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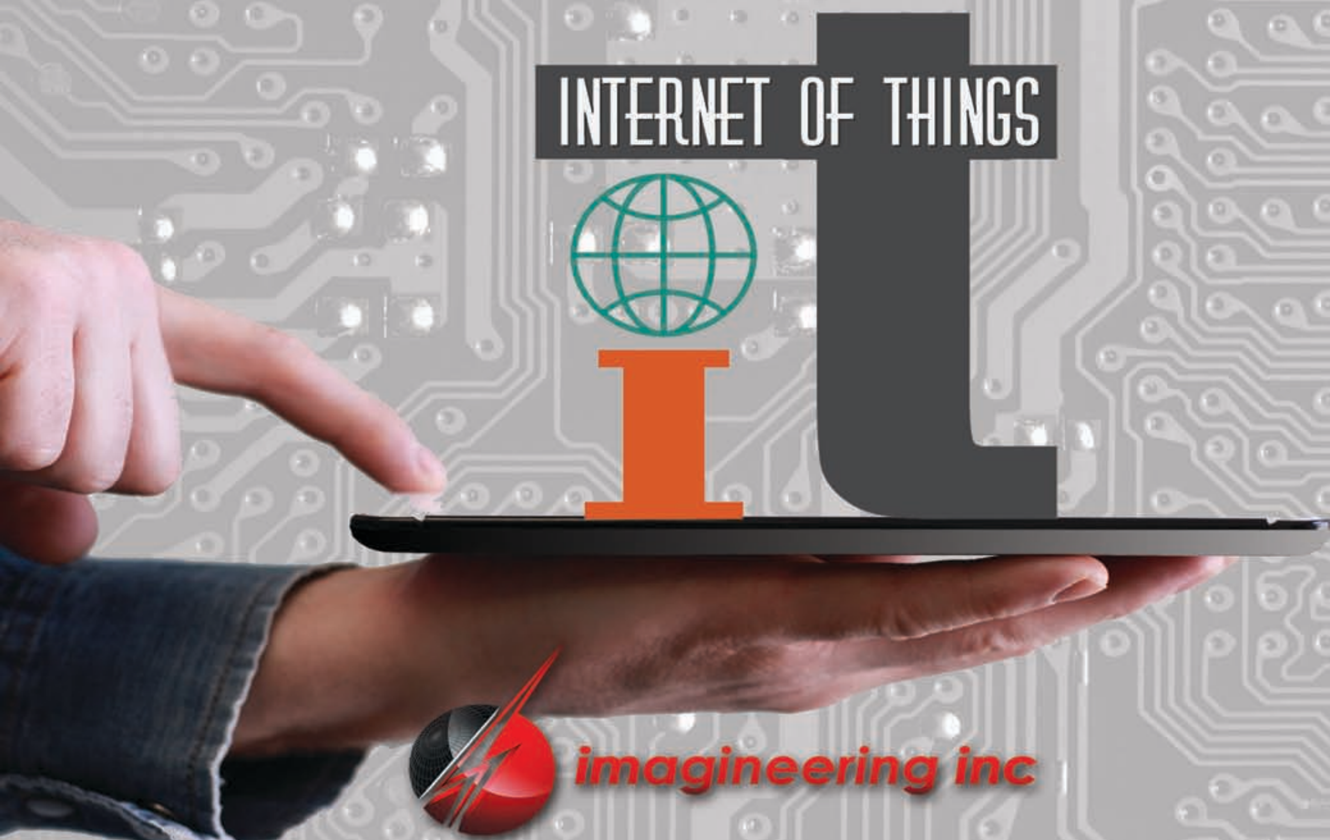

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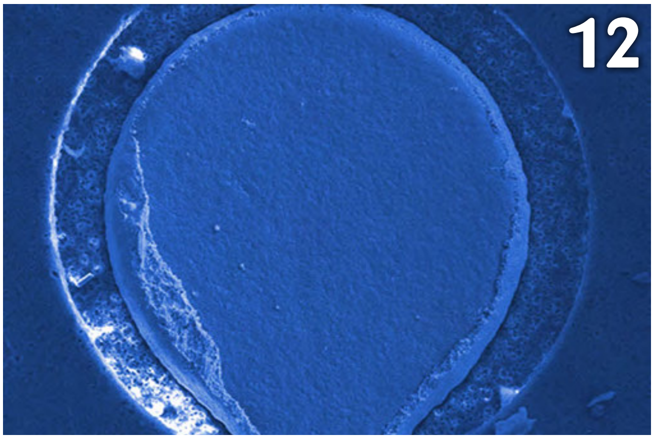
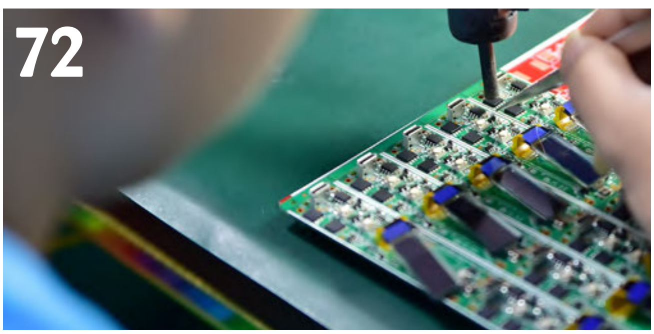
January 2017 • Featured Content

Plating and Surface Finishing: Impact on Electronics Assemblies

This issue of *SMT Magazine* looks into the impact of plating and surface finishing in PCB assemblies, especially when it comes to solderability and solder joint reliability.





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Understanding Plating and Surface Finishing

by Stephen Las Marias
I-CONNECT007

We recently covered the HKPCA and IPC Show 2016 in Shenzhen, China. The overall mood at the event was very bullish on the coming year, despite recent news about raw material cost hikes, in particular that of copper clad laminates. Equipment and systems manufacturers say 2017 is expected to see more capital investments as the electronics manufacturing industry gets a little bit of clarity—for lack of a better word—in terms of the no-longer-hyped Industry 4.0 trend.

That is because China "got it" with its Smart Factory 1.0 model. Basically, Industry 4.0 will take years of development—from an electronics manufacturing standpoint—before we have a fully automated electronics assembly line without human intervention. What Smart Factory 1.0 promotes is that the industry already has advanced equipment with automation features designed to replace manual labor and improve processes—so the first step (the "1.0" tag) is to adopt these systems to transform production processes and make the more efficient. The thing is, it's not so much as shooting for the moon, but taking baby steps to get there. The industry will get to 4.0 eventually; but for now, it's important to optimize processes first and make them more efficient, which I believe is another part of the vision of intelligent manufacturing.

Equipment manufacturers also remain bullish because while most industry segments are not faring so well, one major growth driver remains: the automotive electronics sector. This is due to the continually increasing amount of electronics in cars, the development of more electric vehicles, and government initiatives to make driving safer than ever.

So much for my recap of the general atmosphere at that show and what these manufacturers think 2017 will be. Of course, it is too early to tell, but at least it gives us some sort of insight as to the developments to expect throughout the year.

Moving on, this month's issue focuses on the impact of plating and surface finishing in electronics assembly. True, plating and surface finishing may be more directly significant in PCB fabrication (we are covering the same topic in *The PCB Magazine* and *The PCB Design Magazine* to provide you an end-to-end coverage on


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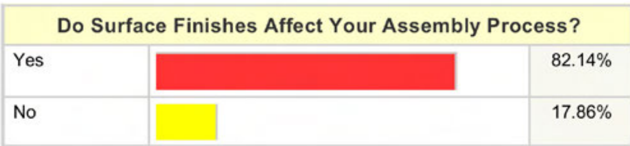
this particular topic), but surely they are important issues as well when it comes to the assembly side. In fact, according to our recent survey, 82% of the respondents said surface finishing impacts their assembly process.



Source: I-Connect007

Key issues include poor solderability and solder joint reliability, wettability, head on pillow issues, and inspection. One particular comment reads: "The most significant impact is on wire-bonding process window and die-attach (epoxy). The delivery inspection process is also painful when it comes to acceptance of imperfections."

On this note, Joemar Apolinario and Dnichols Dulang of EMS firm Integrated Micro-Electronics Inc. elaborated in a short interview how plating and surface finishing impact the assembly process. They talked about solderability, and provided key parameters to consider to help optimize the assembly process.

Inside, you will also find an article by Ben Gumpert, William Fox, and C. Don Dupriest of Lockheed Martin that evaluates the use of electroless nickel/electroless palladium/immersion gold (ENEPIG) plating in small solder joints amid the decreasing size of parts used in electronics assembly.

On a slightly similar topic, Yoshinori Ejiri, Takehisa Sakurai, Yoshinori Arayama, Yoshiaki Tsubomatsu, and Kiyoshi Hasegawa of Hitachi Chemical Co. Ltd discuss the influence of electroless Ni/Pd/Au plating film thickness on solder ball joint reliability.

Finally, Jim Wilcox and Francis Mutuku of Universal Instruments Corp. and Shuai Shao and Babak Arfaei of Binghamton University focus on the different failure modes as observed based on board surface finish.

As always, we also have a lineup of interesting articles to kick-start the year. First, we have Jake Kulp of MC Assembly breaking down the long, complex sales cycle in the EMS industry. Next, we have Eddie Groves of the Selective Soldering Academy writing about the advantages and disadvantages of different fluxes in the selective soldering process, and their impact on solder joint quality and reliability.

Finally, we have Stefan Meissner of ULT AG writing about the influence of clean air on the value-added chain in electronics production.

Of course, *SMT Magazine* is not complete without our columnists. First, Michael Ford continues his "Smart for Smart's Sake" series. This month, he writes about another opportunity offered by the move toward digital manufacturing—the complete traceability of the operation.

Next, Tom Borkes continues on the topic of a new organizational model using logic, cost effectiveness and customer service. In previous columns, he talked extensively about one of the controllable components of labor cost: using automation to reduce labor content. This month, he starts his discussion on the other controllable component of labor cost: indirect labor.

For his part, Bob Wettermann writes about reducing warpage on BGAs to avoid shorts and open circuits post rework.

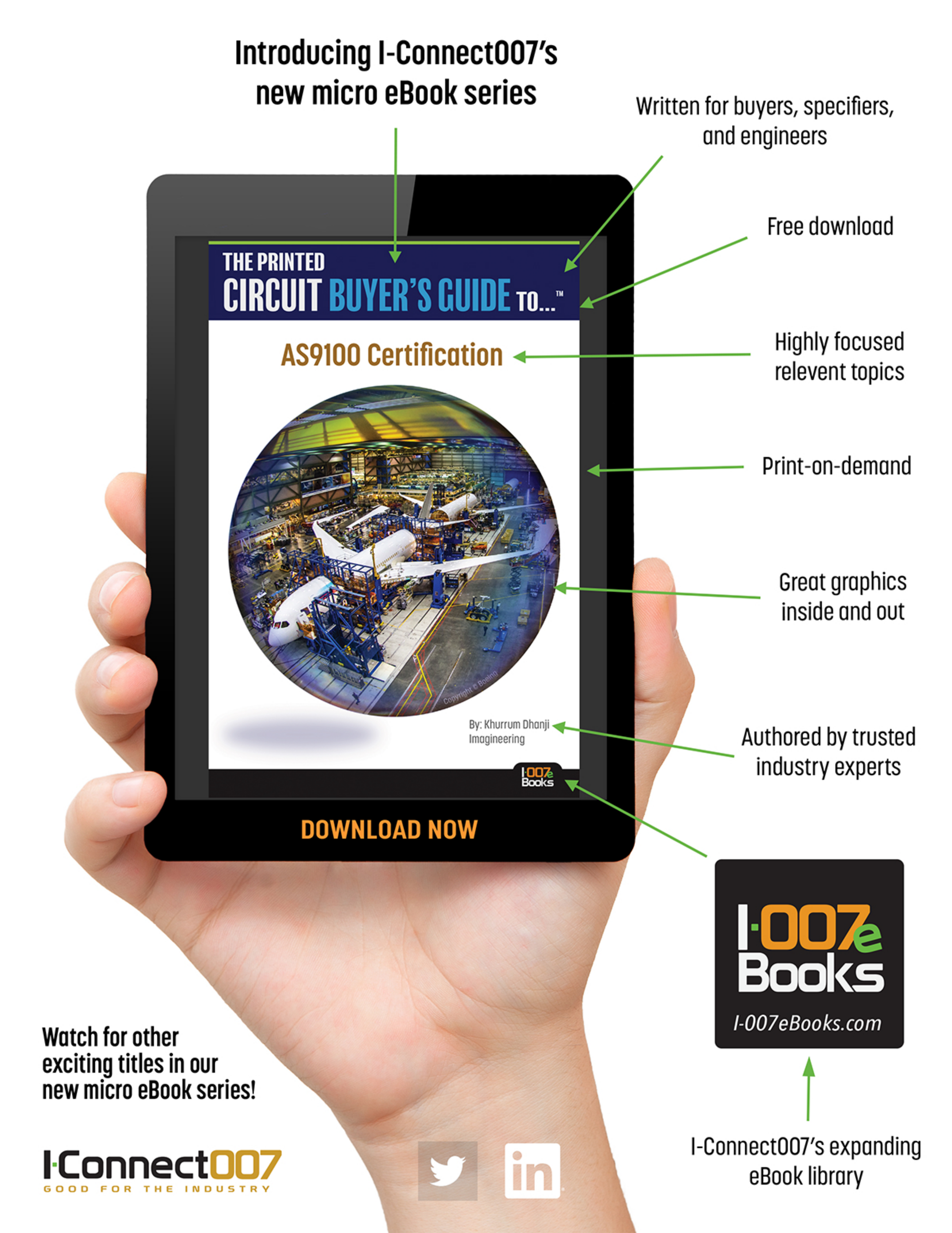
I am happy to announce that we have a new columnist. Richard Heimsch, a director at Protean Inbound, and Super Dry in the Americas, will be writing about management of moisture sensitivity in his column "More Than Just Dry Air." His inaugural column talks about controlling oxidation and intermetallics in moisture-sensitive devices.

Finally, we have Keith M. Sellers, a regular columnist at *The PCB Magazine,* who explores the tin whisker phenomenon, and why testing of your mitigation practices is both critical and prudent in the development of a reliable product.

I hope you enjoy this month's issue of *SMT Magazine*. By the way, IPC APEX EXPO 2017 is just around the corner. I hope to see you there!

