: Relationship between voiding volume and BLT.

BLT (mm)	Voiding (area %)	Voiding (volume)
0.16	28.9	4.71
0.18	30.3	5.44
0.19	24.1	4.59

Table 2.

Figure 8 results indicate that the actual volume of voiding decreased with decreasing BLT. Under the 100-gram weight condition, not only did the liquid solder squeeze out, but the voids formed were not able to expand due to the constrained lamellar flow of liquid solder. Furthermore, the voids formed could not move around, and coalescence of voids became negligible. The X-ray images of 100-gram column in Figure 1 show that no large void image can be observed.

In summary, the weight on the sandwich dictated BLT, which in turn governed the void content. At a very low BLT, the actual void volume was low, although the void area % was not low. With increasing BLT, the void volume increased, but the voiding area % decreased slightly.

Since a very thin BLT is not desired based on reliability considerations, the study will be confined to weight no higher than 30 grams from this point on for comparison of SAC305, 63Sn/37Pb, and 57Bi/42Sn/1Ag. Also, with a small sample size prepared for each condition, data scattering was fairly significant. In order to get a meaningful trend, the effect of any given parameter was examined by taking the average value of all data involving other parameters. For instance, when examining the effect of oxidation on voiding, all data points were derived from the average of all flux quantities reflow peak temperatures, and weights.

5. Effect of Oxidation and Alloy on Voiding: Figure 9 shows the voiding performances of SAC305, 63Sn/37Pb, and 57Bi/42Sn/1Ag on Cu coupons preconditioned with various extents of oxidation. The data for each point was the average of all conditions, including flux quantity, reflow temperature, and weight. Voiding of SAC305 was higher than 57Bi/42Sn/1Ag, which in turn was higher than 63Sn/37Pb. Initially, an insensitivity of voiding toward oxidation was observed, indicating that the oxide formed was easily removable. At 60 seconds of oxidation time, the voiding increased noticeably, reflecting that the oxide amount just reached the limit of fluxing capability. At five minutes oxidation time, most

of the samples showed significant non-wetting. Since the image analyzer could not process those images properly for voiding, this data is not presented in the graph.

6. Effect of Flux Quantity and Alloy on Voiding: Figure 10 shows the two opposite trends of flux quantity that were observed. For SAC305 and 63Sn/37Pb, the voiding decreased with increasing flux quantity. This can be attributed to a better wetting caused by more flux [2,3,4,5]. For 57Bi/42Sn/1Ag, the flux quantity effect showed an opposite trend. The higher voiding caused by the higher flux quantity could be explained by the flux burn-off rate outweighed the wetting improvement rate. Since the flux used in this study was developed mainly for the SAC alloy system, it is reasonable to expect that the flux was much less effective at a low soldering temperature.

7. Effect of Reflow Temperature and Alloy on Voiding: Figure 11 shows that, depending on the alloy type, a totally opposite trend could occur. For the low-temperature alloy 57Bi/42Sn/1Ag, with and increasing peak temperature, the voiding first increased, then decreased. The initial increase trend can be attributed to the low activity of flux, and the vaporization factor dominated the voiding behavior. At this temperature range, the flux activity was low and the more volatile constituents came out.

The subsequent decrease trend at 170°C to 180°C peak temperature can be attributed to the flux wetting factor, which increased considerably from 170°C to 180°C. This flux wetting dominating behavior was also observed on 63Sn/37Pb when the reflow temperature increased from 205°C to 215°C. However, when the reflow temperature further increased from 215°C to 225°C, the voiding increased again. This was attributed to the dominating flux outgassing phenomenon, presumably through

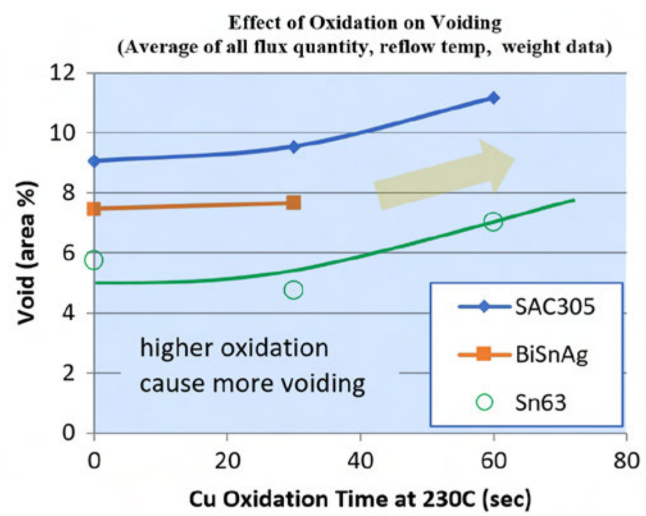

Figure 9: Effect of oxidation and alloy on voiding.

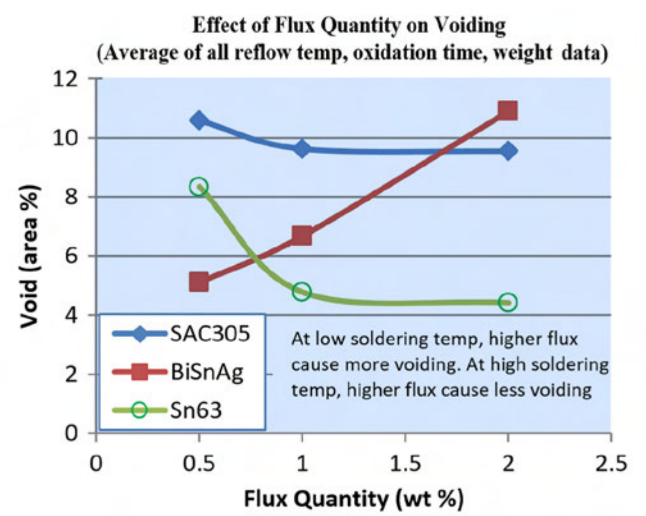

Figure 10: Effect of flux quantity and alloy on voiding.

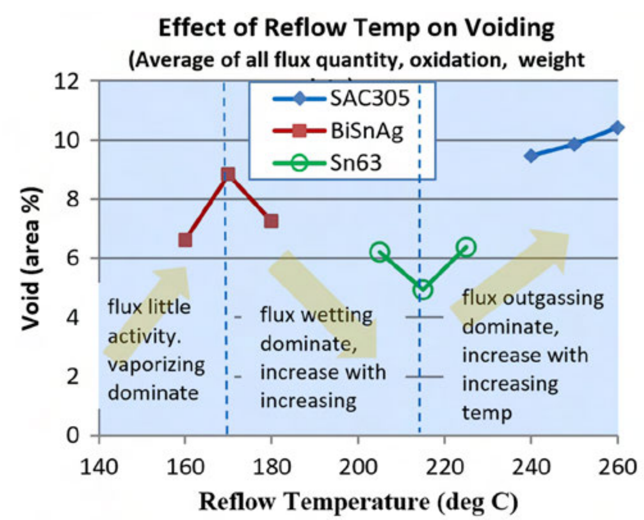

Figure 11: Effect of reflow peak temperature and alloy on voiding.

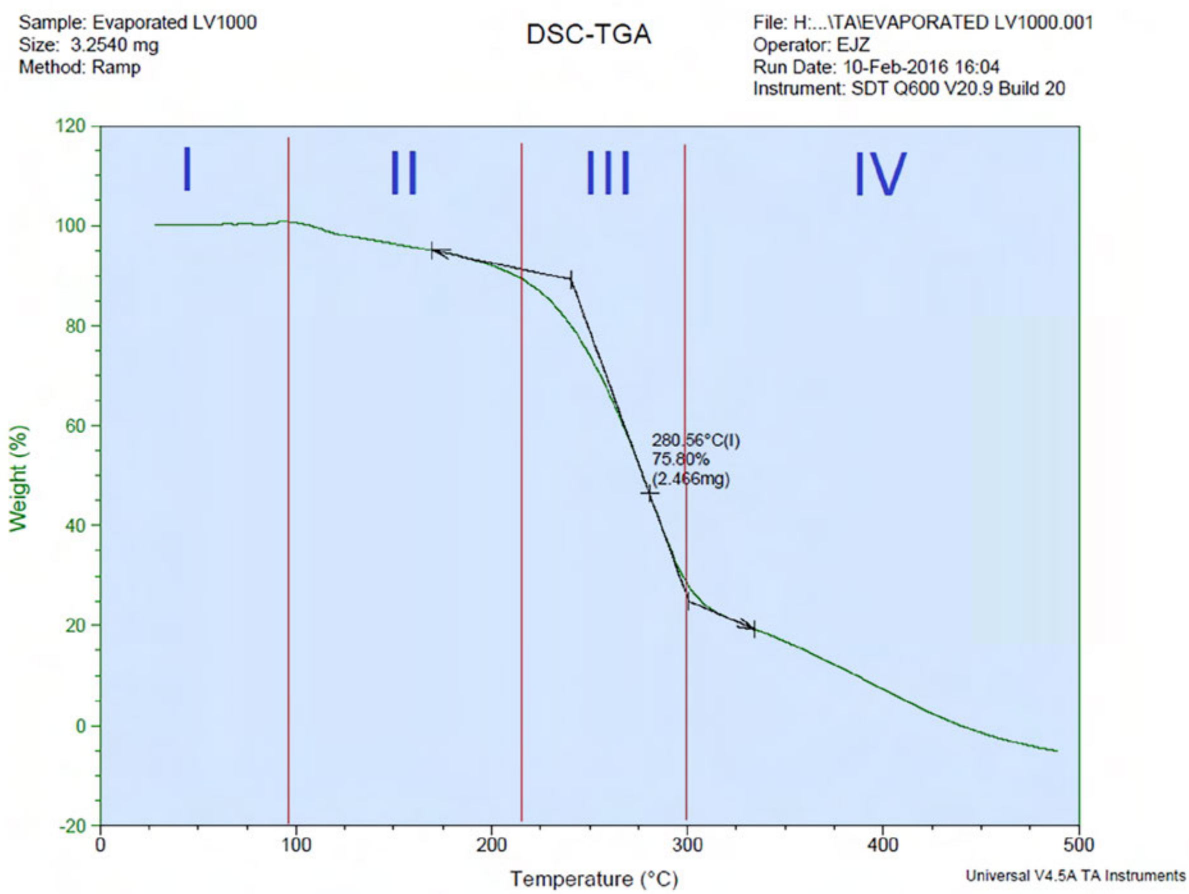

Figure 12: TGA thermograph of flux used in this study.

combined vaporization and thermal decomposition.