And so, Happy New Year! I hope this year will be better than the last and bring you more business and success. **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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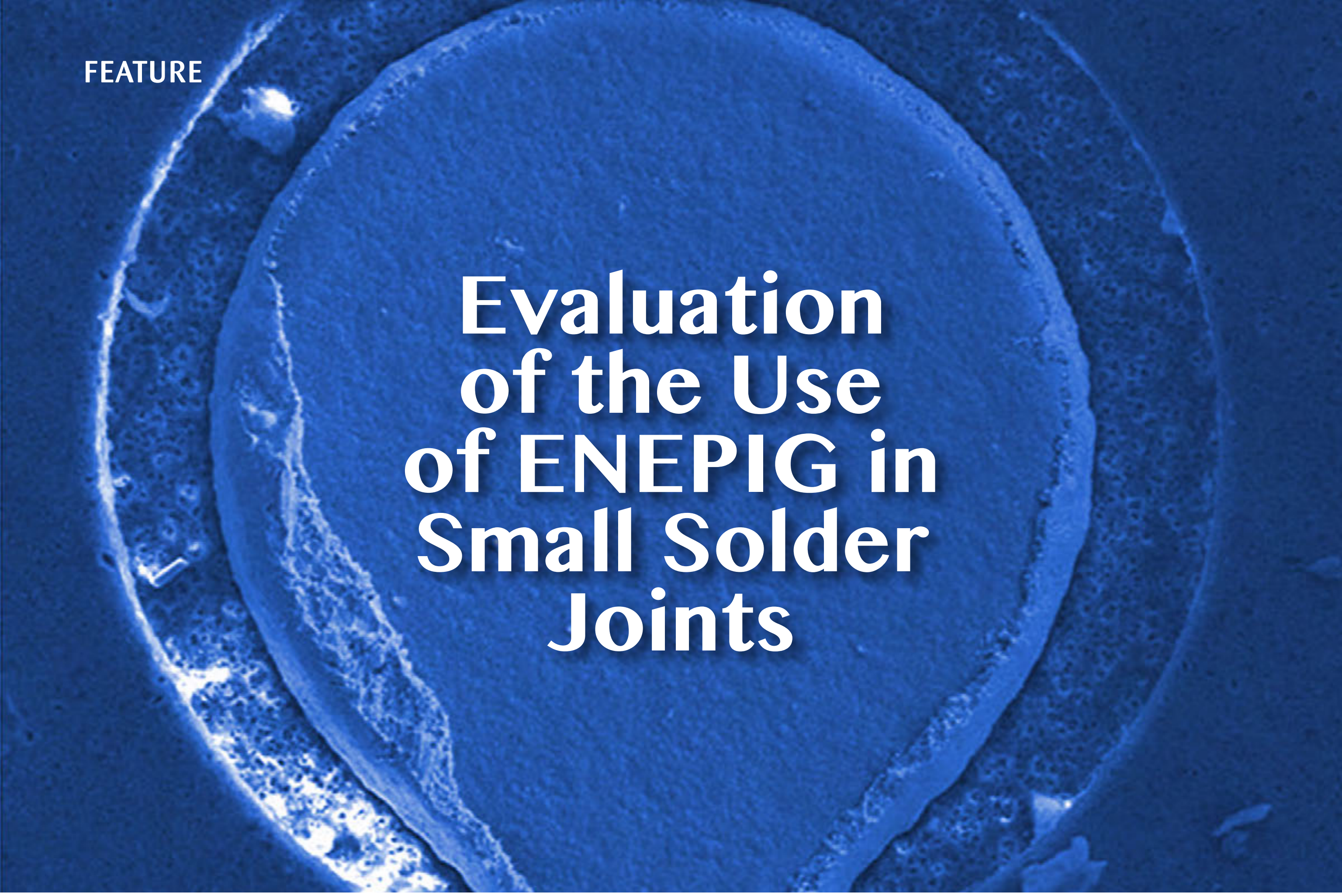

Evaluation of the Use of ENEPIG in Small Solder Joints

by Ben Gumpert, William Fox, and C. Don Dupriest
LOCKHEED MARTIN

Abstract

The surface finish of a printed circuit board provides a number of functions, with impacts starting at the point of design and continuing through the life of the assembled product. Electroless nickel electroless palladium immersion gold (ENEPIG) is a surface finish that has been demonstrated to have a variety of benefits, and to be suitable for both SnPb and Pb-free circuit card assembly. Extensive testing of ENEPIG has demonstrated the reliability of this surface finish and resulted in the creation of an industry standard for its application: IPC-4556 Specification for Electroless Nickel/Electroless Palladium/Immersion Gold (ENEPIG) Plating for Printed Circuit Boards. When soldering to ENEPIG, all of the palladium is dissolved into the solder joint, and creates a palladium-rich region at the base (Pd source) of the solder joint. This palladium-rich microstructure can spall off, exhibiting a columnar shape. With ever decreasing size of parts used in electronics assembly, the size of the solder joints correspondingly continues to shrink, which causes the relative size of this palladium-rich microstructure to grow relative to the overall joint thickness. In this study, the impact of industry standard Pd thicknesses on thin solder joints is evaluated through shear testing.

Introduction

ENEPIG is a multi-layer surface finish for circuit boards. For soldering, the gold and Pd are applied to protect the solderability of the underlying Ni, and they are ultimately dissolved into the solder joint. Excessive amounts of these metals in the solder joint can potentially cause weakness of the solder joint, impacting reliability.

There is an industry specification (IPC-4556) that describes the requirements for ENEPIG, and the finish has some use in the industry, but is limited due to availability and the increased cost of the printed board (PB) relative to other surface finishes. The plated layers of ENEPIG are very flat, as all plated surface finishes

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sales@pkaymetal.com +323-585-5058 pkaymetal.com are relative to Hot Air Solder Leveling (HASL), which makes it advantageous for smaller PB design features. As electronic component packaging technology advances and parts get smaller, the PB must have finer features to attach these parts. This decrease in feature size typically drives a decrease in solder paste stencil thickness for effective solder release, resulting in smaller solder joint volume. As the solder joint size gets smaller, the thickness of the surface finish on the PCB remains constant, so that the relative volume of gold and palladium in the solder joint increases. ENEPIG has been demonstrated to have acceptable performance and reliability for many current packages and solder joint configurations, but some studies raise concerns for use of ENEPIG at high concentrations or in very small solder joints[1].

Round robin testing for the development of the IPC-4556 specification included palladium thicknesses of up to 17.95 microinches (µin). A 0.005-inch-thick stencil was used with a 0.025-inch diameter SnPb solder sphere, resulting a solder joint containing approximately 0.17% Pd. Shear testing of the solder ball on pad resulted in both lifted pads and cohesive failure in the bulk solder.

IPC-7095C Design and Assembly Process Implementation for BGAs warns of reliability impacts from excessive and non-uniform intermetallic compound (IMC) layer growth. IPC-4556 mentions a 3% limit for gold and palladium, and other sources have identified 2% as a limit[2], but these limits based on a percentage are misleading when applied to Pd. Gold can (and is desired to) disperse throughout a solder joint to minimize impact, but Pd tends to form a distinct and concentrated IMC layer above the Ni.

Palladium has a slower solubility rate in molten solder than other metals. During soldering, the tin-palladium intermetallic compounds (either PdSn3 or PdSn4) will rapidly grow in the form of a thick lamellar structure perpendicular to the original palladium surface. Solder, consisting of a lead-rich phase, will be present between the lamellae. Further aging of solder joint can result in the movement (spalling) of the tin-palladium layer into the bulk solder and likely leave tin-palladium crystals within the bulk solder.

ENEPIG has been found to be prone to brittle fractures. The tin-palladium layers that form directly above the nickel plating has been found to be brittle, although some studies indicate that this may be based on weakness of a phosphorus rich nickel layer, not necessarily the Pd intermetallics[3]. The presence of tin-palladium crystals within the bulk solder has not been well-documented in terms of the effect on solder joint integrity; however as a comparison, tin-gold intermetallic crystals in bulk solder have been shown to embrittle a solder joint, enabling fracture of the solder joint along the gold intermetallics. It has not been shown that Pd intermetallics can have a similar effect within the bulk solder, the typical failure is associated with brittle fracture at the PB pad.

Based on the initial formation of a thick lamellar Pd intermetallic structure above the Ni layer, a limit on Pd thickness may be more appropriate to prevent excessive intermetallic layer thickness. A higher Pd thickness leads to an increased interfacial IMC thickness, specifically when SnPb solder is used. A thin palladium layer should dissolve rapidly into molten solder and result in no detrimental effect on solder joint mechanical properties. A variety of Pd thickness percentages or thickness limits have been proposed, some of which are lower than

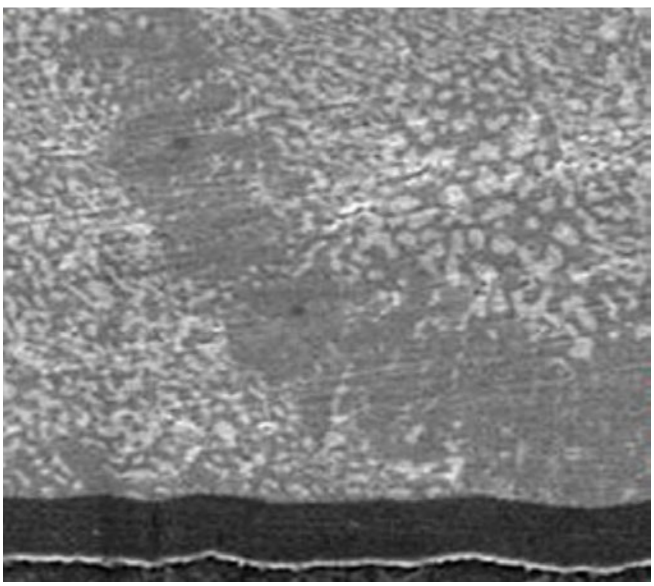

Figure 1: PdSn intermetallic structure spalling off substrate surface.

the 12 µin limit in IPC-4556. One paper suggests a limit of 7.8 µin[4], although one study found that Pd thickness as high as 20 µin had no impact on solder joint shear strength[5].

In this study, PBs plated with a typical ENEPIG surface finish (per IPC-4556) will be assembled with a minimum amount of solder to create a very small solder joint where the Pd concentration becomes larger relative to the overall solder joint. Solder shear strength and solder joint analysis will be used to investigate the acceptability of using ENEPIG with SnPb solder in these very small solder joints.

Experimental Procedure

For assembly and testing, an existing test vehicle was selected for use with a small LGA package. Using an LGA package limits the solder volume in the solder joint since there is no contribution from a solder ball as there is in a BGA package, resulting in a higher Pd concentration in the solder joint. A small LGA package of 6 x 6 pad array was selected and will be installed at the four corners of a larger BGA footprint in a manner so that only the middle 4 x 4 array of pads on the part are soldered. This will be done to increase the quantity of data points for the shear test, and to limit the number of solder joints which will limit the shear force required to remove the part.

The test vehicles (24 total) were separated into four sets, with three of these sets going to three separate vendors (each of which used a different plating chemistry) for application of the ENEPIG finish, and the remaining set coated with HASL (control set). Once returned, the PBs were subjected to XRF for measurement of the tri-metal layer thicknesses. The data from these measurements is shown in Figure 2 (each vendor represented by a different color).

A stencil of 3 mil thickness was used for solder paste application. The apertures of the stencil were matched to the PB pads (as designed) at 14.8 mil diameter. Half of the assemblies were

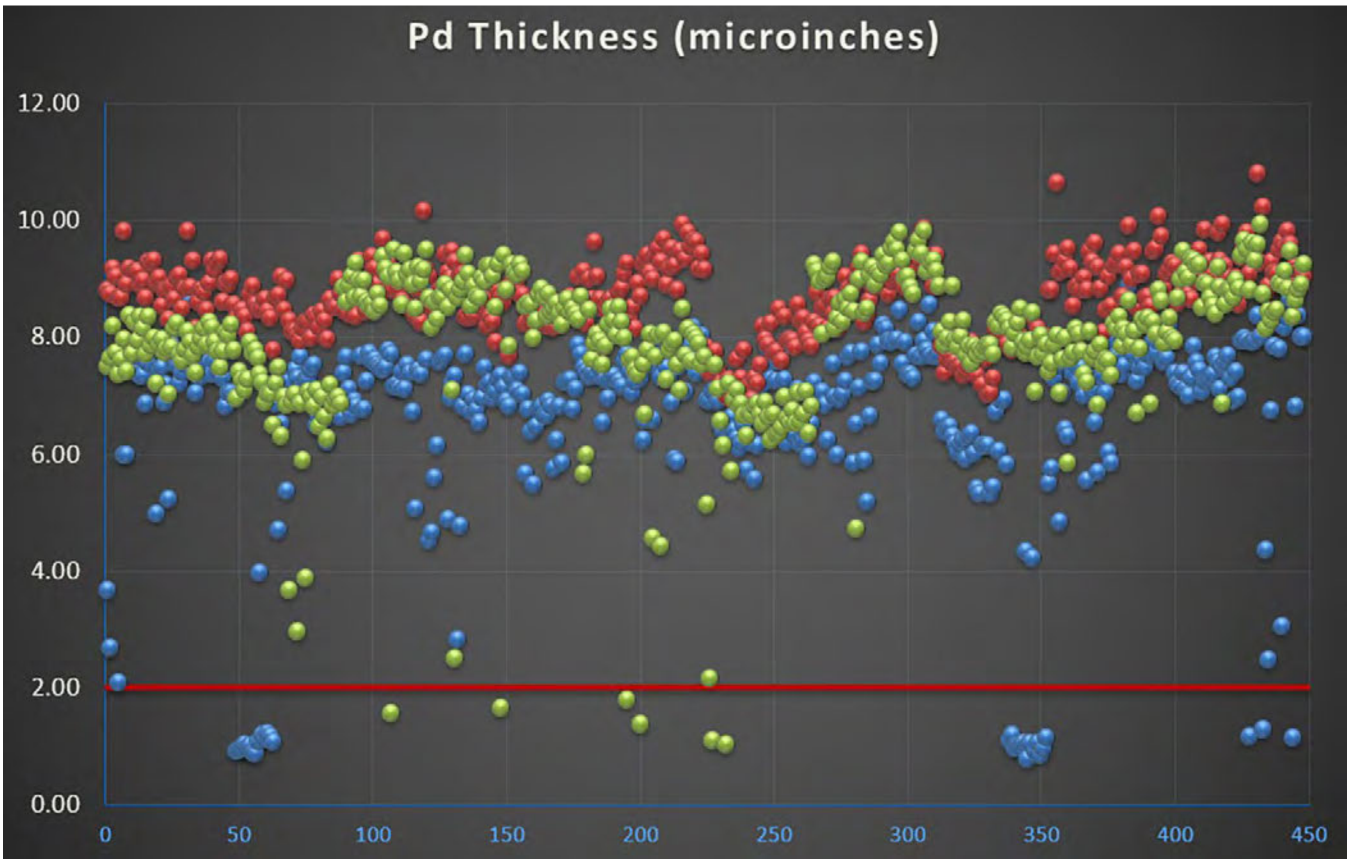

Figure 2: Palladium thickness measurements (color indicates each vendor).

soldered using Sn63Pb37 solder of type 3 with RMA flux. The remainder of the assemblies were soldered using Sn62Pb36Ag2 solder of similar type and flux content.