The dominating outgassing behavior continued on the SAC305 system. Here, the voiding increased continuously with the increasing reflow temperature.

The alternating dominant voiding mechanisms can be elucidated by examining the TGA data of the flux, as shown in Figure 12. At a temperature below 100°C (zone I), no volatiles came out. At 100-210°C (zone II), moderate weight loss occurred. Between 210°C and 300°C (zone III), rapid weight loss was observed. At temperatures higher than 300°C (zone IV), the weight loss rate slowed down again.

A cross-comparison of Figure 11 and 12 shows that the voiding increasing trend at temperatures above 210°C can be easily attributed to the rapid weight loss rate with the increasing temperature. Below 210°C, the weight loss rate is moderate. The turning point on the voiding rate at 170°C can be explained by the flux being activated around 170°C. Below 170°C, the activity was very minute, and voiding increased by the flux vaporization rate was greater than voiding reduced by improved wetting. Once the flux was activated, the flux activity increased with increasing temperature [6], and the voiding decreased with increasing flux activity [7, 8]. The flux was activated above 170°C, thus the voiding reduced by improved wetting outweighed the voiding increased by increased outgassing.

Discussion

1. Solderability Factor

The voiding of SAC305 in the weight study was higher than that in other factors of the study. This was due to the difference in solderability of different sources of Cu coupons employed for those studies.

2. Solder Alloy Factor

The voiding difference between different alloys was mainly attributed to the difference in wettability, with 63Sn/37Pb being the best, followed by 57Bi/42Sn/1Ag, and SAC305 being the poorest, as reported in an earlier work [9].

3. Reflow Temperature Factor

The relationship between reflow temperature and voiding was a complicated one. This was caused by two changes induced by temperature. The first was the weight loss rate of flux, and the second was the flux activity.

4. Flux Quantity Factor

The flux quantity effect showed two opposite trends for different alloys. This was attributed to different reflow temperatures for different alloys.

Conclusion

By studying varying solder alloy types, flux quantity coated on the preforms, extent of oxidation on the Cu coupons, reflow peak temperature, and weight applied on the top of simulated die, we can see the following voiding behavior in high-power die-attached soldering using preforms:

- **BLT:** For SAC305, the voiding area % increased with decreasing BLT at first, then leveled off at a lower BLT, although the voiding volume decreased with decreasing BLT due to constrained lamellar solder flow.
- **Oxidation:** Voiding was the highest for SAC305, followed by 57Bi/42Sn/1Ag, with 63Sn/37Pb being the lowest, and increased with the increasing oxidation of the Cu coupons.
- **Flux Quantity:** As flux quantity increased, voiding increased for SAC305 and 63Sn/37Pb, but decreased for 57Bi/42Sn/1Ag, mainly due to the different temperature ranges at reflow.
- **Reflow Temperature:** Voiding increased with increasing reflow temperature up to 170°C due to increasing vaporization, decreased with the further increase in the reflow temperature up to 210°C due to increasing flux activity, and increased again at a temperature beyond 210°C due to rapid flux outgassing. SMT

References

1. Adamson, "Physical Chemistry of Surfaces," 3rd ed., John Wiley & Sons, 1976.
2. Chingchen S. Chiu, Ning-Cheng Lee, Kimbela Randle and Christopher Parrish, "Voiding in BGA at Solder Bumping Stage," ISHM, p.462-471, Philadelphia, PA, Oct. 14-16, 1997.
3. Wanda Hance and Ning-Cheng Lee, "Voiding Mechanisms in SMT," China Lake's 17th Annual Electronics Manufacturing Seminar, 1993.
4. Wanda Hance and Ning-Cheng Lee, "Voiding Mechanism in BGA Assembly, ISHM, p.24-30, Los Angeles, CA, Oct. 24-26, 1995.
5. Ning-Cheng Lee, "Reflow soldering processing and troubleshooting SMT, BGA, CSP, and Flip Chip Technologies", Newnes, pp.288, 2001.
6. Ning-Cheng Lee, "Optimizing Reflow Profile Via Defect Mechanisms Analysis", IPC Printed Circuits Expo 1998.
7. Yan Liu, Bill Manning, Benlih Huang, and Ning-Cheng Lee, "A Model Study of Profiling for Voiding Control at Lead-free Reflow Soldering", Nepcon Shanghai, China, April 11, 2005.
8. Ning-Cheng Lee, "Critical Parameters in Voiding Control At Reflow Soldering", Chip Scale Review, August-September 2005.
9. Benlih Huang and Ning-Cheng Lee, "Prospect of Lead Free Alternatives for Reflow Soldering", International Microelectronics Assembly and Packaging Society (IMAPS) Conference 1999, Chicago.

Editor's Note: This paper was originally published in the proceedings of SMTA International, 2016.

Dr. Ning-Cheng Lee is the vice president of technology at Indium Corp.

Dr. Arnab Dasgupta is a research chemist at Indium Corp.

Elaina Zito has since returned to school to further her education.

International Conference on Soldering & Reliability

Workshops | June 6
Conference | June 7-8
Toronto Chapter Expo & Tech Forum | June 7

CONFERENCE OVERVIEW

Starting in 2017 the scope of the conference will be broadened to include the physical design aspects relating to electronics component, product and system reliability, involving such topics as thermal and mechanical design, design for manufacturability, test and signal integrity.

SESSION TOPICS

Solder R&D and Applications
Solder Joint Reliability
Future Trends and Technologies
Contamination and Cleanliness Testing
Failure Modes and Mitigation
Reliability
Defect Detection
Bottom Termination Component Design Panel

KEYNOTE PRESENTATIONS

Nanotechnology in Electronics Packaging Interconnect, and Assembly: Hype or Reality?
Chuck Bauer, Ph.D., TechLead Corporation

The Importance of Design to Improve Manufacturing Process Yield and Reliability
Jasbir Bath, Bath Consultancy LLC

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Supply Lines Highlights

[Lenthor Engineering Purchases Mirtec Inline AOI Component Inspection Equipment]

Lenthor Engineering, a California-based designer, manufacturer and assembler of flex and rigid-flex printed circuit boards, has purchased Mirtec's MV-6 OMNI 3D AOI Series inline component inspection machine, which offers 15 megapixel camera technology along with an advanced 8-phase color lighting system.

Nordson Acquires InterSelect to Broaden Selective Soldering Capabilities

Nordson Corp. has acquired InterSelect GmbH, a German designer and manufacturer of selective soldering systems used in a variety of automotive, aerospace and industrial electronics assembly applications.

Computrol Speeds Up Production with VJ Electronix XQuik II

Computrol Inc. has purchased and installed an XQuik II with AccuCount Technology from VJ Electronix. The innovative system uses X-ray imaging combined with proprietary image analysis to quickly and accurately count components without the need to unwind the reels and manually count.

Libra Industries Upgrades Speed on its ACE Selective Solder System

With the new software and drive system, Libra Industries' ACE K.I.S.S. 102 selective solder machine runs up to 30 percent faster and the programming time has been reduced by at least 50 percent.

Nordson to Acquire Advanced Technologies Business of Vention Medical

Nordson Corp. has entered into a definitive agreement to acquire Vention Medical's Advanced Technologies (Vention AT) business for $705 million in an all cash transaction.

SMT Xtra Launches Sister Company – SMT Xtra USA Inc.

SMT Xtra has launched its sister corporation, SMT Xtra USA Inc. The company will provide SMT nozzles, feeders, spare parts, printer parts, and machine sales in the U.S. and Mexico.

Ellsworth Adhesives ESRs Receive Dow Corning 2016 Distributor Seller of the Year Awards

Two of Ellsworth Adhesives' engineering sales representatives (ESRs) have received the Dow Corning Distributor Seller of the Year Award for 2016. Ron Cormier has been awarded the 2016 Gold Level Seller of the Year for North America, and Jason McGough has been awarded the 2016 Bronze Level Seller of the Year for North America.

Indium to Feature Indium8.9HF Solder Paste at SMT Hybrid Packaging 2017

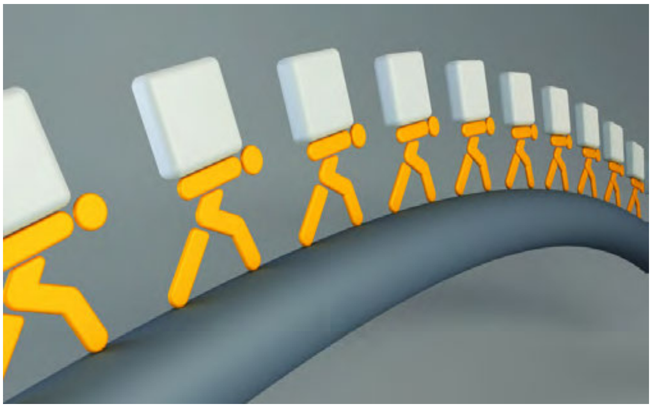
Indium Corp. will feature its void-reducing Indium8.9HF Solder Paste to help customers avoid the void at SMT Hybrid Packaging, which will be held on May 16-18, 2017 in Nuremberg, Germany.

Mycronic Makes Upgrades on Already Ordered Prexision Mask Writer

Mycronic AB has received an order to upgrade an advanced mask writer from the Prexision series for display applications. The upgrade will be delivered when the ordered mask writer is delivered during the first half of 2017.

Electrolube Appoints New Technical Sales Engineer

Electrolube has appointed Bethan Massey as the company's new technical sales engineer. Massey will bring fresh eyes to this dynamic role, enhancing the technical export team further and offering both distributors and end users valuable support and advice.