Results

Fabrication of the test vehicles was completed and it was determined that the solder mask thickness was greater than desired (approximately 3.5–4.5 mil compared to 1.0 mil pad thickness). This was discovered during PB fabrication, as the thickness of the solder mask interfered with board electrical testing and the HASL process. Additional boards were fabricated with thinner solder mask to enable the HASL process on the control units. PBs with ENEPIG surface finish were not replaced.

XRF measurements were taken on the PBs at 26 locations on each board and at 20 locations on additional test coupons. These measurement locations were located on both sides of the PB, and it was found that some of the Pd layer thicknesses did not meet the IPC-4556 specification requirements. In a typical production run, each board may not be measured, but a sample would be taken. Samples are collected over time and a standard deviation is calculated; this standard deviation is used to determine if the process is in control per the standard, along with the individual measurements. In our testing, multiple locations on every board were measured, so the data itself is compared to the specification limits without consideration of standard deviations.

Assembly of the test units was completed with SnPb or SnPbAg solder, then each component was removed by applying force to the component edge at a speed of 0.5 in/min (Figures 3 and 4). The force required to remove the test parts is given in Table 1. The shear strength

			Shear Load (lb)			
S/N	Finish	Solder	1	2	3	4
1001	ENEPIG 1	SnPb	12.6	9.8	11.2	13.5
1004	ENEPIG 1	SnPbAg	10.7	7.9	12.7	13.8
1007	ENEPIG 1	SnPb	13.5	13.3	12.0	13.9
1010	ENEPIG 1	SnPbAg	7.5	17.6	13.2	7.1
1013	ENEPIG 2	SnPb	11.1	15.3	13.3	12.6
1016	ENEPIG 2	SnPbAg	11.7	16.0	15.5	8.9
1019	ENEPIG 2	SnPb	13.6	13.4	13.1	6.8
1022	ENEPIG 2	SnPbAg	11.9	14.0	8.8	7.5
1025	ENEPIG 3	SnPb	14.2	10.2	10.7	6.4
1028	ENEPIG 3	SnPbAg	15.5	8.9	9.5	7.3
1031	ENEPIG 3	SnPb	15.9	7.1	10.9	13.2
1034	ENEPIG 3	SnPbAg	15.9	6.0	7.6	7.0
1061	HASL	SnPb	18.8	19.2	15.8	16.1
1064	HASL	SnPbAg	18.6	21.3	14.9	12.3
1069	HASL	SnPb	19.1	19.2	14.5	17.6
1071	HASL	SnPbAg	15.7	12.2	11.3	8.5

Table 1: Shear test results.

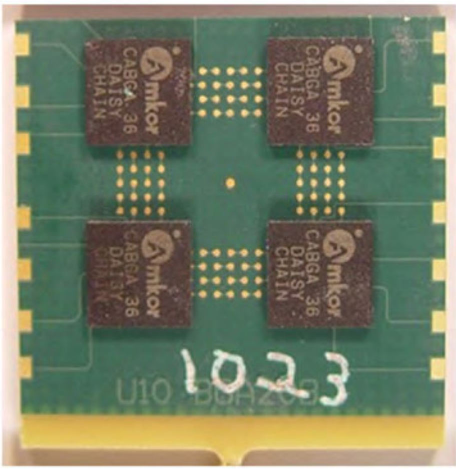

Figure 3: Test sample containing LGA36 (4 components per test sample) prior to shear test.

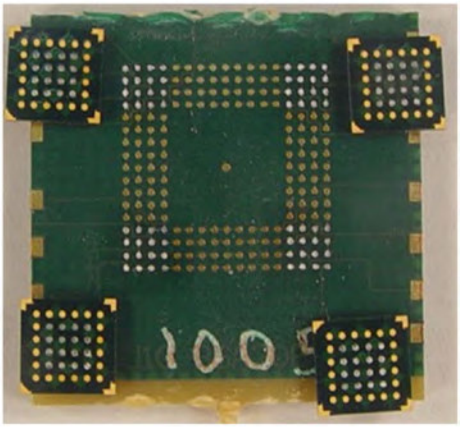

Figure 4: Sample after components have been removed through shear test.

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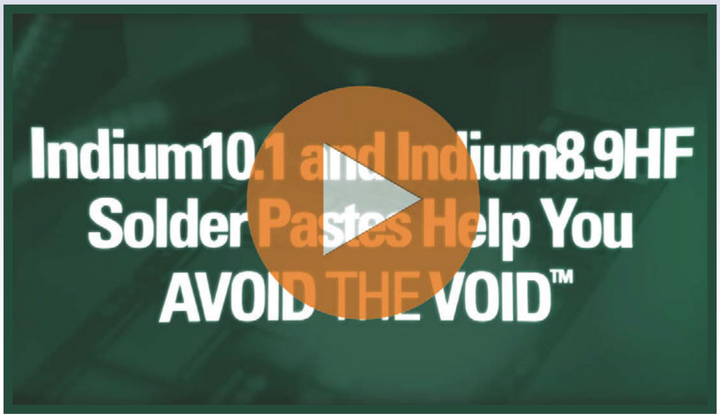

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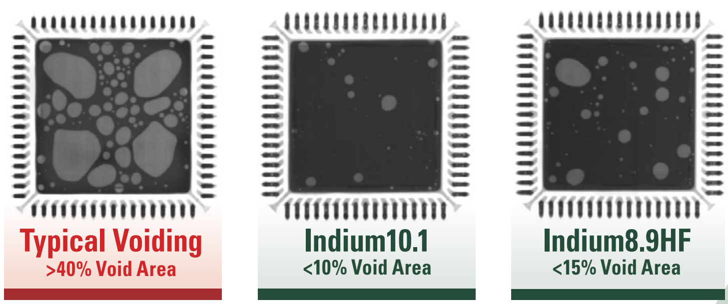

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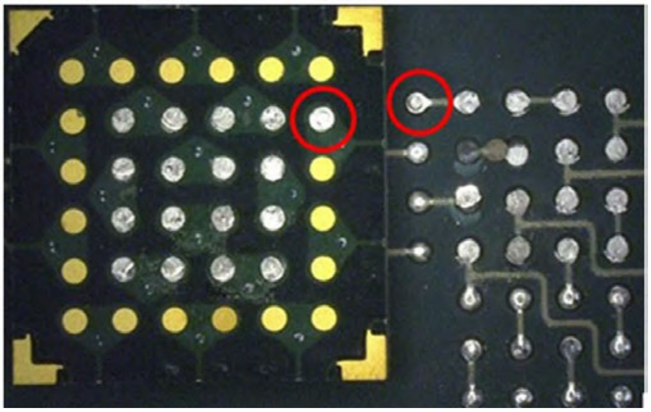


Figure 5: Example of HASL unit removed in shear test with 'extra' solder joint.

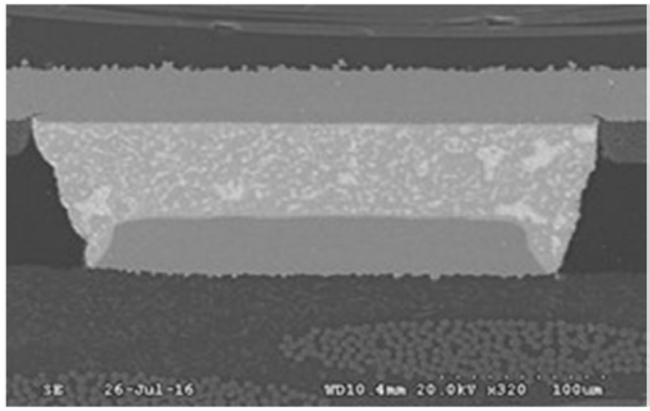


Figure 6: Cross-section of solder joint on HASL.

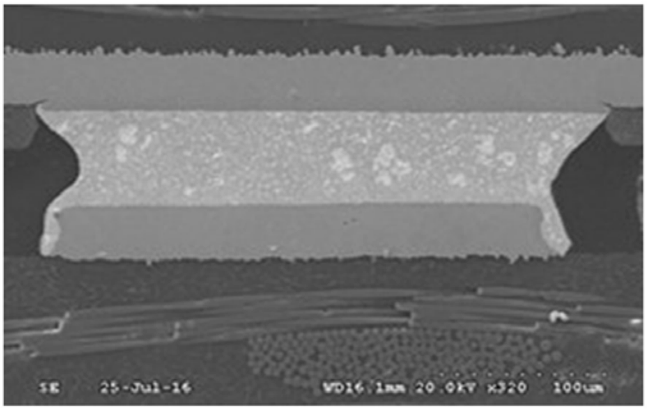


Figure 7: Cross-section of solder joint on ENEPIG.

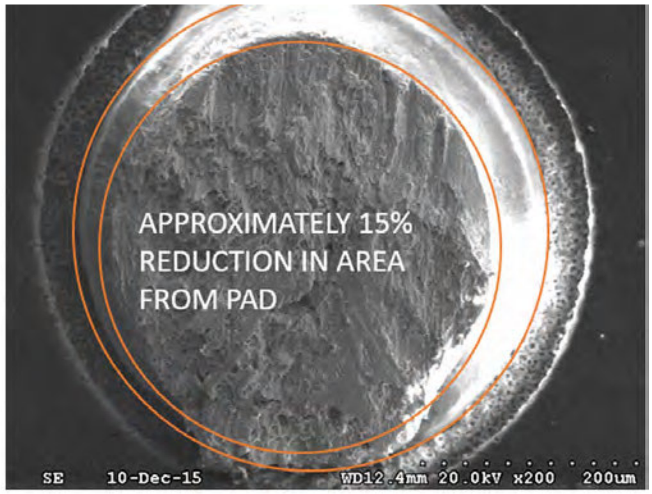


Figure 8: Shear fracture surface of ENEPIG sample with ductile fracture surface.

values for the samples with ENEPIG finish were lower than those on HASL. For all finishes, there was a mixture of bulk solder fracture and pad lifting. For HASL, the fracture occurred in the bulk solder 18% of the time (the remaining portion resulted in pad lifting), while for ENEPIG pad lifting occurred about 35% of the time, with the remaining failures predominantly exhibiting bulk solder failure, and some instances of brittle fracture (approx. 3%) at the PB pad.

The average shear strength for ENEPIG in this test was 11.5 lbs. and the average shear strength for the HASL samples was 16.0 lbs. While the difference in these results initially appear to be significant, two factors are important to comparing these values. The first is that in some cases, there was an extra solder joint that formed outside of the intended 4 x 4 array. This only occurred on the HASL boards, and is attributed to an excess amount of solder from the HASL process on the pad, which was enough to solder to the part. These connections varied from relatively little connection between the PB and component to 'full' solder joints similar to those within the 4 x 4 array. Table 1 indicates the locations where an extra solder joint occurred with values in red. Cells of this table highlighted in orange indicate that some or all of the pads lifted at that test site. The average of the shear strength values for HASL samples that did not contain any extra solder joints was 15.2 lbs., but this significantly limits the sample size.

The second factor impacting the shear test results is observed in a comparison of the cross sections from an ENEPIG sample and a HASL sample. On the ENEPIG units, the excess thickness of the solder mask previously identified prevented the parts from sitting as low as they would have otherwise. This caused the solder joints to form an hourglass shape (Figure 7). The shape provided a smaller cross-section at the middle, which reduced the overall strength of the solder joint. This reduction was in the range of 10–20%. Figure 8 shows a typical 15% reduction in solder joint cross sectional area at the fracture point. A reduction in fracture cross-sectional area due to the solder joint geometry contributed a considerable portion of the difference between HASL and ENEPIG in shear strengths. The combination of thinner solder mask and additional solder from the HASL process resulted in a different solder joint geometry on the HASL units.

A second set of test units for all surface finishes was aged at 100°C for 10 days. Results for these units in shear testing were similar, with several consistent differences from the initial shear testing. The force required to shear the parts increased slightly for each surface finish, the standard deviation of values went down slightly in each group, and there was a significant reduction in the number of lifted pads. The incidence of pad lifting dropped from 50% to 3%. These values are based on the number of individual pads lifted rather than the locations indicated in Tables 1 and 2 (identified by highlighted cells). It is expected that this is a result of further curing of the PB to improve pad adhesion. Remaining failures on the HASL samples were exclusively ductile failures in the bulk solder again.

			Shear Load (lb)			
S/N	Finish	Solder	1	2	3	4
1002	ENEPIG 1	SnPb	14.6	15.1	13.3	
1005	ENEPIG 1	SnPbAg	11.2	14.6	9.8	12.4
1008	ENEPIG 1	SnPb	15.0	14.3	16.0	16.1
1011	ENEPIG 1	SnPbAg	14.2	16.5	13.4	9.6
1014	ENEPIG 2	SnPb	16.7	15.0	15.3	
1017	ENEPIG 2	SnPbAg	14.6	15.2	15.4	14.3
1020	ENEPIG 2	SnPb	16.3	12.1	14.5	14.5
1023	ENEPIG 2	SnPbAg	15.6	15.3	15.4	11.1
1027	ENEPIG 3	SnPb	11.4	9.5	9.5	
1029	ENEPIG 3	SnPbAg	16.7	14.9	15.8	11.2
1032	ENEPIG 3	SnPb	15.9	15.3	15.8	13.2
1035	ENEPIG 3	SnPbAg	13.4	15.5	12.8	13.4
1062	HASL	SnPb	19.9	19.7	19.6	
1067	HASL	SnPbAg	15.8	19.7	20.5	14.9
1072	HASL	SnPb	19.4	22.1	21.9	17.2
1070	HASL	SnPbAg	19.6	19.4	19.6	20.5

Table 2: Shear test results (lbs.) after isothermal aging.

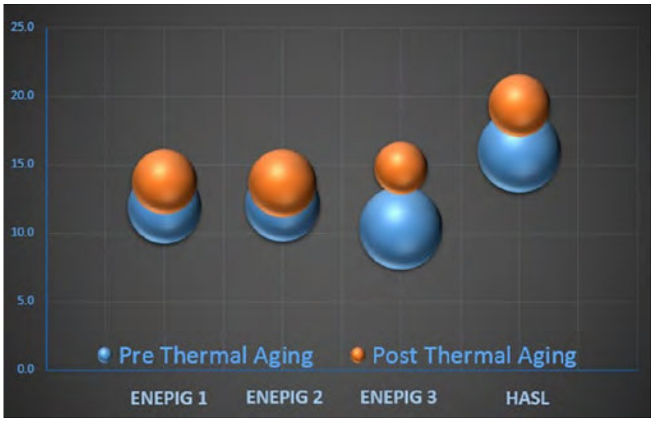


Figure 9: Shear force of failure (lbs.) for each surface finish prior to and after thermal aging. The size of each bubble indicates the standard deviation of the data for that group.

When the solder type is considered, SnPbAg solder had a lower force at failure relative to SnPb (11.8 vs. 13.4 lbs). After thermal aging, the average shear values relative to solder alloy both increased, but SnPb still demonstrated a slightly higher strength (15.1 lbs. for SnPbAg vs. 15.7 lbs. for SnPb).

In both the pre-thermal aging samples and the post-thermal aging samples, there were some instances of brittle facture on the ENEPIG units. Some of the brittle fractures were associated with each of the three ENEPIG surface finishes. The proportion of this failure mode was very low at about 3% regardless of thermal exposure, although the occurrence of brittle failure on the post-thermal samples was limited to two part locations, and was associated with lifted pads at each of those locations.

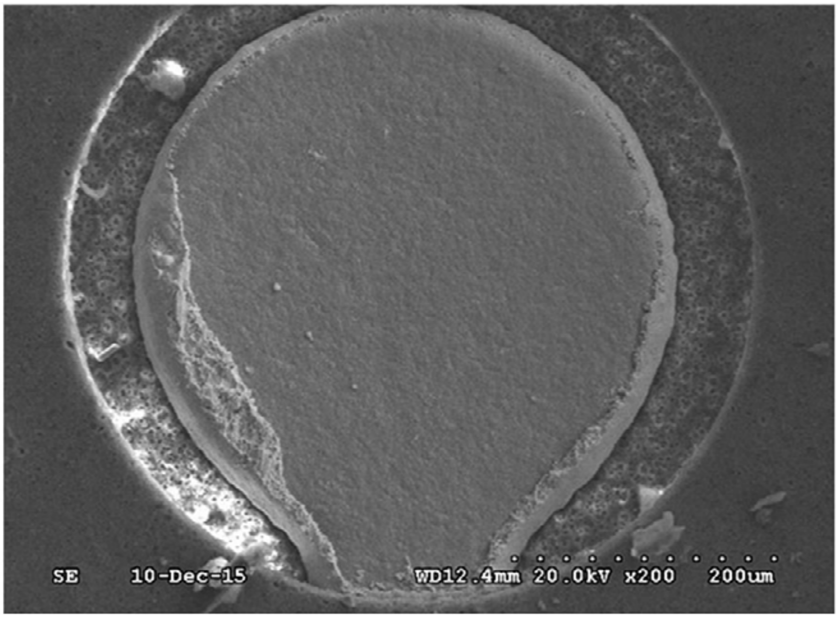
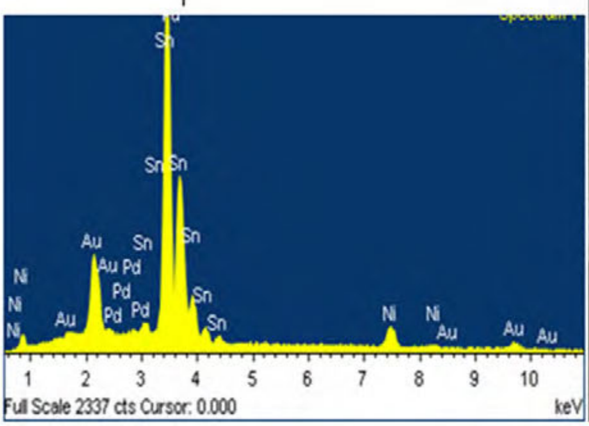


Figure 10: Brittle fracture surface on PB pad with small amount of solder remaining around perimeter.

Several locations of brittle fracture on the ENEPIG samples were selected for further evaluation. Analysis of the PB pad surface using EDS indicates that the remaining surface is predominantly nickel, with a small amount of tin. The material exposed on the solder joint side of the fracture surface was measured to have a high level of tin, but also up to 0.79% by weight Pd and 17.5% by weight Au (as well as low levels of Pb and Ni). These values varied based on the area selected (Figure 11 for an example). Analysis of an overall solder joint in cross section showed 0.5% by weight Pd and 3.3% by weight Au. Considering the volume of solder that was applied to the joint, this level of overall Pd is consistent with the Pd layer thicknesses measured on the PBs, but the level of Au is higher than expected.

It was anticipated that the part had an ENIG finish, which would

Element	Weight %	Atomic %
Ni K	9.75	18.81
Pd L	0.79	0.84
Sn L	76.10	72.66
Au M	13.37	7.69



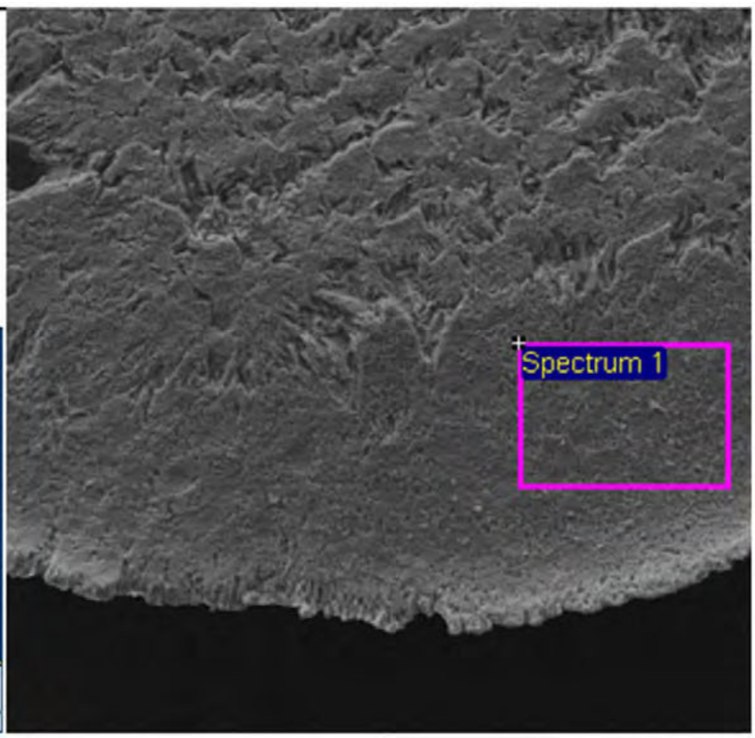


Figure 11: Cross-section and EDS analysis of brittle fracture surface (solder side).

add only a small amount of gold to the solder joint and which, in combination with the Au present on the PB, would not be a major factor to integrity of the joint. Actual measurements of the part, however, indicated that it had a thicker gold finish (14.3–15.5 µin), which resulted in the higher level of gold in the final solder joint. The high level of gold measured at the fracture surface indicates that could have played a role in the brittle nature of the failure.

Conclusion

The thick solder mask present on the PBs in this test not only had an impact on the solder joint geometry, it also had an apparent impact on solder volume applied during the card build, which affected the resulting metal content of the solder joints. This resulted in a lower level of Pd than originally intended for this study. As expected, the Pd formed a lamellar intermetallic with the Sn in the solder, but did not create a continuous layer due to the limited amount of Pd.

Incomplete curing of the PB appears to have contributed significantly to lifted pads in the unaged test samples, and brittle fracture of the solder joints on ENEPIG was often associated with those lifted pads. Isothermal aging of the test samples decreased the occurrence of both lifted pads (on both HASL and ENEPIG samples) and brittle fracture failure (on ENEPIG samples). It should be noted, however, that bulk solder failures on the ENEPIG samples occurred at the narrow point of the solder joint (the middle of the hourglass shape), and this solder joint geometry may have an impact on the failure point.

The results confirm that the shear strength of SnPb solder joints on ENEPIG is similar to that of solder joints on HASL (when the results of this study are adjusted for solder joint geometry). The specific cause of the brittle fracture on ENEPIG, however, was not determined in this study, and so the influence of the Pd content is not known.

The use of a Ag bearing solder had a small impact of shear strength, but there was not a significant difference of this impact when HASL and ENEPIG are compared. **SMT**

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Smart for Smart's Sake, Part 3: Unification & Traceability

by Michael Ford
MENTOR GRAPHICS CORPORATION

All of the recent innovations in electronics manufacturing, including Industry 4.0, the Internet of Manufacturing, smart factories, digital manufacturing, etc., bring digitization to many aspects of the factory operation. The names don't really matter, as most people's understanding of what these initiatives are continues to differ. However, concerns with implementing these innovations include the compatibility of information transfer, as we discussed in Part 1 of this series, as well as actual Smart application examples as we saw in Part 2, and the need for an open platform of information, which is being enabled by such technologies as the open manufacturing language (OML).

Digital data capture presents another opportunity for innovation—the complete traceability of the operation. Now, at last, traceability for electronics is defined by a dedicated standard in IPC-1782, which is designed to bring the appropriate levels of traceability without any net cost to the operation, that is, in a smart way.

Traceability is like having a CCTV camera that watches the manufacturing operation and records everything that happens. If a defect is detected in any aspect of production, the recording can be played back as if in slow motion to identify exactly what happened. The camera can see many different things happening because it has a point of view that includes the whole factory operation. Total traceability is not driven from a single point of view, such as the data from an SMT machine. The advantage of complete traceability is the ability to gather big data, that is, data from all of the different aspects of manufacturing, in such a way that information can be analyzed to understand the interaction of the different processes, events, and actions that are happening in the factory.

For example, we can watch the SMT placement machine. Our camera can see the placement of components onto the PCB. While this happens, the SMT machine provides a data record of these placements as the machine follows the engineering information that it was given. However, the data output is founded on the association of feeder position that the material was taken from for each individual placed

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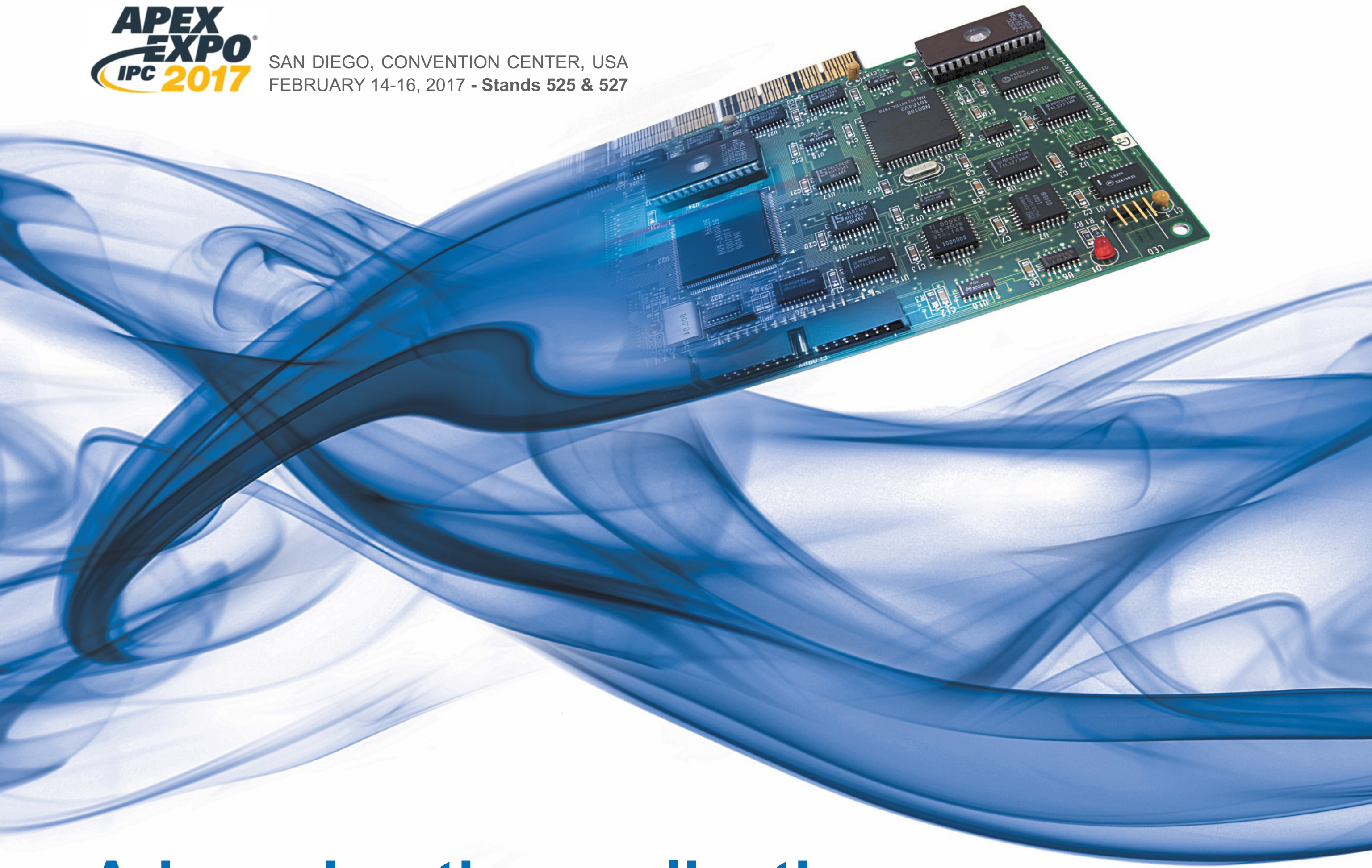

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component on the PCB. The engineering data identifies each feeder position with a part number, so the data looks as though it is reporting part number against reference position on each PCB.

The assumption, however, is that the correct part number was set up at that feeder position. The material verification records need to be checked to make sure this is true. The setup verification may have been done by the machine software or by a third-party software. For complete traceability, we need to rewind our recording to see the actual events related to the verification.