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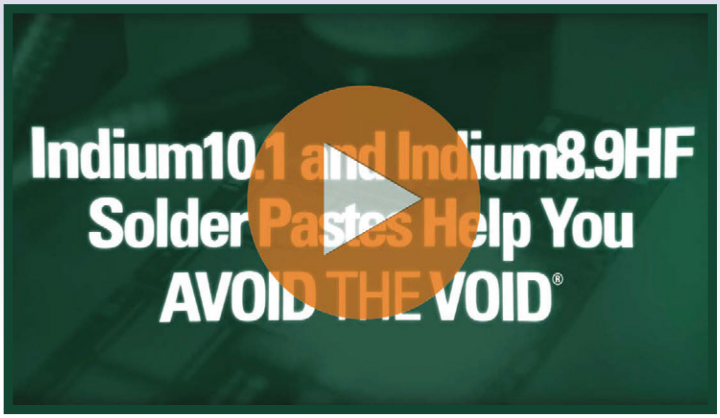

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Indium8.9HF Solder Paste

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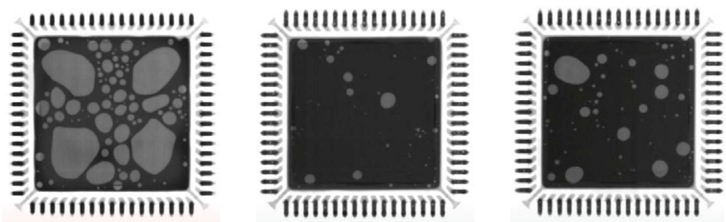

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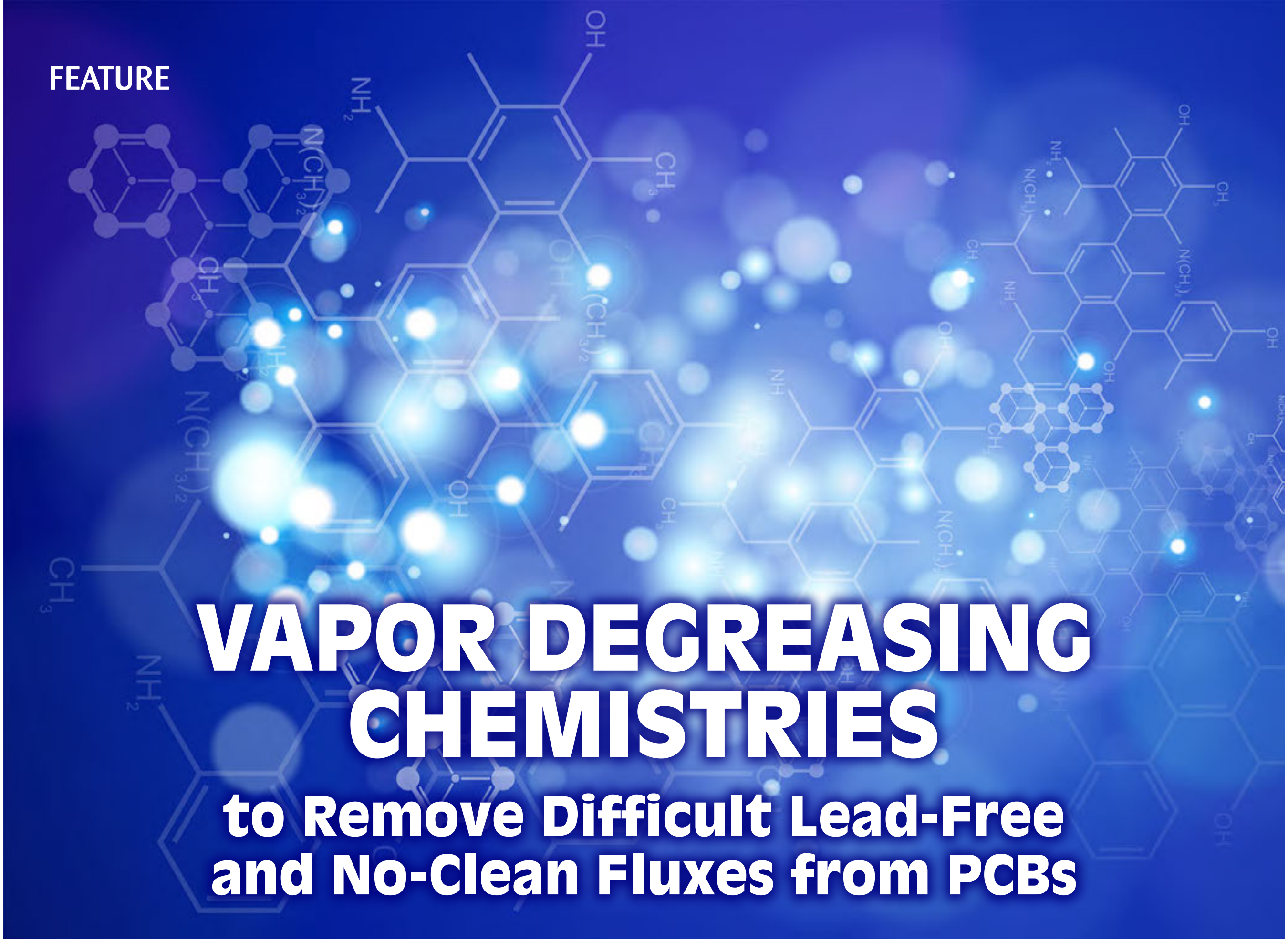
FEATURE



VAPOR DEGREASING CHEMISTRIES

to Remove Difficult Lead-Free and No-Clean Fluxes from PCBs

by Venesia Hurtubise, Elizabeth Norwood, Wells Cunningham, and Laura LaPlante
MICROCARE CORP.

Abstract

Advancements in the electronics industry are continuously leading to more sophisticated, more intricate and more miniaturized circuitry. In conjunction with increasing regulations on electronics manufacturing, many changes have been made to the electronics world, and thus the circuit board manufacturing process. Lead-free, no-clean and halide-free flux formulations have introduced new cleaning obstacles, especially on ever-shrinking component sizes. In order to maintain high cleanliness standards for modern circuitry, new sophisticated cleaning chemistries are required.

The purpose of this paper is to present a cleaning process for difficult no-clean, lead-free and high temperature flux residues on reflowed PCBs. The proposed cleaning solvents are drop-in replacements for outdated solvent technology, or alternatives for elaborate aqueous systems. These cleaning technologies are used in traditional vapor degreaser systems, which allow for fast cleaning times and spot-free results without the need for additional rinsing or drying equipment. The improved formulas have low surface tensions (less than 20 dynes/cm), which allow access to low stand-off components and high solvency to combat the most difficult flux formulations and white residues. Visual and quantitative data are presented to assess the overall cleaning efficiency of the solvent system. Cost analysis is investigated to assess the efficacy of solvent vapor cleaning for PCB industry.

INTRODUCTION

Background

The beginning of the electronics manufacturing industry was, for lack of a better word, messy. Circuit boards were slathered with thick layers of fluxes, primarily foam flux agents, which would coat the entire underside of a circuit board. Aside from the inefficiency and visual untidiness, excessive flux can also lead to electro-chemical migration within the circuit and cause unintentional failures during use. Figure 1 shows an example of dendritic growth between two contacts. This migration can occur due to changes

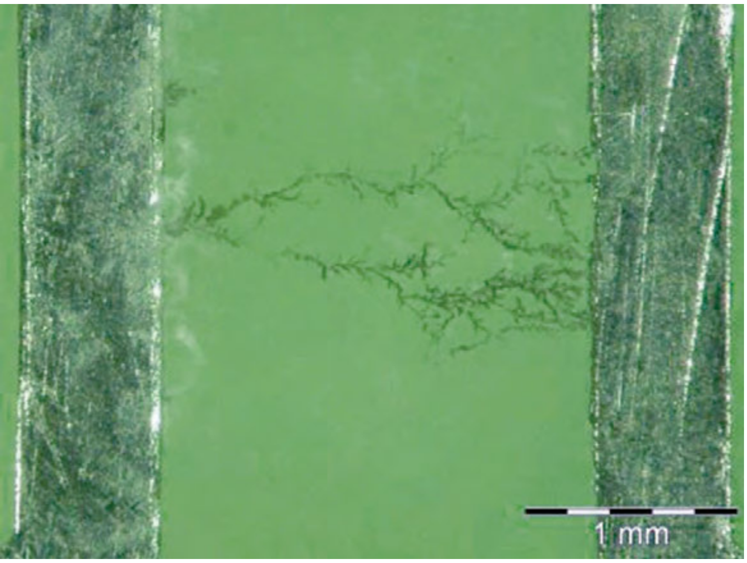


Figure 1: Dendrite growth between two leads.

in temperature or humidity. Once the dendrite connects the two leads, the circuit can short and cause failures to the overall system. Needless to say, cleaning quickly became as important to the electronics production process as assembly.

At the start of the electronics cleaning frenzy, vapor degreasing reigned dominant thanks to its ease-of-use, quick processing times and spot-free, dry results. One of the most common electronics cleaners of the 1980s was CFC-113 (more commonly known as Freon 113). Roughly 70% of Freon 113 use was designated to the electronics industry and in 1986 roughly 94 million pounds of Freon 113 was used in electronics manufacturing[1]. However, FREON's reign was cut short in 1988 when the US ratification of the Montreal Protocol on Substances that Deplete the Ozone Layer forced the cleaning industry to discontinue the production of CFCs[2]. The Clean Air Act Amendment of 1990 increased the enforcement of ozone depleting substances and further restricted the cleaning industry[3]. At the same time, advancements in flux formulations lead to the development of no-clean and low-residue fluxes. These no-clean flux formulations are intended to remain on the board and leave minimal residues, which allows manufacturers to skip the cleaning process altogether. However, time has shown that these residues are still capable of attracting moisture, inhibiting conformal coating uniformity, or simply leaving aesthetically unacceptable visual results.