"Usually, verification is done using a barcode on both the feeder and the material being read to associate the two together. The material barcode should provide the part number, which is checked against the engineering information for the machine for the intended position used."

First, we can see that a reel of material was loaded onto a feeder. Usually, verification is done using a barcode on both the feeder and the material being read to associate the two together. The material barcode should provide the part number, which is checked against the engineering information for the machine for the intended position used. Assuming this process is done correctly, then the machine can have the feeder loaded, which can be then a simple automated confirmation that the material has been loaded in the right place.

However, there can still be sources of doubt. The part number used for verification is either a generic "internal" part number, or it could be the material vendor's part number. The latter case is difficult to manage because of the lack of standardization currently with labeling of materials from suppliers. The label format and content have to be "learned" by the verification software, which, if done "on the fly" at the time of material preparation, can lead to a significant risk of error. The barcode labels are notoriously unreliable, and conflicts between material vendors can happen.

The better approach is to label the material as it comes into the factory, or at least the SMT warehouse area, on a unique material basis. Where this is done, we can gain better traceability by rewinding our recording to see these events taking place. As material comes in, the vendor barcode is read, and a conversion is made to the generic internal part number. As is most often the case, materials of the same generic part number can come from two or more suppliers. The shape, size, orientation, and even the way in which the materials are packaged for use on the machine can be different.

Simply labeling the material with the internal part number would mean that these differences would not be noticed until the material was at the machine, if you were lucky. The verification process would not record any issue, but a different behavior of the machines, including an epidemic series of defects, can occur if the differences are not noticed. Instead, unique identification of materials can be used to maintain a record about not only the part number but also all other information about the material that may be significant to the operation, including the physical differences, vendor specific metrics, and things such as moisture sensitivity device (MSD) parameters. With a unique profile maintained for each material in this way, the verification process can be much more secure and reduce variation in the material replenishment process, with automated consistent selection of materials by supplier as replenishment materials are needed.

Simple verification software at the machine may not provide the higher level of checking required unless it can understand the full profile of each individual material. Therefore, the machine software needs to be closely linked to the material management software of the factory. The smart and lean material management functions in use at the factory level can then also make use of the machine data, providing mutual operational value.

The series of these processes is recorded by our traceability camera. A base level of traceability may be satisfied with just a check that the part number was correct. On the other hand, most reputable electronics manufacturers will need to have clear control of quality and responsibility, requiring a higher level of traceability that goes into the detail of the handoff between these different systems within the factory.

This simple example of the traceability of SMT materials illustrates that the whole solution cannot come solely from one point. Automatic collaboration needs to be done. Many other processes consume materials, including manual assembly and repair, as well as configuration using virtual materials such as MAC addresses. There are also consumable materials such as solder paste, which in itself has a complex working procedure to follow, with similar different levels of traceability data capture.

Traceability does not stop with simple materials, however. Quite often, subassemblies are used as part of the product assembly, which need to have their traceability data inherited from their production history. Our recording of assembly operations has to be linked with other recordings made at different times and in different places, but they need to be are completely compatible to create a complete record of the build of the finished product.

Traceability covers more than just materials though. The process history is also a key part of any build record. Smart factory systems continuously plan the factory operation, making decisions about the best product flow and the best machine configuration setups. The information associated with each work order of products, including process setup configurations also needs to be seen by our traceability camera. This link of planning information is critical because we need to ensure that all processes have been set up and executed in the right sequence in the correct conditions, and that the result of the process has been good.

Test processes especially provide a large amount of data about each product, as well as the simple pass or fail result. Products that do not pass a test must be routed to a repair station. These processes also need to interact directly with the traceability data to determine any possible cause that may have arisen from deviations that were recorded throughout the production cycle, as recorded by the traceability data. The defect, once found, triggers an assessment to be made as to whether corrective action needs to be taken in the process or whether previously completed production units need to be double-checked.

In this simple example of just a cross-section of the factory operation, we can see the need for the exchange of data from all aspects of production: direct, indirect, and transactional. Data collected directly from processes is only valid where qualified against the prior processes and transactions through which the materials, the PCB, and operations that the machine went through to get to that point in time. The importance of the machine data is that it allows our traceability camera to see the progress of the operation, establishing the timeline against which every other aspect can then be related, looking backward or even forward in the recording.

About IPC-1782

The IPC-1782[1] traceability standard for electronics is a comprehensive specification for the capture of both material and process data, with four defined levels of detail/specification for each. Understanding traceability requirements is essential for expectations to be fulfilled, especially if and when traceability data is needed to identify the causes of complex issues or to identify the exact scope of an issue. Having the specification clearly defined also means that only the necessary data is captured, reducing costs.

About OML

The OML[2] specification is designed to enable the interconnection of all machines and processes using a single language definition, including transactional activities on the shop floor. OML supports all forms of smart factory activity for use in any digital factory/Industry 4.0 solutions, as well as being a conduit for all levels of traceability data. Virtually every machine and process has just one point of data collection. OML allows the use of that data by many different Smart applications simultaneously.

Smart Traceability

The use of data flowing in an automated way from processes provides almost all of the required data for traceability, at any level. It is analogous to the video feed from our camera, with every aspect of the picture included. It means that the cost of traceability can actually become negative. Instead of having additional operations to gather, qualify, and catalog traceability data, the whole process can be automated in a way that is synergistic with the Smart factory operation. Having this "video" record of all the events, the full potential of traceability data can be realized, which brings opportunity of the highest level of active quality management, as well as full control over any issues that may occur. Bringing these elements of Smart technology together, whatever the priority or approach, the effective common Smart or Digital Factory platform brings all of the elements together for full traceability as defined by IPC-1782. SMT

References

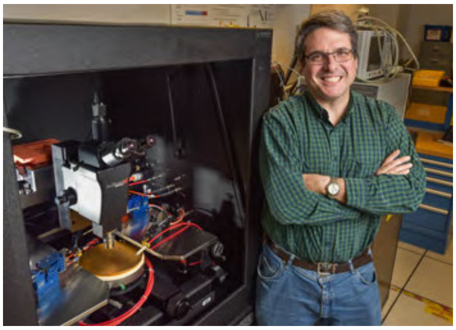
1. IPC-1782 can be purchased by clicking here.

2. The OML Community website is at www.omlcommunity.com.

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

Honey, I Shrunk the Circuit

Sandia National Laboratories researchers have shown it's possible to make transistors and diodes from advanced semiconductor materials that could perform much better than silicon. The breakthrough work takes a step toward more compact and efficient power electronics, which in turn could improve everything from consumer electronics to electrical grids. The research was published this summer in Applied Physics Letters and Electronics Letters and presented at conferences.



"The goal is to be able to shrink power supplies, power conversion systems," said electrical engineer Bob Kaplar, who leads a Laboratory Directed Research and Development project studying ultrawide bandgap (UWBG) semiconductor materials. The project explores ways to grow those materials with fewer defects and create different device designs that exploit the properties of these new materials.

The project is laying the scientific groundwork for the new UWBG research area, answering such questions as how the materials behave and how to work with them. It also will aid Sandia's broader work through developments, such as compact power conversion by using better semiconductor devices.

Sandia researchers demonstrated the highest-bandgap transistor ever, a high electron mobility transistor, and published those results in the July 18 edition of Applied Physics Letters. Sandia published papers in June and July in Electronics Letters analyzing the performance of diodes made from gallium nitride (GaN) and aluminum gallium nitride (AlGaN).

"All three of these papers represent progress on the road to more compact and higher-efficiency power converters," Kaplar said. However, he cautioned that the work doesn't mean UWBG devices are ready for the marketplace.

"There are a lot more improvements that need to be made to the transistor," he said.

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[Tin Whisker Mitigation Methodologies: Report from SMART Group, Part 1]

Since the introduction of the RoHS legislation in 2006, the threat of tin-whisker-related short circuit failure from pure tin finished components has remained a major concern within the high-reliability electronics manufacturing industry. In this article, Editor Pete Starkey reviews a recent seminar by the SMART Group to discuss tin whisker mitigation methodologies and strategies.

Kitron Receives Contract from Northrop Grumman

Kitron has been selected by Northrop Grumman Corp. as an international source for manufacturing of a sub-assembly for the F-35 Joint Strike Fighter.

Kingfield Electronics Welcomes Jon Hall

Kingfield Electronics has announced that Jon Hall, a 20-year veteran in the electronics industry, has joined the company in the role of manufacturing engineer.

Plexus Receives New Product Development Supplier of the Year Award from Honeywell Aerospace

Honeywell Aerospace has recognized Plexus Corp. with its 2016 New Product Development Supplier of the Year award for providing exceptional engineering, supply chain and global project management services to support the development of Honeywell Aerospace's new 777X Lighting product line.

EPE Purchases Nordson ASYMTEK Spectrum S-920 Automated Fluid Dispense System

EPE Corp., a Service-Disabled, Veteran-Owned Small Business (SDVOSB) electronics manufacturing company, has purchased a Nordson ASYMTEK Spectrum S-920 Automated Fluid Dispense System.

Alpha Facility in Altoona, Pennsylvania Receives ITAR Certification

As an ITAR-certified service provider, Alpha, a part of the MacDermid Performance Solutions group of businesses, can assure that scrap boards do not leave the United States, which is of particular concern to those manufacturing military and aerospace electronics who have to disassemble and dispose of assemblies without compromising the top-secret design of the circuit.

Libra Industries Dallas Renews Defense and Medical Certifications

EMS firm Libra Industries has announced that its Dallas facility has passed the recertification audits for its ISO 9001:2008 and ISO 13485:2012 certifications.

Dynamic EMS Receives ISO 9001:2015 Certification

Dynamic EMS Ltd has become one of the first UK-based EMS providers to be accredited ISO 9001:2015.

IEC Swings to Profit in FY2016

IEC has reported a net income of $4.8 million for fiscal 2016, compared to a net loss of $10.2 million in the same prior year period.

Libra Industries Installs New SPI Systems in Mentor and Dallas Facilities

Libra Industries has completed the installation of two new Omron CDK VP5200-V solder paste inspection systems. One system was installed at Libra Industries' Mentor facility, and one was i nstalled at the Dallas facility.

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FEATURE

Effect of Solder Composition, PCB Surface Finish and Solder Joint Volume on Drop-Shock Reliability

by Jim Wilcox, Ph.D. and Francis Mutuku,
UNIVERSAL INSTRUMENTS CORP.;
and Shuai Shao and Babak Arfaei, Ph.D.,
BINGHAMTON UNIVERSITY

Abstract

Drop shock reliability testing was performed on circuit boards assembled with several different lead-free solder alloys including SAC305 (Sn3.0Ag0.5Cu). The solder compositions tested range in Ag content from 0 to 3.0% by weight. Alloys with various secondary alloying elements were also included. All drop test boards were assembled such that the solder paste composition matched that of the BGA solder ball alloy to produce homogeneous solder joints of known compositions. An alternative test board design (not JEDEC standard) was used for this drop test evaluation. The test board contains a centrally located CABGA 256 package (17x17 mm body, 1 mm pitch). The board was designed with solder-mask defined pads to minimize the occurrence of pad cratering failure modes in the laminate material. The test package was soldered to the drop board using either BGA or LGA interconnections to explore the effects of solder joint volume. A direct comparison in drop performance was made between test boards having two common PCB surface finishes: OSP and immersion Ag.

All samples were repetitively dropped until electrical failure. Drop shock events were characterized with acceleration monitoring and strain gage measurements on the mounted test boards. Solder joint microstructural analysis was performed on failing parts to establish the failure modes. The dominant failure mode was observed to be solder joint failure, either in the bulk solder or cracking along the interfacial intermetallic compound on the board pad. For the PCB laminate material used, SAC305 solder joints were observed to produce the best alloy drop performance in both BGA and LGA joint formats.

Introduction

Lead free solder joint reliability in drop shock loading has been a recurring issue in mobile and handheld consumer electronics. Changing solder composition may offer an opportunity to improve joint drop reliability. Low Ag alloys such as SAC105 have for instance been reported to have better drop performance than high Ag alloys such as SAC305[1-5]. Some investigations suggested that this was because the fail-

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ure mode changed from solder bulk failure (low Ag) to cracking of the interfacial intermetallic (high Ag)[1-5]. Others attributed it to a dominate failure mode of pad cratering for SAC105 on Cu-OSP, yet for SAC305 on Cu-OSP PCB surface finish failure was due to fracture of the Cu6Sn5 intermetallic compound (IMC)[6].

Mattila[4] explained that IMC cracking happens when the increased yield strength of the solder at high strain rate limited the strain accommodation provided by plastic deformation in the solder during the shock event. Thus, the brittle intermetallic layers failed due to increased stress concentration. Solder bulk failure on the other hand, occurred when solder strength was lower, usually the case for low silver alloys. Large plastic deformation in the solder reduces the overall stress in the connection and leads to a ductile bulk solder failure mode. Other researchers have reported that the strength response of SnAgCu solders may indeed vary by the drop acceleration level, increasing with the higher strain rates of large drop acceleration[3,7].

> "Typically, circuit boards are more flexible than the components attached to them."

Tensile or peeling stress plays an important role in solder joint failure during the drop test[8,9]. Typically, circuit boards are more flexible than the components attached to them. Considering that laboratory test assemblies are often dropped component side down with rigidly affixed board corners, the outermost solder joints will be under tension when the board flexes downward on initial impact. This tensile stress drives crack propagation of any crack initiated in the corner solder joints or in the underlying laminate. Joints at other locations may similarly fail but the outmost corner joints have the highest probability of producing the first failure.

Tensile test for bulk solder joints was performed at various strain rates and aging times by Luan, et al[9]. Three failure modes of bulk solder were reported: brittle failure, ductile failure and mixed mode failure. Their reported data showed that higher strain rate led to statistically more brittle failure in the interfacial intermetallic compound. Longer aging time resulted in a thicker IMC layer and more brittle failure.

Solder alloys doped with various elements can lead to very different drop shock behavior. The effect of micro alloying elements on failure mechanism is not simple. For example, the effect of the addition of 0.1% Bi in high strain rate failures was dependent on the base alloy[10]. For low Ag alloys (Ag<1%), Bi improved drop shock and ball pull performance while the same Bi addition reduced both attributes for the higher Ag SAC305 alloy.

Recently, new candidate board designs have been proposed as replacements for the JEDEC JESD22-B111 drop test board[11]. Design changes were motivated primarily by concerns that the existing JESD22-B111 configuration does not provide the same stress distribution for all the components during drop, although some components are mounted symmetrically on board[11]. Attributes of some of the new designs include a single component per board[12], four components per board mounted symmetrically[12] or eight components mounted centro-symmetrically on a round test board[13]. Another advantage of the new designs is that they usually have the board size close to that of hand-held portable devices, which can help provide a more realistic reliability assessment[12].

A common shortcoming of many developed interconnection reliability models is neglecting changes in failure modes. This makes the overall validity of these models questionable as drop tests producing different failure mechanisms are not simply comparable. This project is intended to study the failure behavior of several solder alloys in drop test. Each alloy is used to assemble LGA and BGA components on either a Cu-OSP surface finish board or an immersion silver surface finish board. The test board used is one redesigned from previous drop test efforts to influence the primary failure mode. Failure rates in drop shock are fitted to Weibull distributions for comparison. Characteristic failure modes for each solder alloy/board finish combination are identified.

Experiment Preparation

Test Board Assembly

A revised test board design is used for this study rather than the previously used JEDEC standard drop test board. In the multi-component JEDEC drop test board design, the stress distribution experienced during drop is not identical for all the components making analysis and interpretation of results difficult. The test board used is constructed of 6-layer 370HR laminate material with a body size of 77 x 77 mm. The boards were sourced with either Cu-OSP or immersion Ag surface finish.

The Chip Array BGA256 test component has a body size of 17 x 17 mm. The BGA footprint is full array with solder mask defined pads on a 1.0 mm pitch. The component surface finish is electrolytic NiAu. It is assembled to the test board in either the BGA or LGA (solder paste only) configuration.

The five solder alloys evaluated, in order of decreasing Ag content, are SAC305, SN99CN, SAC105, SAC-M, and SN100C. Solder alloy compositions are listed in Table 1. For those samples evaluated in BGA format, the component ball attach process was performed in the Universal Instruments SMT laboratory using 16 mil (400 µm) spheres. A solder paste print process is used for subsequent assembly of the balled components to the test board using pastes with compositions matching the associated ball alloy. All assemblies are reflowed in a nitrogen environment with a peak temperature of 239°C. LGA components were attached using an analogous paste-only SMT assembly process. Sixteen samples for each combination of solder alloy (five), surfaces finish (two) and joint configuration (two) required the assembly of 320 test boards. Fifteen boards are dropped for each experimental cell with the remaining board allocated for initial microstructure inspection.

Alloy	Composition
SAC305	Sn - 3.0Ag - 0.5Cu
SN99CN	Sn - 1.1Ag - 0.7Cu - 0.05Ni
SAC105	Sn - 1.0Ag - 0.5Cu
SAC-M	Sn - 0.5Ag - 1.0Cu - - 0.03Mn
SN100C	Sn - -0.7Cu - 0.05Ni +Ge

Table 1: Solder Alloy Compositions.

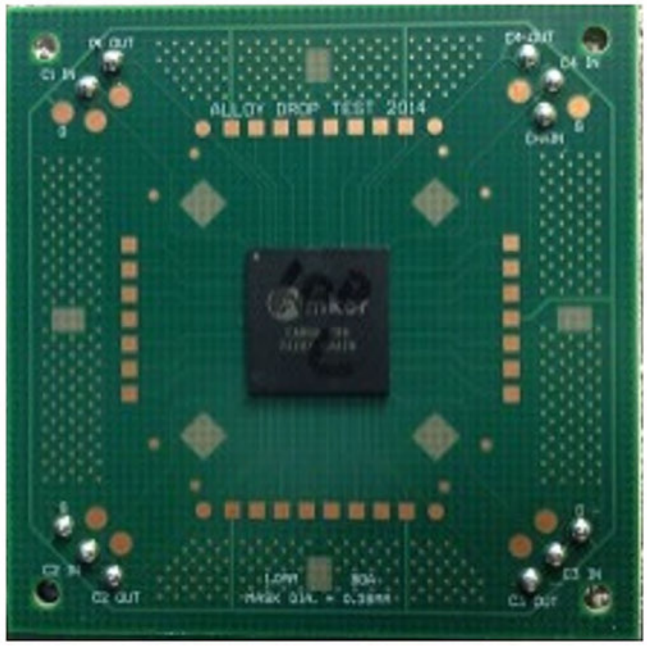


Figure 1: Assembled test board (77 mm ×77 mm) with two monitor channels (input, output) accessible at each corner.

Board Design and Failure Detection

The assembled test board is shown in Figure 1 Each corner of the board has two input channels connecting the outermost corner BGA pad from two sides. In the assembled structure, a continuity monitor signal passes through corner joint A and adjacent joint B into ground as shown in Figure 2. Electric resistance of the input channels to ground is monitored during drop events. If either input 1 or input 2 fails, followed by the other failing after some additional drops, the likely failure mode is pad cratering. It indicates cracks inside the test board laminate propagating from one side to the other severing the two copper traces in sequence. On the other hand, when both channels fail at the same time, solder fatigue in corner joint A or other failure path around adjacent joint B would be the presumed failure mode. Experience indicates that adjacent joint B is unlikely

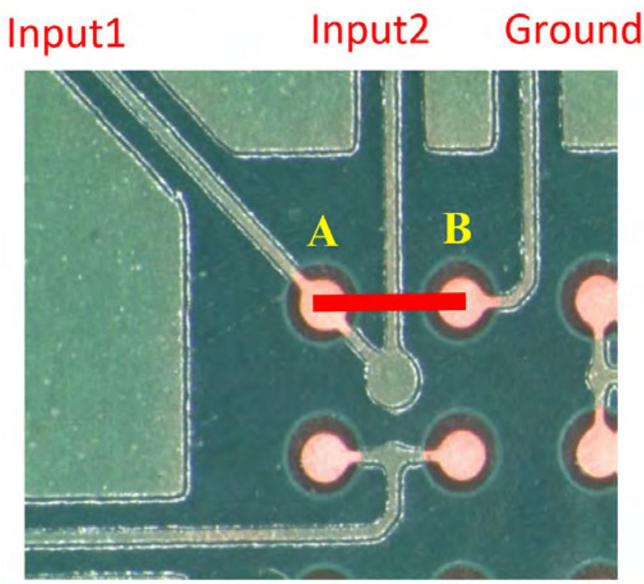


Figure 2: Channel traces at one corner (A) of the BGA array. Red line represents the attached component chain. (Image from previous study[14] using NSMD pads.)

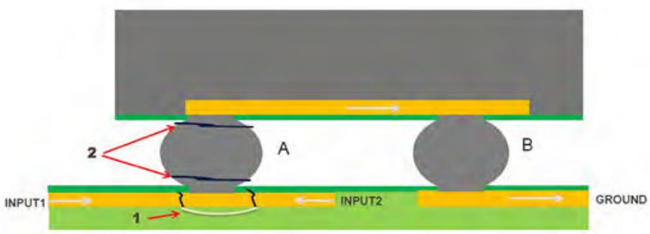


Figure 3: Illustration of event detection for failure mode.

to fail before corner joint A meaning that simultaneous failure of both channels is anticipated to be solder failure in the corner joint (Figure 3). The remaining solder joints in the assembled solder joint array (i.e., beyond the two monitored joints in each corner) are stitched together in a single test net.

A similar board design was used in a previous drop reliability study[14]. Some effects of solder alloy on drop lifetime were observed in that study. However, the dominant failure mode was laminate pad cratering. Shock induced cracks propagated in the board laminate rather than through the solder joints of interest. For an alloy study, it was considered desirable to compare failures occurring in the sol-

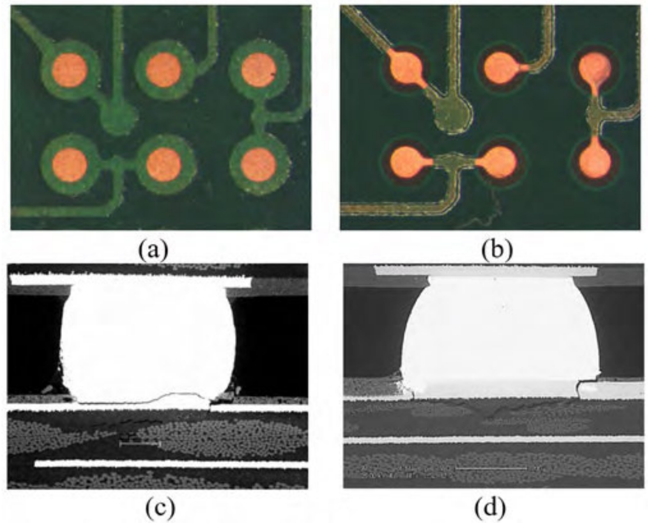
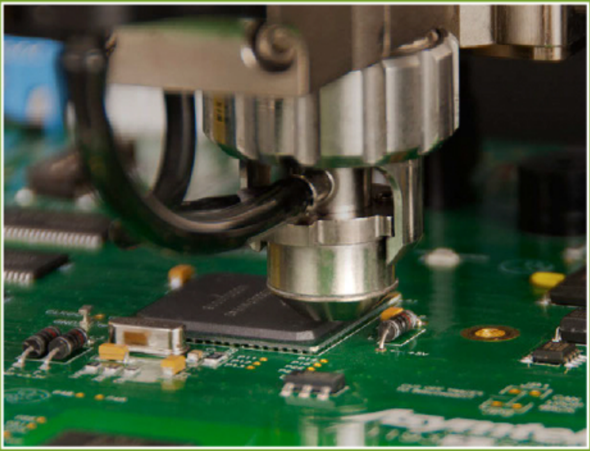


Figure 4: (a) Redesigned test board and (c) its failed joint; (b) previous test board and (d) its failed joint.

der alloys of interest rather than failures in the underlying laminate material. The board design used in this study strengthens copper signal traces and pads as well as uses solder mask defined pads for both component and board side (Figure 4) to promote solder joint failure. Failure is identified by significant increase of electrical resistances through an event detector. While the test circuit is designed to provide some indication of failure mode through event detection, the actual failure mode is always confirmed by cross-sectional observation (Figure 4).

Drop Test Apparatus

Service condition "F" of JEDEC Mechanical Shock Standard (JESD22-B104C) is applied in this study: 900G acceleration peak value, 0.7ms pulse duration, and 386 cm/s (152 in/s) velocity change. The drop test apparatus is a Lansmont shock table illustrated schematically in Figure 5. To expedite testing of the large sample quantities required by this study, mounting fixtures for the simultaneous drop of four test boards were included on the table surface. Each mounting fixture consisted of four standoff posts for the corner mounting holes the board. They were arranged in a two by two array centered on the table.



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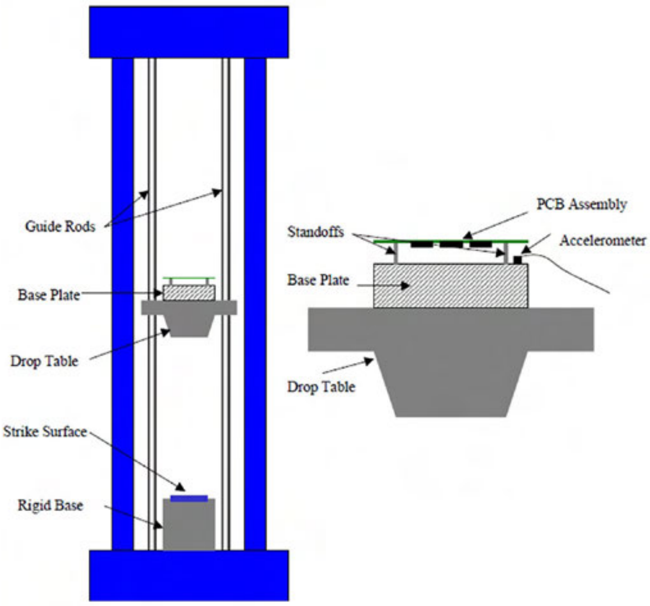


Figure 5: Diagram for drop test apparatus and mounting scheme for assembled test board[11].

Shock Response on Fixture

Shock impulses should be uniformly distributed over the four boards on the drop table. The shock responses on the four fixtures are checked as follows. Fixtures are screwed to the drop table. No boards are mounted, only standoffs. One reference accelerometer keeps the same location on the table for each drop to ensure shock values repeat closely from drop to drop. A second accelerometer is placed on the table surface sequentially at the projected center of each test board location to measure the shock responses during successive drops. Accelerometer readings at the four board locations are plotted in Figure 6. Maximum acceleration values are listed in Table 2. The variation in maxima by location is 1.6% (907G ± 0.8%).

Strain Measurement on Board

Strain gages are mounted at designated solder mask opening locations on the assembled side of the board near the component corners, one gage on each of the four boards mounted. The strain gage locations for each board are shown in Figure 7. Because of a channel count limitation only strains at 45° are measured. Due to the design symmetry, these 45° strains are expected to be the principal strains. Samples are

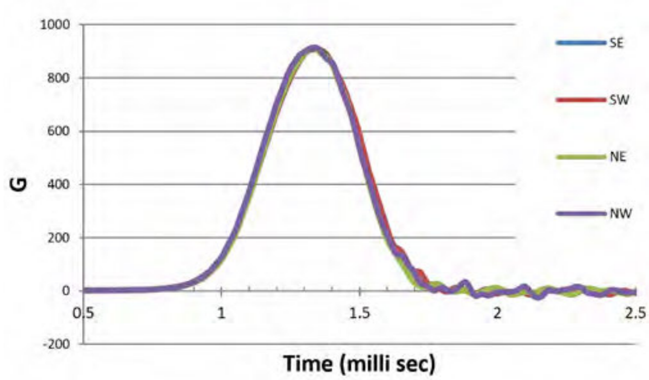


Figure 6: Accelerometer readings on the table fixture measured at the projection of each board center.

Location	Maximum Response (G)
SE	899.7
SW	907.6
NE	914.1
NW	914.5

Table 2: Peak table acceleration response by location.

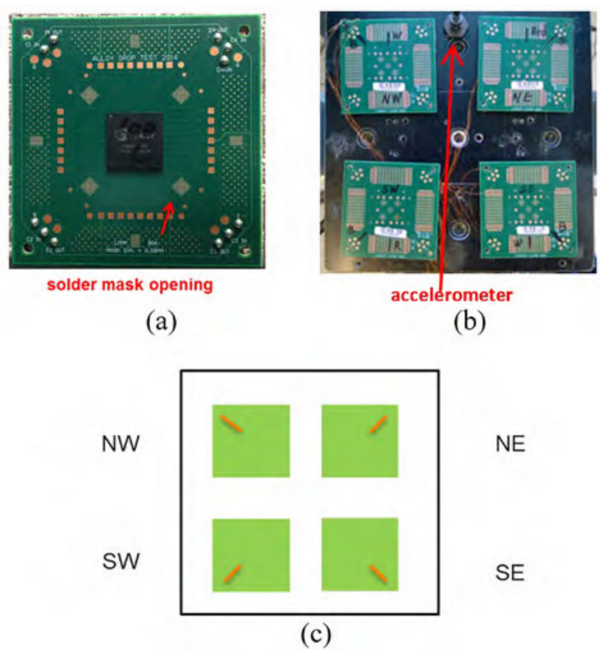


Figure 7: (a) Solder mask opening for attaching strain gage, (b) four boards mounted on table with table accelerometer location indicated and (c) board location identifiers.