During the past decade, the growing demand for smaller electronics has forced circuit board manufacturers to miniaturize circuits, and pack more components into tighter spaces. This miniaturization causes a greater likelihood for even minor electro-migration to bridge components and result in failures. Figure 2 depicts an example of a low-standoff integrated circuit component on a substrate. A very low surface tension liquid would be required to penetrate the small space between the solder bumps and remove any debris, flux, or residues from the component underside. It is also understandable how even minor dendritic growth or debris could impact such an intricate circuit.

Further regulation restrictions have also forced electronics manufacturers to reduce or remove leaded ingredients from solder; this has forced solder and flux manufacturers to reformulate to accommodate higher melting-point metals. These high-temperature soldering jobs often leave burned flux residues, which are more difficult to clean. Although the aqueous cleaning industry has been the superior cleaning guru for the past 10 years, these new soldering hurdles have shed light on the limitations of water. The surfactant formulations are continuously advanced to assist in removing these difficult resi-

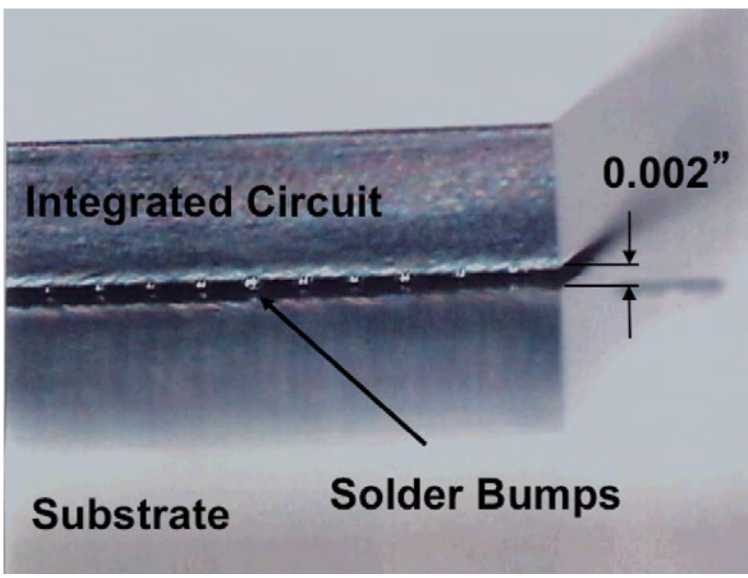


Figure 2: Integrated circuit on a substrate.

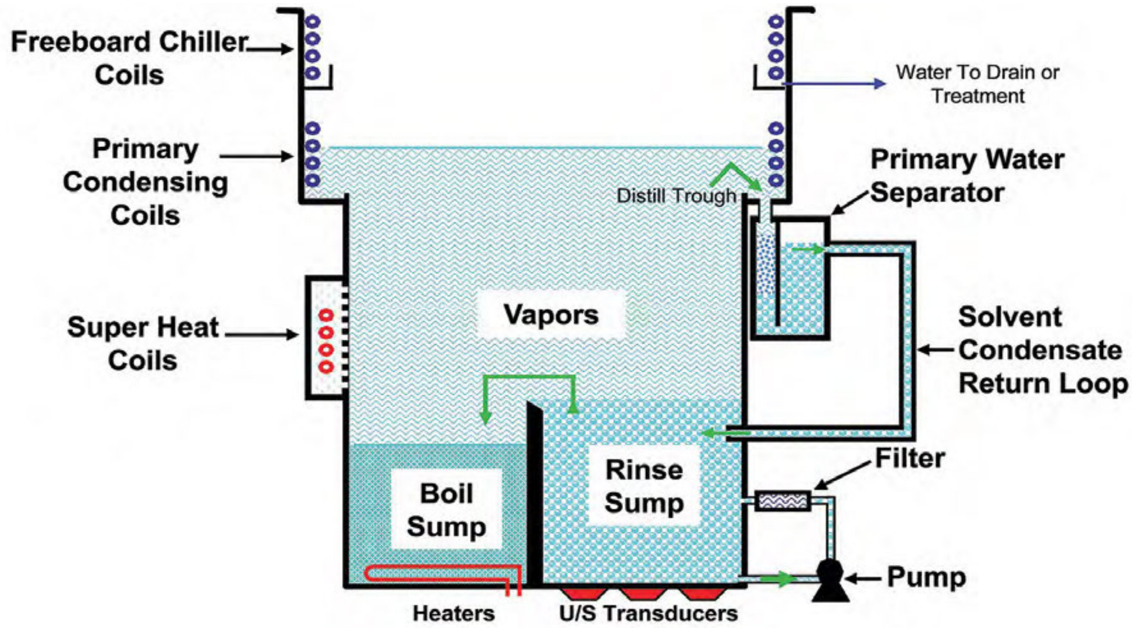


Figure 3: Modern two-sump vapor degreaser.

dues, however, the high surface tension of water still restricts rinsing capability. If the surface tension of the mixture manages to allow for cleaning under the low-standoff circuitry, it is unlikely that the deionized water will penetrate the same areas to remove the residing surfactants. Other factors to improve cleaning include operating temperature, chemistry concentrations, rinse cycles, water purity and spray/wash mechanisms. With all of these different elements, it is easy to be overwhelmed with numerous options that provide less than ideal cleaning. Electronics manufacturers who have considered solvent cleaners have also been met with shortcomings; ionic removal is a difficult task for many hydrofluorocarbon-based solvents due to their lack of polarity. However, new solvent and co-solvent formulations coming to the market have proven capabilities at removing ionic contamination and cutting through burned-on residues. Most importantly, these advanced solvent formulations offer new benefits to solvent-cleaning without the need for new equipment.

Manufacturers who are currently using a vapor degreasing process but looking for new solvents to improve cleaning will be able to do so without additional capital investment in equipment.

Vapor Degreasing

The original concept of vapor degreasing revolved around vapor-only cleaning; however, modern vapor degreasers have been modified to allow for liquid immersion in addition to vapor cleaning. This has further improved the ability for solvent to penetrate intricate geometries and solubilize difficult soils. Many modern machines are equipped with two immersion tanks for cleaning: the "boil sump," which contains the heating elements to produce the vapor zone, and the "rinse sump," which collects the clean distillate. These machines function, essentially, as industrial stills; the liquid is boiled in the boil sump, condensed in the vapor zone, and then collected in the rinse sump as pure solvent. This means that even as contamination is introduced into the machine during the cleaning process, clean solvent is continuously distilled into the rinse sump, allowing for the contamination to stay trapped in the boil sump. Modern equipment also benefits from improved cold traps, which restrict solvent emissions and improve the distillation process. Figure 3 illustrates the design of a modern two-sump vapor degreaser with two sets of cooling coils.

The cleaning process in a vapor degreaser typically requires only minutes to complete. Although cycle times vary based on part geometry and soil difficulty, most cleaning cycles require less than 15 minutes to completely clean and dry a rack of parts. Cleaning a circuit board can take place in either one or multiple immersion sumps, depending on the difficulty of the flux residue. For RMA and rosin-based fluxes, cleaning can typically occur in the vapor zone and rinse sump only. Difficult no-clean and high-melt-point fluxes may require immersion in both the boil sump and the rinse sump. The boil sump is very important to the cleaning process, as the hot solvent can provide better solubilizing properties. Additionally, as flux residues begin to accumulate in the boil sump, the dissolved residues actually help the solubility; in the cleaning industry, it is well known that “like dissolves like.” Some electronics manufacturers express concerns about immersing circuitry into the “dirty” boil sump due to recontamination or damage from solid particulate, such as solder balls. However, recontamination is avoided by following the boil sump immersion with a rinse in the rinse sump, and solder balls can be contained by using an auxiliary still or filtering the boil sump fluid, which is common in most vapor degreasing equipment. Once the boards have been cleaned in the boil sump and rinsed in the rinse sump, the vapor zone will remove any remaining particulate or residue with clean distillate and allow for instant drying as the boards are removed from the equipment.

Cost of Ownership

Although cleaning is crucial to many electronics industries, it is still only one aspect of the total manufacturing process, and so the cost of cleaning needs to remain reasonable to the overall manufacturing cost. Fortunately, the cost-per-cleaning for the vapor degreasing process is considerably low and can be comparable or less than that of aqueous cleaning. When comparing solvent vapor degreasing to aqueous cleaning systems, there are many factors to consider including capital investment, equipment footprint, power supply, cleaning time, detergent/solvent supply, and waste disposal. In other words, a vapor degreaser and an aqueous machine capable of cleaning the same number of parts-per cycle will have different overall costs, thus different costs-per-part cleaned. Aqueous systems typically have larger working footprints, power requirements, and longer cleaning cycles; these are due to the need for several washing and rinsing stations, high temperature inputs, and reliance on mechanical spraying and washing mechanisms[4]. Although vapor degreasers require less time and overall maintenance, the cleaning solvents are typically more expensive than aqueous detergents; however, properly maintained equipment should retain solvent, and the distillation process keeps solvent pure for continuous use.

Table 1 compares cost and maintenance differences of an aqueous system and a vapor degreasing system using the same sized basket and cleaning the same number of parts. Many of the maintenance and operation requirements of the aqueous system are greater than those of the vapor degreasing system. However, the cost of the solvent is three times greater than that of the aqueous detergent. There are certainly other cleaning processes outside of vapor degreasing and aqueous cleaning that are less costly, such as manual cleaning with water or solvents, though these processes tend to compromise the

Comparing common market equipment: aqueous in-line system and an open-top vapor degreaser both using a $1600in^3$ basket

	Aqueous	Vapor Degreasing
Capital Investment	>$100,000	<$100,000
Power	~20kW/hr	~7kW/hr
Footprint	~40sqft	~20sqft
Cleaning Cycle	20-25 minute	10-15 minute
DI Water	30-40 gallons/hr	None
Waste Treatment	100,000 gallon/yr	10 gallons/yr
Detergent/Solvent	$50/gallon	$160/gallon

Table 1: Operation of Aqueous vs. Vapor Degreasing.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effectiveness of cleaning. The most important factor to keep in mind when comparing cleaning processes is the outcome. In most industries, the cost of cleaning is less than the price of product failure.

Current Study

The MicroCare laboratory conducted cleaning trials in order to evaluate the cleaning capability of new vapor degreasing chemistries on difficult flux and solder paste formulations. The study evaluated three flux formulations and seven solder pastes containing leaded or unleaded ingredients. The pastes and fluxes were chosen based on customer recommendations and market trends. The flux pastes evaluated were AIM 217, AIM No-Clean Paste Flux and AIM Flux Pen. The solder pastes that were evaluated were AIM M8, AIM RMA258-15R, Loctite GC3W, Alpha OM350, Indium 8.9HF1, Loctite GC10 and Indium SMQ92-J. The Loctite GC3W, Alpha OM350, Indium 8.9HF1 and Loctite GC10 are all lead-free, no-clean formulations. The AIM M8, AIM RMA258-15R and Indium SMQ92-J are leaded pastes. The Loctite GC3W was the only water-soluble paste chosen for this study.

Two specially formulated solvents were selected for the cleaning trial and were compared to a more common, hydrofluorocarbon solvent. The specialty vapor degreasing solvents will be referred to as Solvent A and Solvent B*. Solvent A is composed of a blend of trans-dichloroethylene, alcohol and hydrofluorocarbons with a proprietary additive to improve flux removal. Solvent B is a non-chlorinated blend of hydrofluorocarbons, alcohol and proprietary non-volatile ingredients. Both chemistries can be used in modern two-sump vapor degreasers without modification, so long as the equipment has adequate cooling. These solvent compositions were compared to a common SNAP-approved flux-cleaning solvent with a composition of hydrofluorocarbons, trans-dichloroethylene and an alcohol; this solvent will be referred to as "Classic Solvent."

Surface Insulation Resistance (SIR) testing was performed in order to evaluate the boards for failure due to dendritic growth. SIR testing is common in electronics manufacturing in order to verify that changes in temperature and humidity will not cause unexpected failures in the field. Many no-clean fluxes and pastes have been formulated to pass SIR evaluations, though not all. In our study, we found that most of the no-clean pastes were capable of passing SIR evaluation without cleaning; however, three of the no-clean pastes did suffer failures during the evaluations when they were not cleaned.

PROCEDURE

Visual Evaluation

A visual analysis was preformed to compare the cleaning efficiency of Solvent A, Solvent B and the Classic Solvent. B-36 coupons were reflowed with three different no-clean solder pastes: Indium NC-SMQ 92 SAC305, Indium 8.9HF1 and Alpha OM-350 96.5sn/3.0Ag/0.5C. The boards were prepared and reflowed by Altek Electronics in Torrington, Connecticut. Ten boards were prepared with each paste. An additional set of ten B-36 boards was prepared with AIM NC217 flux at the MicroCare laboratory according to the product's technical specifications. Boards were visually examined at 15x and 40x magnification before cleaning. One set of traces was photographed for each paste type before cleaning as a reference.

The boards were separated by flux type and labeled to represent the flux/paste and the cleaner to be used. Three boards of each paste were cleaned in each of the solvents: Solvent A, Solvent B and Classic Solvent. The remaining boards were retained for future cleaning. Cleaning was conducted at the MicroCare laboratory in a Branson B452R two-sump vapor degreaser, and an Ultronix BBMLR120 with retrofitted Zero-0-Coils and an automatic hoist. No ultrasonic agitation was used during cleaning. Each vapor degreaser was fitted with a basket of ap-

Cleaner Designation	Cleaner Formulation
Solvent A	Hydrofluorocarbons, alcohol, trans-dichloroethylene, proprietary additive
Solvent B	Hydrofluorocarbons, alcohol, proprietary non-volatiles
Classic Solvent	Hydrofluorocarbons, trans-dichloroethylene, alcohol

Table 2: Evaluated Cleaners.

proximately 500in^3 in size. The three boards of the same paste were cleaned simultaneously. The three boards were stacked vertically in the baskets with wire boundaries on each side to keep the boards from touching. The cleaning cycle remained consistent for each set: 30 seconds in the vapor zone, five-minute immersion in the boiling liquid, five minutes in the rinse liquid and 30 seconds in the vapor zone. The timing was controlled and monitored by an operator or by a timed automatic hoist when available. After the final 30-second vapor rinse, the boards were held in the cooled freeboard area for approximately 30 seconds to allow for any excess solvent to drip off. After cleaning, the boards were immediately inspected at 15x and 40x magnification and evaluated for cleanliness. One representative set of traces was photographed for each paste and each cleaner.

SIR Evaluation

The two advanced solvent formulations, Solvent A and Solvent B, were selected for cleaning evaluation with visual inspection and SIR analysis. The Classic Solvent was omitted from the second round of visual analysis and the SIR testing due to the poor cleaning results of the first visual evaluation. A selection of three fluxes and seven solder pastes were evaluated. A total of 98 B-24 boards were prepared for the SIR testing: six boards were supplied without flux—three were cleaned in Solvent A and three were cleaned in Solvent B; 60 boards were reflowed with flux/paste—30 were cleaned in Solvent A and 30 were cleaned in Solvent B; three boards of each flux/paste were reflowed and left un-cleaned as controls; two boards were supplied with no flux/paste and were un-cleaned as blanks.

Each of the boards contains four pads of traces. No components were attached to the pads. All of the B-24 boards were prepared and reflowed by the AIM Solder lab in Montreal, Canada, per IPC-J-STD-004A controls. Cleaning was again conducted at the MicroCare laboratory in a Branson B452R two-sump vapor degreaser, and an Ultronix BBMLR120 with retrofitted Zero-0-Coils and an automatic hoist. No ultrasonic agitation was used. All boards were visually inspected before any cleaning was performed. The boards were visually examined at 15x and 40x magnification and one of the four pads was photographed for each representative paste/flux.

The boards were separated by flux type and labeled to represent the flux/paste and the cleaner to be used. Three boards of the same flux type were cleaned simultaneously in one of the solvents. The cleaning process used for all solvents was the same as the visual evaluation cleaning: 30 seconds in the vapor zone, five minute immersion in the boiling liquid, five minutes in the rinse liquid and 30 seconds in the vapor zone. The timing was controlled and monitored by an operator or by a timed automatic hoist when available.

After the final 30-second vapor rinse, the boards were held in the cooled freeboard area for approximately 30 seconds to allow for any excess solvent to drip off. The boards were immediately inspected again at 40x magnification, photographed, packaged in ESD anti-static bags and labeled. Visual evidence was recorded with photographs and an overall assessment of the cleanliness was determined. The packaged boards were boxed and shipped out to the National Technical Systems laboratory in Baltimore for SIR evaluation. The SIR method followed IPC-TM-650 Method 2.6.3.3, requirements per IPC J-STD-004A, paragraph 3.2.4.5. After testing, all boards were sent back to the MicroCare laboratory for disposal.

Results

Visual analysis of the boards prior to and after cleaning showed positive effectiveness of the cleaners. Visual analysis was conducted on each pad of traces on each board at 15x and 40x magnification. The visual results were approximately quantified using a percentage system: if all three boards of the same paste set had no visible residue after cleaning they were designated 100%; if one-three visible contaminated traces were found on the three boards of a paste set they were designated 90%; if more than a total of three contaminated traces were found on the three boards of a paste set they were designated 50%; if boards contained mostly contaminated traces with softened or dried residues they were designated 10%. Contamina-

Flux	SIR Results	Visual Results Classic Solvent	Visual Results Solvent A	Visual Results Solvent B
AIM 217	A: Pass B: Pass	100%	100%	100%
AIM NC Paste Flux	A: Pass B: Pass	NA	100%	100%
AIM Flux Pen	A: Pass B: Pass	NA	100%	100%
AIM M8	A: Pass B: Pass	NA	100%	100%
AIM RMA258-15R	A: Pass B: Pass	NA	100%	90%
Loctite GC3W	A: Pass B: Pass	NA	100%	100%
Alpha OM350	A: Pass B: Pass	10%	50%	100%
Indium 8.9HF1	A: Pass B: Pass	10%	50%	50%
Loctite GC10	A: Pass B: Pass	NA	100%	90%
Indium SMQ92-J	A: Pass B: Pass	10%	50%	50%
10% = mostly contaminated traces on paste set (3 boards) 50% = more than three contaminated traces on paste set (3 boards) 90% = less than three contaminated traces on paste set (3 boards) 100%= no visible contamination on paste set (3 boards)				

Table 3: Flux Cleaning Results.

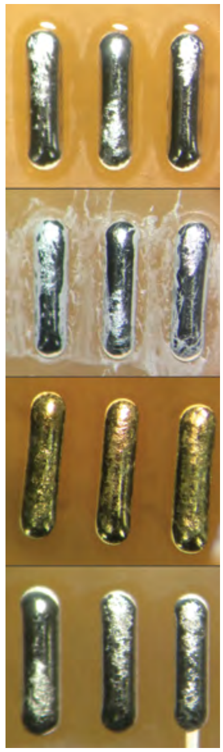

Table 4: Visual Cleaning Comparison 1.

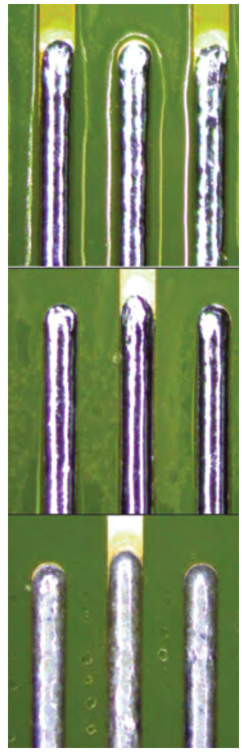

Table 5: Visual Cleaning Comparison 2.

tion is defined as any solid or liquid substance found on or around a trace where there was once flux. The full set of results is summarized in Table 3.