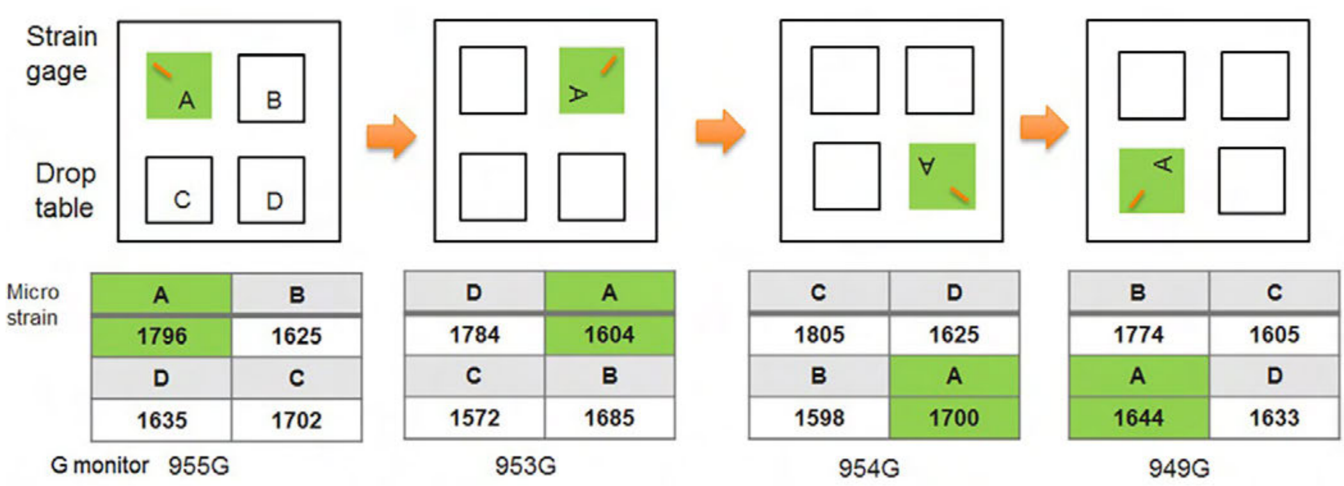


Figure 8: Board strain measurement (maximum principal strain, in microstrain) by table mounting position.

dropped with the component facing downward so that the initial drop impact will record board surface tensile strains on each corner.

Mounting Location Sensitivity

Mechanical variation (post alignment, washer dimension, etc.) among the four board mounting fixtures on the table may impart some positional dependency in the drop shock impulse. The magnitude of this variation (and thus positional experimental error) is measured through board bending strain measurements during drop events at each mounting position. Four instrumented boards are mounted as shown as Figure 8. Individual strain monitor boards are identified as A, B, C, and D. After one instrumented drop with boards in the initial position shown on the far left, the boards are cycled clockwise to the next mounting position. For example, board A is moved from NW location to NE. Board A is also rotated 90° such that the strain gage orientation will be still be radial, emanating from the center of the table. The other three boards are similarly rotated into new positions. The resultant strain measurements from successive drops are listed in Figure 8 for each of the four unique board placements. Tracking any given board through the four different positions reveals the experimental strain variation. Positional variation exceeds the individual test board variation by an order of magnitude with the NW position consistently producing the highest strain (6% above the overall mean). Individual test boards are consistent to within 1% relative to the overall mean.

Results and Discussion

Weibull Distribution Plots of BGA Drop Failures

Figure 9 shows Weibull failure rate distribution plots by solder alloy for drop shock failures with (a) Cu-OSP board surface finish and (b) ImmAg board surface finish. The drop lifetimes indicated are those for the first failing corner on each test board. The SAC105 alloy was limited to eight samples due to yield fallout at assembly.

SAC305 can be seen to be the best performer for both board surface finishes. Noting the variability in drop lifetime (i.e., low Weibull shape factors, β), the other alloys can all be considered to have lower but similar drop performance. In this experiment, the SAC-M alloy on the Cu-OSP finish failed with considerably lower variability than all other experimental cells (β = 8.5).

Figure 10 compares the characteristic drop lives of BGA interconnects among the five solder alloys between the two PCB surface finishes. The effect of alloy silver content is seen to be similar for both finishes with the highest silver content (3%, SAC305) showing superior performance and drop lifetime generally decreasing with the silver alloying content. BGA com-

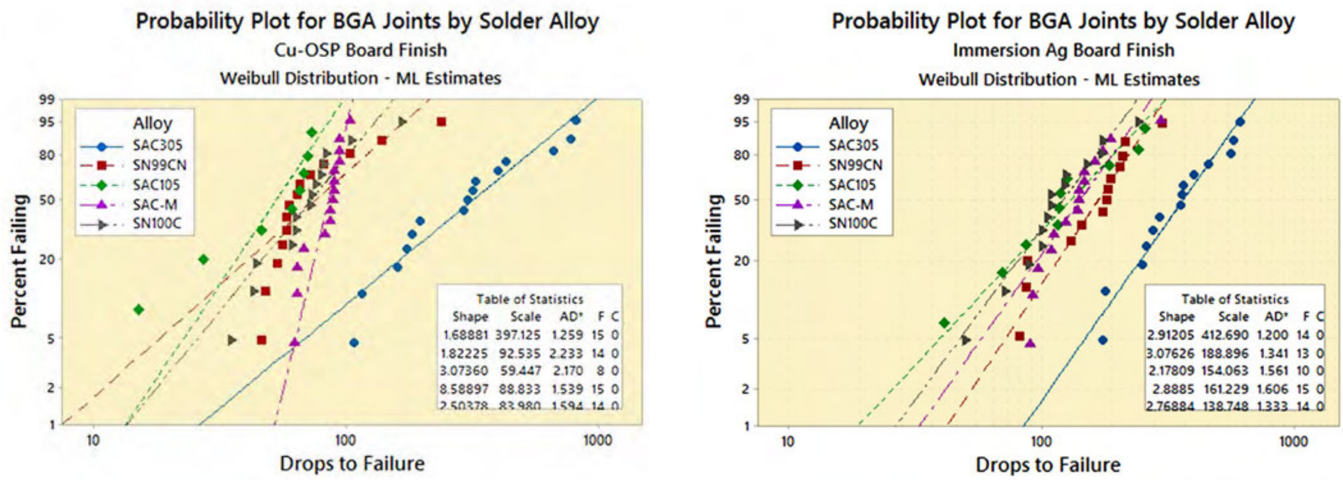


Figure 9: Weibull plots of BGA joints for five alloys on (a) Cu-OSP PCB surface finish (b) ImmAg PCB surface finish.

ponents on ImmAg PCB surface finish uniformly display slightly better drop reliability than those on the Cu-OSP finish.

Microstructure and Failure Analysis of BGA Joints

Microstructural analysis was performed for all alloys, both as-reflowed (before drop) and after repetitive drop failure.

The assemblies were cross-sectioned along the body diagonal of the board such that the traces of two input channels at the corner pad are visible on either side of the sectioned joint. Metallographic sections are prepared in the usual manner: sequential grinding using 80, 200, 800, 1200, 2000 and 4000 grit SiC papers followed by a final polish with 3µm and 1µm diamond compounds and 0.05µm Al2O3.

BGA Failure Modes

Solder failure is identified during repetitive drop using an event detector to capture excursions of electrical resistance beyond a threshold value. Failure is declared when three such events are observed within five consecutive drops. The drop test of each assembly is stopped after its first failure was confirmed. In 95% of samples, a corner joint was found to fail first. Metallographic samples are oriented such the failed corner joint is viewed on the right side of the cross-section, the component on the top side of the image and the circuit board on the bottom.

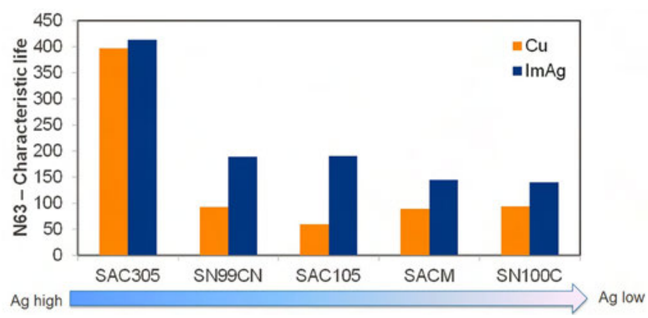


Figure 10: Comparison of characteristic drop life of BGA256 components between two surface finishes for the five solder alloys listed in order of decreasing Ag content.

The opposite corner joint (not yet failed) will then be visible in the far-left side of the section.

Figure 11 shows a representative image of one of the drop failure modes observed: pad cratering beneath the BGA pad. One can see in Figure 11a a complete crack traversing from one side of the joint to the other in the PCB laminate structure beneath the pad. There is also a shorter crack visible on the left, inside IMC layer. The inner side and outer side labeled in Figure 11a refer, respectively, to the side nearest the center of the package and side away from the package corner. The crack within the IMC layer initiates from the inner side of the corner joint (Fig. 11b), while the PCB laminate crack initiates from outer side of the corner joint. The

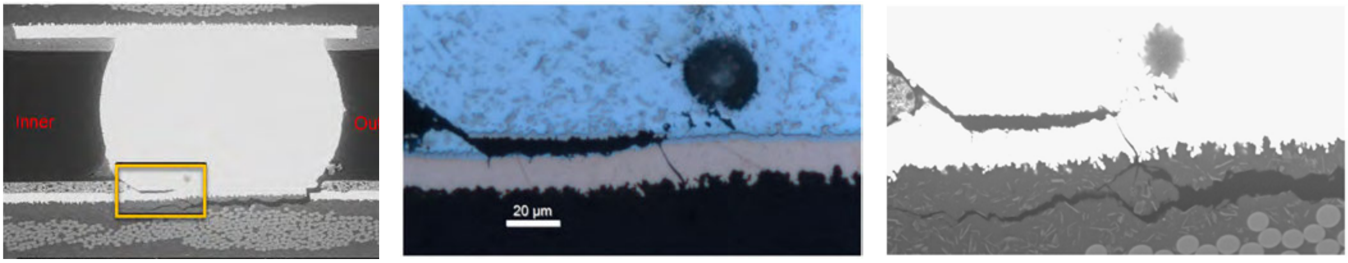


Figure 11: Pad cratering failure mode: (a) full BGA view, (b) the local region of IMC cracking, and (c) SEM image of the same local area showing PCB laminate cracking.

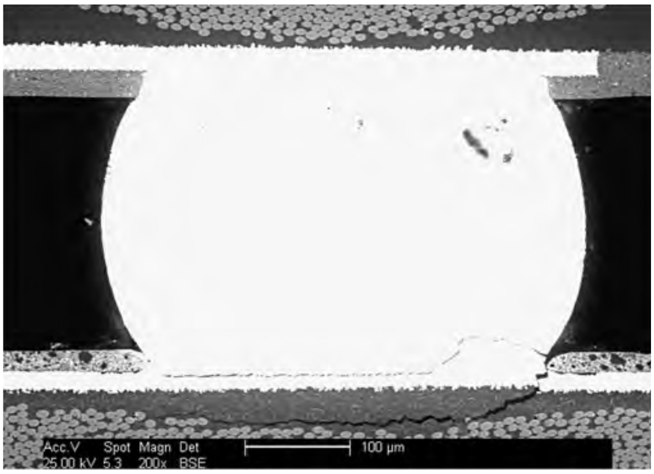


Figure 12: BGA failure mode: IMC/solder failure.

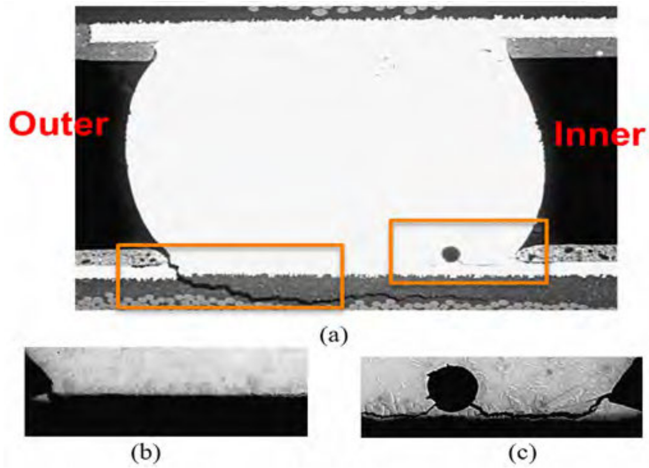


Figure 13: Crack in a non-failed BGA corner joint (a) whole cross-section (b) local area of high magnitude on the left (c) local area of high magnitude on the right.

SEM image of Figure 11c reveals the connecting crack between the two competing crack paths producing the electrical failure.

Figure 12 shows a different joint with a similar laminate crack emanating from the outer sider the joint and propagating under the pad. It has not yet propagated through the joint to produce a failure. A second BGA failure mode also observed: a combination IMC/solder failure. A complete through crack is seen to propagate in the solder as well as along the interfacial IMC. Since this IMC/solder crack has fully transected the joint, the direction of propagation is not obvious simply from this image.

The characteristic starting location for this failure mode, however, can be determined from the symmetrical opposite corner joint where the failure process is not yet complete. This joint is shown in Figure 13. Here, the outer side will be to the left of the joint. This joint has not yet failed and none of the visible cracks are complete. Again, a laminate crack can be observed starting from outer side of the corner joint and propagating under the pad. There is also a crack propagating along the interface solder joint IMC similar to that observed in the opposite corner joint. This IMC crack is not complete and thus can be clearly seen to emanate from the right (inner) side of the joint (detail shown in Figure 13b). The left side detail image in Figure 13c confirms the IMC/solder cracking process is yet incomplete.