The rosin-based and RMA fluxes were fully cleaned (100%) in both classic vapor degreasing solvents and in the advanced solvent formulas. No-clean fluxes cleaned in classic vapor degreasing solvents resulted in only 10% cleaning and formed white ionic residues. Solvents A and B fared better on the no-clean formulations; most of the solder pastes could be entirely removed by at least one of the formulations. A visual cleaning comparison of the Classic Solvent and Solvents A and B can be seen in Table 4. The Indium 8.9HF1 and Indium SMQ92-J were the most difficult for both of the solvent formulations to remove. Visual comparisons of Indium SMQ92-J can be seen in Table 5.

Solvent A was able to clean seven out of 10 fluxes to 100% flux removal and Solvent B was able to clean six out of 10 fluxes to 100% flux removal. The lead-free, no-clean formulations were the most difficult to clean, though all formulations had at least 50% of the flux removed during the cleaning cycle. The SIR testing showed favor to the advanced solvent formulations; all of the boards that were cleaned in Solvents A and B passed SIR testing, while some of the un-cleaned fluxes suffered failures. This verifies that even though cleaning was not 100% successful on some of the boards, the residues were not altered in a way that caused electrochemical migration when exposed to heat and humidity.

Conclusion

New flux and solder formulations with better safety profiles and processing efficiency hold an importance in modern electronics assembly; however, these benefits come with hurdles of their own, including potentially detrimental residues.

Processes that require high-reliability electronics require high-reliability cleaning. Modern vapor degreasing techniques and solvent formu-


mechanical
environmental
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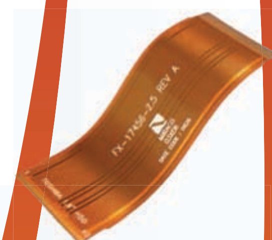
SOLUTION



lations are environmentally conscientious, time efficient, safe and effective on some of today's most difficult soils. Although ionic residues may be an issue for current vapor degreasing solvents, there are new technologies available to combat even the toughest flux residues. Solvents A and B showed major visual improvements over the Classic Solvent when cleaning no-clean and lead-free flux residues. The advanced solvents were able to remove at least 50% of the flux residue from all of the different flux formulations during the cleaning cycle. Increasing cleaning cycle times or utilizing ultrasonic agitation may be able to further improve the visual results.

The SIR evaluation confirmed that the cleaning formulations did not impact the circuit operation and that any remaining residue was not detrimental to the circuit performance.

Acknowledgements

The authors would like to thank the solder suppliers involved in this study, in particular AIM Solder for supplying the necessary materials. Special thanks to Tim O'Neill of AIM for assisting with this project. **SMT**

References

1. USA, EPA, Office of Air and Radiation Stratospheric Protection Division. The U.S. Solvent Cleaning Industry and the Transition to Non Ozone Depleting Substances. ICF Consulting, 1725 Eye Street, NW Washington, DC 20006.

2. M. Konrad, Cleaning and Contamination Equipment & Environment Guide, Corona, Calif. Aqueous University, 2014.

3. Highlights of the 1990 Clean Air Act Amendments.

4. S. Stach, M. Bixenman, "Optimizing Cleaning Energy in Batch and Inline Spray Systems," SMTAI Conference, 2004.

Editor's Note: This paper was originally published in the proceedings of SMTA International, 2016.

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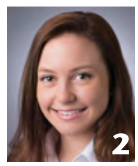
2. Venesia Hurtubise is a sales engineer at MicroCare Corp.
3. Elizabeth Norwood is a senior chemical analyst at MicroCare Corp.



Real Time with... IPC: OK International Brings Disruptive Technology in Hand Soldering

During the recent IPC APEX EXPO 2017 show in San Diego, California, Christopher Larocca, president and CEO of OK International, tells I-Connect007 Publisher Barry Matties their strategy for improving the hand solder process.

Larocca describes a lack of process feedback to the operator as a core problem inherent in the hand soldering process. He discusses how the team at OK International has developed an innovative solution to address the issue and to take another step in their Industry 4.0 strategy.

To view the whole video, click here.

New ON IPC EDGE

IPC Provides ESD Certification For Trainers and Operators

Why is ESD certification important?

- Dual certification program from IPC and EOS/ESD Association, Inc.
- Third-Party Certification verifies technical competence and problem-solving ability
- Third-Party Certification facilitates uniform ESD control
- Certification confirms that high standards are met
- In compliance with ANSI/ESD S20.20
- In compliance with training requirements for MIL-Spec.-1686
- In compliance with IEC61340-5-1
- Fills a training gap within the electronics industry

Learning Objectives

- Covers basic ESD theory/physics
- Covers advanced theory for trainers
- Provides strategies to protect increasingly sensitive components
- Provides technical requirements for operator training
- Operators learn basic theory from the online course
- Operator-led classroom training by certified trainers

ESD certification can be found on IPC EDGE, the industry's leading online education portal: edge.ipc.org.

Contact ipcmail@ipc.org with your questions.

IPC EDGE Online Education and Training for the Electronics Industry

IPC EDGE

Electronics Industry News
Market Highlights

Driving Value in the Digital Era: Smart Mobility Disrupts the Traditional Dealer Model

As consumers demand greater transparency, influence, and efficiency from the auto purchasing process, most also wish to minimize time spent at a dealership. In its new smart mobility report, ABI Research finds recent, rapid gains in vehicle technology will soon infiltrate the mainstream automotive market and disrupt traditional business models and consumer experiences.

Connected Home Solutions Adoption Remains Limited to Early Adopters

Adoption of newer connected home solutions is still at the early adopter phase, according to a recent survey by Gartner Inc. The survey of nearly 10,000 online respondents in the U.S., the U.K. and Australia during the second half of 2016, found that only about 10% of households currently have connected home solutions.

3D ICs Will Meet the Miniaturization Demands of Next-Generation Electronics

With 2D integrated circuit (IC) technology nearing its scaling limit, there is an urgent need to scale up vertically to cope with the breakneck pace of advances in digital technologies.

BOE Takes First Spot in Large Display Unit Shipment

Chinese display maker BOE takes top position in terms of large TFT-LCD display unit shipments in January 2017, according to IHS Markit. For the first time ever, a Chinese display maker, taking a total share of 22.3% in unit shipments, is displacing South Korea's display makers, the historical leaders in shipment volumes.

February 2017 Manufacturing ISM Report on Business

Economic activity in the manufacturing sector expanded in February, and the overall economy grew for the 93rd consecutive month, according to the latest Manufacturing ISM Report On Business.

New iPhone Production Volume to Exceed 100M Units This Year

The next major iPhone release will certainly be one of the most anticipated events in the global consumer electronics market in the second half of 2017. TrendForce's recent findings on the 10th anniversary iPhone release reveal that Apple's latest refresh of the device series will include three new models, with one of them having significant hardware and design upgrades such as an AMOLED display.

Global Tablet Shipments Down 6.6% Annually in 2016

Market research firm TrendForce reports annual tablet shipments worldwide posted a decline for 2016, dropping 6.6% to 157.4 million units. However, total shipments from branded tablet vendors surpassed expectations because of the robust year-end holiday sales.

Increasing Sales of Smartphones Trigger Demand for Global ASIC Market

According to Transparency Market Research, the global application specific integrated circuit (ASIC) market is expected to be worth $35.23 billion by the end of 2024 from $16.29 billion in 2015. The progress of the market is estimated to be at a CAGR of 9.2% between 2016 and 2024.

Worldwide Enterprise Storage Market Sees Decline in Fourth Quarter

Total worldwide enterprise storage systems factory revenue was down 6.7% year-on-year while reaching $11.1 billion in the fourth quarter of 2016, according to the International Data Corp. (IDC) Worldwide Quarterly Enterprise Storage Systems Tracker.

Intel Continues to Drive Semiconductor Industry R&D Spending

Intel Corp. continued to top all other chip companies in R&D expenditures in 2016 with spending that reached $12.7 billion and represented 22.4% of its semiconductor sales last year.

Solutions for Long-term Storage of Electronic Components and Compositions

by Rich Heimsch
SUPER DRY-TOTECH EU

The storage of moisture sensitive electronic components and materials is problematic, and manufacturers with long term storage requirements face additional obstacles.

Requirements for long-term storage are increasing. Why?

1. Component Obsolescence

Due to rapid changes in packaging design and material, companies find themselves forced to purchase additional quantities of components in order to guard against the impact of component obsolescence on their final product designs. This in turn creates an issue of long-term inventory storage.

2. Short Product Lifecycles

Product lifecycles have become very short with new models being released sooner than ever before. However, many manufacturers in industries including automobiles, aviation and avionics, military and railway must guarantee the availability of replacement parts including PCBs for ten or even twenty years. This demands the advance purchase and extended storage of components and materials. Further complicating the problem is that most components cannot be stored for more than a few years without very special handling procedures.

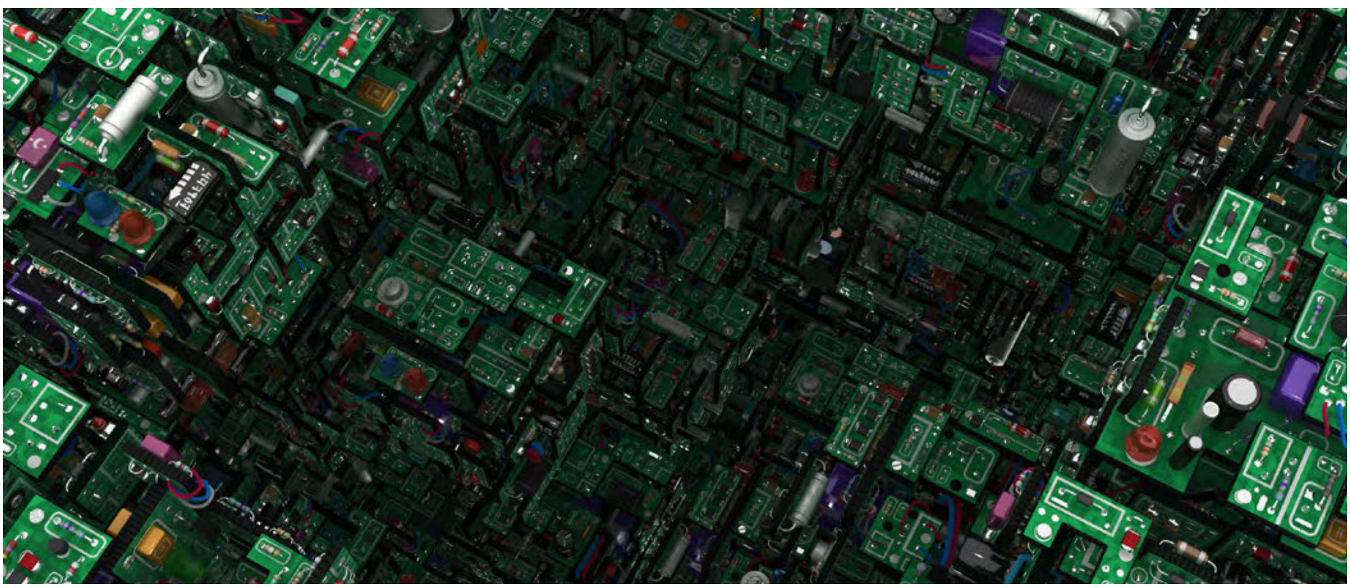
Risks

The biggest danger posed is humidity. It is the cause of two of the biggest defect causes: oxidation and diffusion.

Because of surface oxidation, components and PCBs can suffer from reduced solderablity, which often results in complete failure. Diffusion of vapor and noxious substances in the inner structure of the components or PCBs can result in long-term disintegration of conductor paths and insulation layers. Both risks can be avoided by correct handling and dry storage.

The Oxidation Process—Contact Corrosion

In an ultra-dry atmosphere, there is no corrosion. For corrosion to occur, two demands must be met: there must be a means of oxidation and a watery solution, which works as an electrolyte.



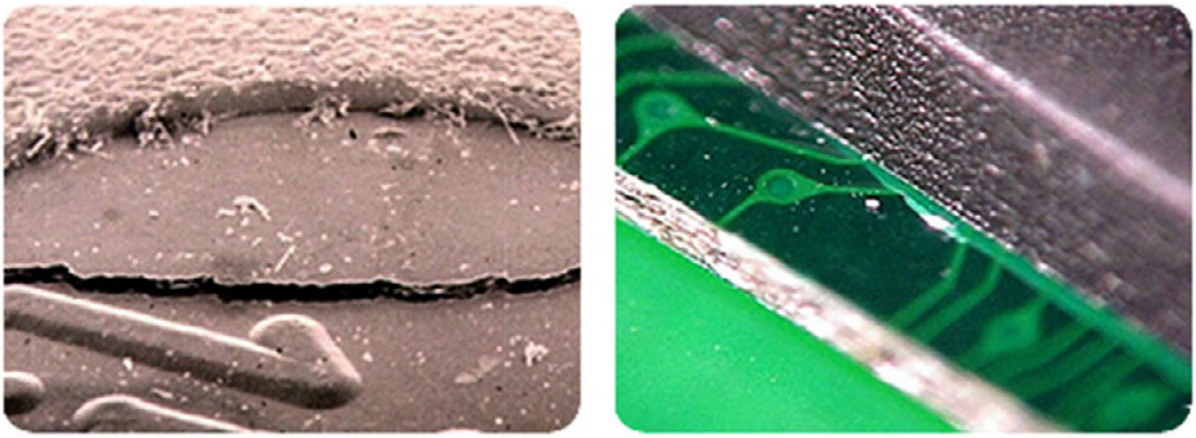


Figure 1: Component micro-cracking resulting from the absorption and rapid release of moisture.

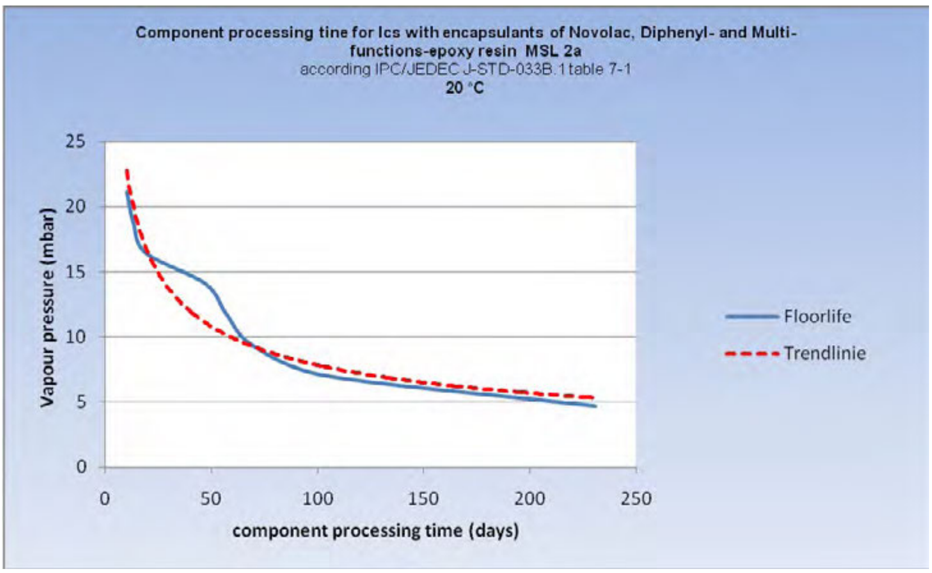


Figure 2: Component processing time.

The oxygen in the air forms the means of oxidation, the vapor (humidity) the electrolyte.

The critical limit at which oxidation with oxygen takes place lies in accordance with the metal or alloy at between 40–70% RH. This means that more than eight grams of vapor per cubic meter must be present.

The Diffusion Process

The vapor in the atmosphere diffuses into hygroscopic materials. The cause of this is the so-called vapor pressure—this means the partial pressure of the vapor which is present in the air. The higher the vapor pressure, the faster the components or PCB's absorb humidity and with this the permissible processing time decreases.

All components classes 2a to 5a in accordance with the classification of IPC/JEDEC J-STD020D absorb no moisture with a vapor pressure of < 2.82. At this level, they can be stored and processed indefinitely. (IPC/JEDEC-STD033C table 7-1).

Storage cabinets should maintain, over 24 hours, on average a vapor pressure of <0.95 mbar. In a humidity protection bag with a rest pressure of <6 mbar the vapor pressure is <0.15 mbar.

Both systems, dry storage cabinet and hu-

midity protection (a.k.a. moisture barrier) bag, reliably and effectively protect from moisture diffusion.

For storage periods of more than five years, a combination of the two systems is recommended. The storage in humidity protection bags with nitrogen present within a simple dry storage cabinet with 5% RH.

Critical to the effectiveness of the bags, however, is that the construction is mechanically stable and exhibits a very low percentage of diffusion. The IPC/JEDEC-STD033C demands a Moisture Vapor Transmission Rate (MVTR) of less than 0.002 g/100 in² in 24 hours at 40°C. This demand is only met by bags which have a thickness of 150 µm; 90 µm-bags have a substantially higher diffusion percentage and are therefore not suitable. Moisture barrier bags are available that remain significantly below the maximum value as laid down in the IPC standard with an MVTR of 0.0006 g/100 in².

The bags must of course also be ESD-safe; they must be marked as receptive to humidity and be provided with a label upon which the moisture-sensitivity-level and the packing date are clear.

Procedures such as those outlined above have been successfully utilized to eliminate the oxidation and diffusion hazards of long term storage. However, another risk of long term storage must also be considered.

Intermetallics

Intermetallic compounds form when two unlike metals diffuse into one another creating species materials which are combinations of the two materials. Intermetallic growth is the result of the diffusion of one material into another via crystal vacancies made available by defects, contamination, impurities, grain boundaries and mechanical stress. There are a number of locations within the electronic package where these dissimilar metals are joined. These include die level interconnects and wire bonds, plating finishes on lead frames, solder joints, flip chip interconnects, etc. Growth of intermetallics during the storage period can occur and reduce the strength.

Intermetallic growth rate is strongly temperature-dependent and doubles for each 10°C temperature increase. This aging process can be slowed by appropriate cooling. However, the risk of whisker formation of tin alloys increases with decreasing temperature. Studies and practice have shown that a storage temperature of 12°C is optimal in order to best mitigate both risks. **SMT**

Rich Heimsch is a director at Protean Inbound and Super Dry-Totech EU in the Americas. To read past columns or to contact Heimsch, click here.

SMTA

Certification Program

About SMT Certification

Each SMTA Certification course is a three day course on topics in SMT Processes or Lean Six Sigma Green Belt. The program concludes with an open and closed book examination (SMT Processes) and open book exam (Lean Six Sigma Green Belt). This challenging examination requires both written answers and calcuations with the intent to enable the attendee to establish competitive credentials as “Certified” by the SMTA in SMT Processes or Lean Six Sigma Green Belt.

2017 Course Dates

SMT Processes

May 2-4 - Eden Prairie, MN

May 6-8 - Markham, Ontario, Canada

August 15-17 - Portland, OR

September 19-21 - Rosemont, IL

October 16-18 - Guadalajara, JL, Mexico

November 14-16 - Dallas, TX

Lean Six Sigma Green Belt

September 19-21 - Rosemont, IL

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Photo Credit: Staff Sgt. David Owsianka, 03-20-17, U.S. Air Force

VirTex on Miltary & Aerospace Electronics Requirements

By Stephen Las Marias
I-CONNET007

In an earlier interview, VirTex CEO Brad Heath discussed with SMT Magazine his company's activities, how they stay ahead of their competition and the new technologies and trends that are having a significant impact in the electronics assembly industry. In the second part of this interview, we are joined by Upinder Singh, Vice President and General Manager at VirTex MTI, to discuss their company's military and aerospace business, and how they are addressing their customers' requirements

***Stephen Las Marias:** What is the percentage breakdown of VirTex's aerospace/defense electronics business, automotive, medical electronics, and industrial electronics?*

Brad Heath: Our major market segment is industrial, which is focused on several strategic divisions; our second largest segment is military; then automotive, communications and medical.

***Las Marias:** Can you please tell our readers what two primary challenges the aerospace and defense industries present to an Electronics Manufacturing Service provider (EMS) and what does VirTex do differently to address these challenges?*

Upinder Singh: This depends on the customer-related technologies. The most significant challenge is the design and QFNs, BGAs and micro-BGAs. Our customers, the Original Equipment Manufacturers(OEMS) require this level of talent in-house to make continuous improvements, product advancements, and design changes, while in parallel, they are fighting an aggressive timeline. This is one of our differentiators, how we enable our OEM customers to transition from existing technologies to new innovations, ensuring design for manufacture and commercialization throughout their production lifecycle, at speed.

VirTex addresses these challenges by introducing a top-of-the-line supply chain. We have developed an award-winning supply chain software solution that is tried and tested that we have been utilizing for several years. Our software solution provides complete transparency, traceability and visibility over our supply chain to bring parts, some often on an expedited schedule as per our customers' needs, together at the same time, to meet even the most progressive production schedules. Our team of in-

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dustry experts helps our customers, we guide them through the design process, into new product introduction (NPI), while we help them to build a supply chain that propels their time to market to maximize their time in the market.

Upinder Singh

Las Marias: The aerospace/defense electronics industry is typical of a high-mix/low-volume production model. How does VirTex manage the variety of high-reliability work in assembly lines geared for only a few line changes?

Singh: The level changeover required and scalability depends on the customer. At VirTex we utilize our in-house software solution to customize an execution program. This allows us to minimize set-up times and changeover times with commonality of different families. VirTex has been working with technology customers for over 20 years and through experience, we have an extensive portfolio to draw from in terms of standardizing the execution and trying to minimize the effect on the lead-time for our customers.

Las Marias: Do you see the rigid-flex PCB segment growing in terms of adoption in the military/aerospace electronics field?

Singh: For VirTex, about 95% of work is rigid. Less than 5% would be rigid flex. Flex, by itself, has a component of rigid attached to it. That's not to say that there are no applications out there that are using strictly flex. But, at VirTex, we are witnessing a trend towards FR4 rigid PCBs, versus non-rigid or flex components.

The application of flex itself as a flex material is more of a specific application need; you cannot make the whole FR4 flex, such as a control board or landing gear board, or a communication control board strictly on flex material; you simply cannot do this at present. So flex is application specific. Hence, VirTex is utilizing rigid and rigid-flex FR4 boards for our day-to-day operations.

Las Marias: Given the long period for developing wins in aerospace/defense electronics contracting, how does VirTex balance that strategic business development effort in aerospace/defense with more immediate opportunities in non-military markets you serve, like medical and industrial electronics?

Singh: The simple answer to this is, that's the beauty of our execution. You are absolutely right that some of the defense and aerospace applications have a longer development cycle than other high reliability markets. The conversion cycle for automotive and industrial applications is getting shorter and shorter, as these markets drive efficiencies through the supply chain to maximize their time in the market and yield.

VirTex serves all major electronic market segments, as we have significant bandwidth and experience to execute customer requirements across a diverse portfolio.

One of your earlier questions is what OEMs look for in their EMS partner. The perfect EMS partner is the one who is flexible enough to quickly adapt to the market trends and customer requirements. That's what VirTex takes pride in. We are dynamic and responsive and that's what differentiates VirTex from most of the other EMS providers.

If you look at the larger Tier-1 or Tier-2 EMS companies, you can understand why they must have rigid production boundaries. VirTex, on the other hand, can adjust its strategies and move with a customer or industry requirements for growth.

Las Marias: What is the greatest challenge with ITAR?

Singh: Once you have put the controls in place, in terms of assessment, training, IT control, back up, controlling the data and licensing, it operates smoothly. If a company is going through the process for the first time, my advice would be to do your due diligence and put in place processes, controls, and licenses. I personally wouldn't call the process challenging, it just puts a requirement onto the applicant to focus and strategize. If something is worth

doing, which ITAR absolutely is, it is worth doing right.

***Las Marias:** Developing trust with OEM customers has never been easy for EMS companies. Typically, OEMs don't fully trust EMS providers with their complete product roadmaps for fear portions of the roadmap or strategy might be shared with competing OEMs that the EMS provider also serves. How do you see the EMS industry moving past this?*

Brad Heath

Singh: There's a saying, that the proof is in the pudding.

At VirTex, we have been servicing the needs of our OEM customers for over 30 years. If you look at our customer base, we have customers who started with us in the early 80's or early 90's and as they have grown, we have grown with them.

Relationships and partnerships are a two-way street. At VirTex we want our customers to grow and we want to be the driving force behind them to sustain their competitive advantage. The longevity of our customer base and the relationships we have, allow us to confidently state that we are our customers trusted technology partner.

***Las Marias:** Counterfeit components are a growing problem in aerospace/defense electronics supply chains. What are some of the things VirTex is doing to help mitigate the risk of receiving or installing a counterfeit part?*

Heath: We avoid non-franchise distribution and if we do have to go outside the normal franchise channels, there has to be traceability and a chain of custody. We involve both the customer and an independent testing lab to make sure that the components are genuine.

***Las Marias:** What demands are your mil/aero customers placing on you?*

Singh: All customers need a perfect product, on time, every time. That is a requirement, not a demand or a challenge.

Challenges exist with lead times and aggressive time-to-market, a new design, a change in design, or a product upgrade. The lead times are shorter, so we need to perfectly execute operations and the supply chain, as speed to market matters.

***Las Marias:** What are the top criteria OEMs should consider when evaluating an EMS partner?*

Singh: Firstly, like in any relationship, look at the history. For example, how long has the organization been serving in this type of environment, what is their reputation for quality, on-time delivery? What certification do they hold to validate their quality standards or credentials? What metrics and key performance indicators (KPI's) do they use to measure success and what do their customers say within their quarterly business reviews (QBRs)?

Secondly, VirTex has a high-reliability customer base. The application of our customer's products can be life critical, therefore we anticipate their requirements to meet and exceed their expectations. We understand the nature of their environment, so we nurture an internal culture to ensure demands are met.

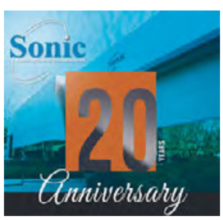
So, history and culture to ensure that demand is met, combined with experience, certification, financial stability and technical know-how is how we at VirTex have become our customers manufacturing partner of choice. **SMT**

Recent Highlights from SMT007

1 Managing Millennials: Eric Hassen Discusses the Importance of Balance and Clear Communication

Eric Hassen, vice president of test engineering at Saline Lectronics, gives his views on the millennial workforce in manufacturing, along with tips to successfully manage and grow them into becoming strong leaders.

2 Sonic Manufacturing Celebrating 20 Years in EMS Industry



Mya Walton, associate coordinator in the test department at Saline Lectronics, talks about how working in the manufacturing industry opened up a new world of possibilities for her, and how it feels to be creating products that help other people, such as heart monitors and black boxes.

3 Neways Posts Strong Results in 2016

EMS firm Neways Electronics International N.V. has reported net turnover of €393.2 million for the full year ending 31 December 2016, up by 5.1% year-on-year and primarily driven by automotive, semiconductor, and defense sectors.

4 IPC Elects New Board Member

Cao Xi, technical director at Huawei Technologies Co. Ltd, was elected as a new member of the IPC Board of Directors and will serve a four-year term through February 2021.

5 Vexos Appoints Paul Jona as President & CEO

The board of directors of EMS provider Vexos has appointed Paul Jona as the new president and CEO, following the resignation of David Buckley.

6 SMART Group Releases Conformal Coating & Cleaning Defect Guide 2

SMART Group, Europe's largest technical trade association focusing on surface mount and related technologies, announces the release of its "Conformal Coating & Cleaning Defect Guide 2". The guide provides examples of the most common process defects and common cures. It also features many of the less obvious defects seen during production, including those associated with components, printed circuit boards, design, materials, assembly and rework. It also includes some of the issues that are seen on field returns.

7 IPC Bestows Debbie Wade with President's Award

In recognition of her significant contributions of time, talent and ongoing leadership in IPC and the electronics industry, long-time IPC volunteer Debbie Wade of Advanced Rework Technology was presented with an IPC President's Award at IPC APEX EXPO 2017.

8 Industry 4.0: Nine Key Points Electronics Manufacturers Must Not Ignore

The Fourth Industrial Revolution is nothing if not massive and complicated. There is a huge amount of information out there, some useful and some perhaps less so. But, among the hype, there are a few consistent themes that really must not be ignored by manufacturers wishing to remain competitive in the future.

9 Flex Enters Agreement to Acquire AGM Automotive

Flex has entered into a definitive agreement to acquire AGM Automotive (AGM), a global supplier of automotive interior components and systems.

10 ITL Group Marks 40-Year Milestone

2017 marks a milestone celebration for ITL Group as it celebrates its 40 years in the industry.

SMT007.com for the latest SMT news and information—anywhere, anytime.

Events

For IPC's Calendar of Events, click here.

For the SMTA Calendar of Events, click here.

For the iNEMI Calendar, click here.

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

NEPCON China 2017
April 25–27, 2017
Shanghai, China

The 14th Electronic Circuits World Convention
April 25–27, 2017
Goyang City, South Korea

KPCA Show 2017
April 25–27, 2017
Goyang City, South Korea

IPC Reliability Forum: Manufacturing High Performance Products
April 26–27, 2017
Chicago, Illinois, USA

IMPACT Washington D.C. 2017
May 1–3, 2017
Washington D.C., USA

Thailand PCB Expo 2017
May 11–13, 2017
Bangkok, Thailand

SMT Hybrid Packaging
May 16–18, 2017
Nuremberg, Germany

JPCA Show 2017
June 7–9, 2017
Tokyo, Japan

IPC Reliability Forum: Emerging Technologies
June 27–28, 2017
Düsseldorf, Germany

SMTA International 2017 Conference and Exhibition
September 17–21, 2017
Rosemont, Illinois, USA

electronicAsia
October 13–16, 2017
Hong Kong

productronica 2017
November 14–17, 2017
Munich, Germany

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