From the above analysis, we see that two distinct cracking mechanisms are competing to produce interconnect failures in this BGA256 component. These alternate crack paths, shown schematically for a corner joint in Figure 14, arise from the oscillating flexure of the board after initial impact. Board flexure from the initial

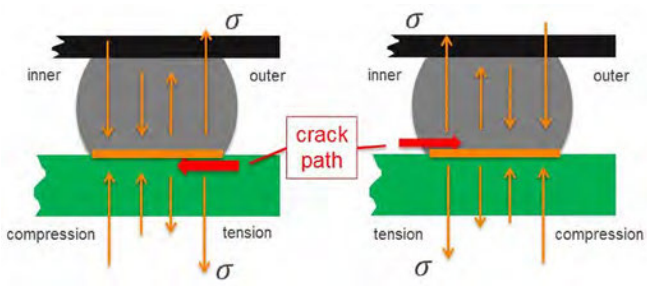


Figure 14: Illustration of crack path competition in corner BGA solder joints due to cyclic oscillations after drop. Stresses due to (a) downward board deflection at initial drop impact and (b) upward rebound deflection.

drop impact imposes a tensile load on the 'outer' side of the joint at the base of the BGA pad, initiating and propagating a crack into the laminate. The upward rebound board flexure then imposes a tensile impulse on the 'inner' side of the BGA pad and compression on the outer side. The magnitude of the second impulse is necessarily smaller than the initial impact loading. The magnitude of the rebound flexure is reduced through dampening. Moreover, the board cannot flex away from the plane of the package on the inner side as readily as it can on the outer side because the inner side board is constrained by the adjacent solder joints attached to the package above. That's not to say however the outer crack will always preferentially produce a failure. Different levels of fracture toughness are encountered along the two crack paths as well as different path lengths being required to produce a failure. Depending on solder alloy and interfacial toughness considerations either the solder/IMC crack path or the laminate crack path under the pad may win out, transecting the interconnect to produce an electrical open.

For certain alloy:finish combinations, pad cratering proved to be a relatively common failure mode. In these instances, the laminate crack shown in the diagonal cross-section of Figures 11–13 propagated to meet another opposing laminate crack from the other direction. When viewed from a section taken in the plane of board (Z-section) this failure mode is characterized by a circular crack propagating into the plane of the BGA pad from the perimeter of the solder mask opening until the central laminate crater separates from the pad. An example is shown in Figure 15. All pad cratering events that produced electrical failures did so with such circular cracks through the BGA pad. No failures through the input copper traces were observed. This mode of circular pad cratering causes the two input channels appear to be open simultaneously (Figure 3), the same failure signature as the IMC/solder failures. Thus, the event detector could detect failure but not uniquely identify the failure mode as anticipated. All failures must be cross-sectioned to identify the failure mode.

The observed failure modes of the BGA256 package in 900G drop shock are summarized in Table 3 for all solder alloys tested. For each

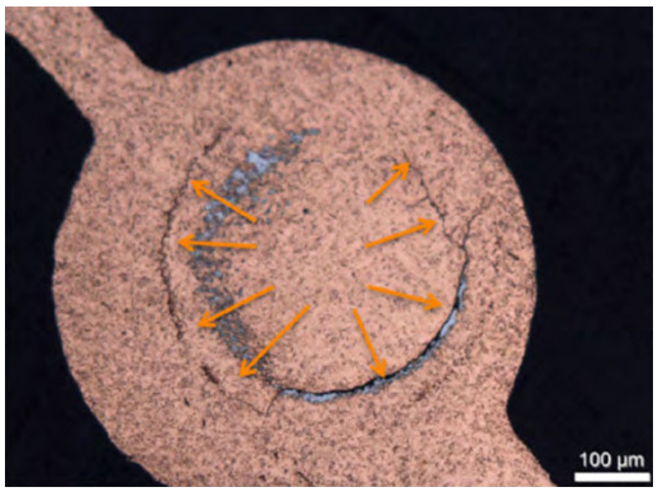
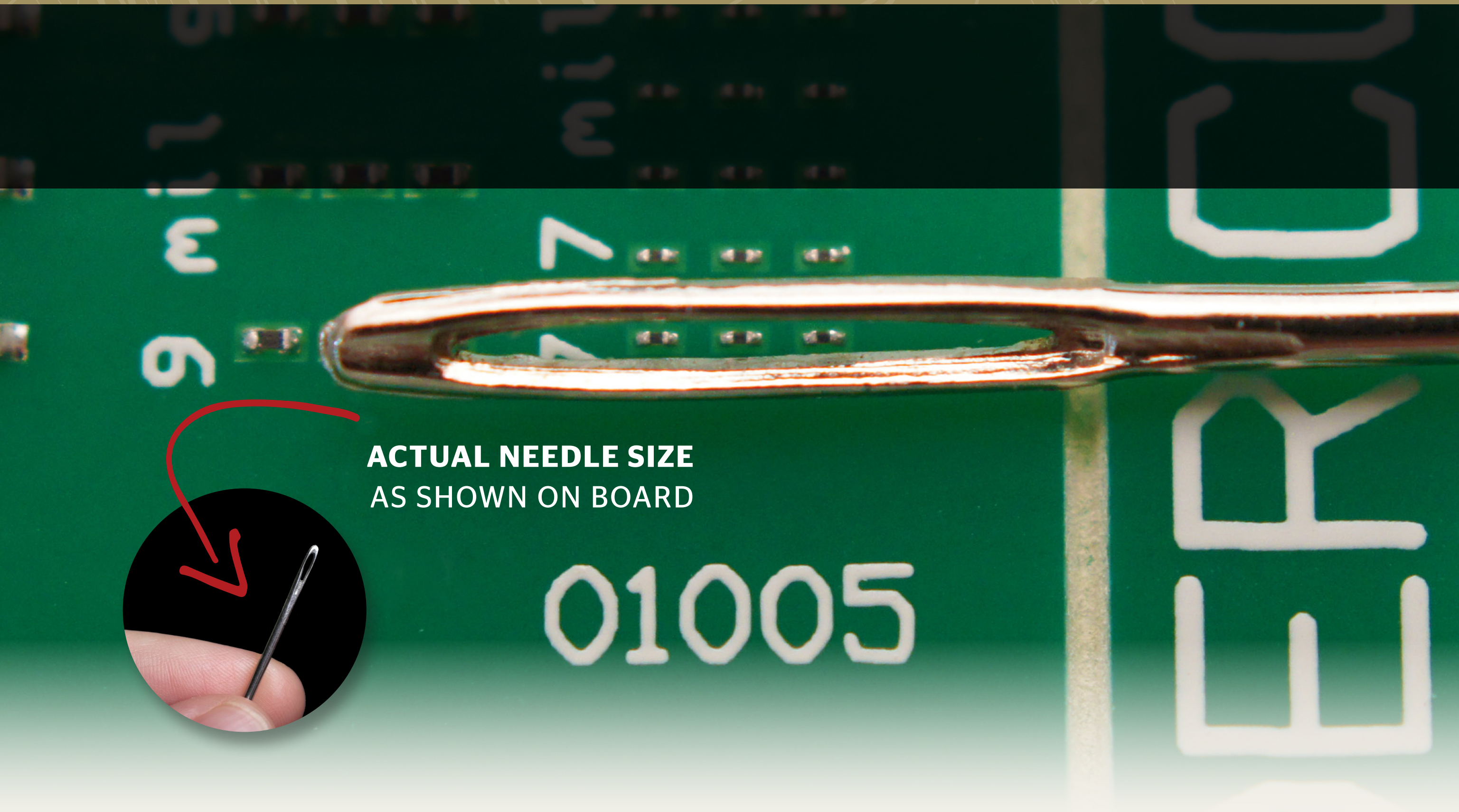


Figure 15: Z-direction section of failed corner joint with pad cratering.

BGA	Failure Mode					
	Cu-OSP			ImmAg		
	Early	N63	Late	Early	N63	Late
SAC305	IMC/solder	Pad cratering	Pad cratering	IMC/solder	IMC/solder	IMC/solder
SN99CN	IMC/solder	IMC/solder	Pad cratering	Pad cratering	Pad cratering	Pad cratering
SAC105	Pad cratering	IMC/solder	IMC/solder	IMC/solder	Pad cratering	Pad cratering
SAC-M	IMC/solder	IMC/solder	IMC/solder	Pad cratering	IMC/solder	Pad cratering
SN100C	IMC/solder	Pad cratering	IMC/solder	Pad cratering	Pad cratering	Pad cratering

Table 3: Failure Modes of BGA256 in Drop.



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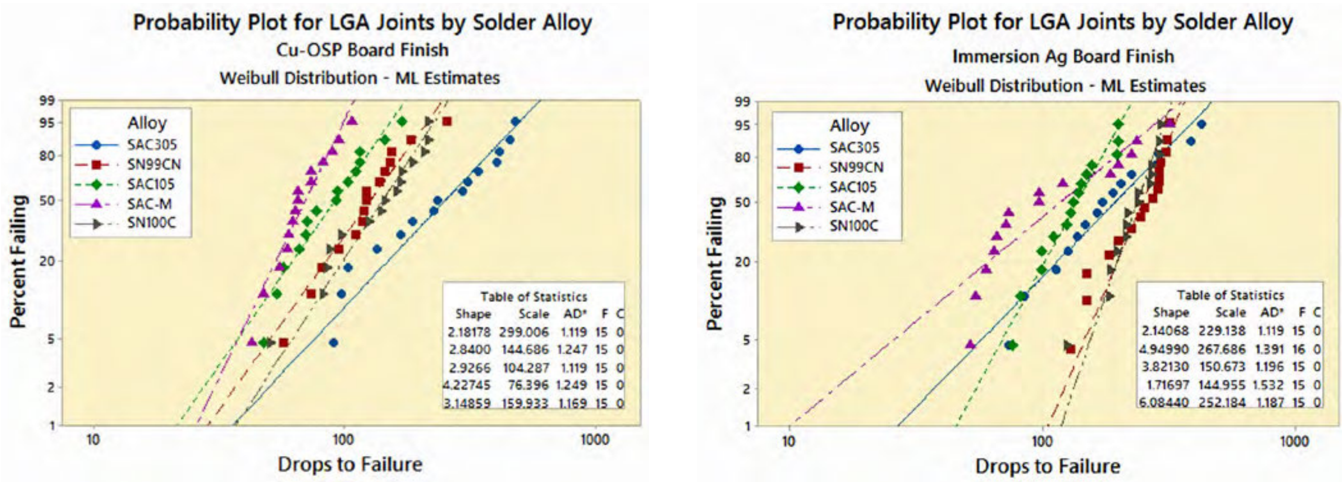

Figure 16: Weibull distribution plots of LGA joints failures in drop for five solder alloys on (a) Cu-OSP PCB surface finish and (b) ImmAg PCB surface finish.

alloy:finish combination, the failure modes were sampled at three different places in the failure rate distribution: early failure, characteristic life failure (N63) and late failure. The early and late failure cases examined samples that failed with the shortest and longest drop lifetime, respectively. For N63, samples that failed nearest the characteristic life of the Weibull distribution fit are selected. From Table 3, one can see that more pad cratering failures occur for BGA joints with the ImmAg PCB surface finish than those with Cu-OSP finish. In general, the combined IMC/solder failures tend to produce shorter drop lifetimes than pad cratering failures. It is interesting to note that the lowest variability case (SAC-M on Cu-OSP) produced only IMC/solder failures.

Weibull Distribution Plots of LGA Drop Failures

Weibull distributions fits of drop test life of LGA assemblies for five solder alloys on two PCB surface finishes are shown in Figure 16. LGA joints with the SAC305 alloy show the best performance on Cu-OSP PCB surface finish. On immersion Ag boards however, LGA joints of the SN99CN and SN100C alloys are seen to have the best drop performance.

Figure 17 compares the characteristic drop lives of LGA interconnects for five solder alloys on two finishes from the Weibull fits of Figure 16. With the notable exception of SAC305, the drop life of LGA joints on ImmAg is greater than that of LGA joints on Cu-OSP. Observed failure modes provide some insight into these relative behaviors.

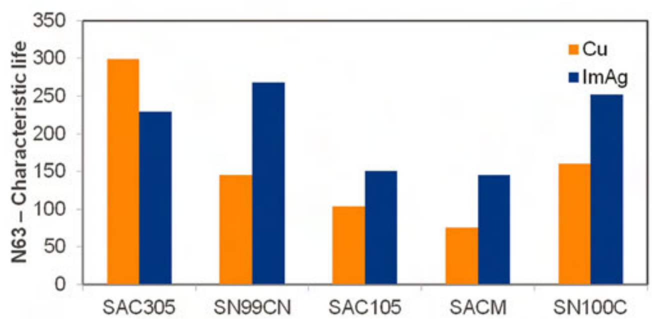

Figure 17: Characteristic drop life of LGA joints for five alloys and two PCB surface finishes. Alloys listed in order of decreasing Ag content.

LGA Failure Modes

The failure modes observed in LGA solder joints at different relative drop lifetimes are listed in Table 4. For LGA joints on Cu-OSP finish, all drop failures exhibit bulk solder failure (see for example, Figure 18). This failure mode was not observed in the larger volume BGA solder joints for any alloy. For LGA joints on ImmAg finish, IMC failure, IMC/solder mixed failure, pad cratering and bulk solder failures are

LGA	Failure Mode				
	Cu-OSP		ImmAg		
	Early	Late	Early	N63	Late
SAC305	Bulk	Bulk	IMC	IMC/solder	Pad cratering
SN99CN	Bulk	IMC/solder Pad crater	IMC/solder	IMC/solder	Pad cratering
SAC105	Bulk	Bulk	Bulk	IMC/solder	Bulk
SAC-M	Bulk	Bulk	Bulk	Bulk	Pad Cratering
SN100C	Bulk	Bulk	Bulk	Bulk	Bulk

Table 4: Failure Modes of LGA256 in Drop.

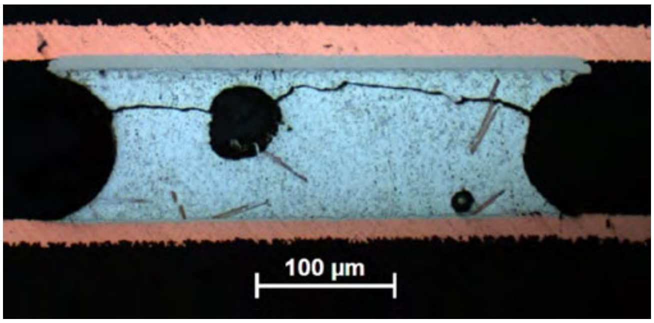

Figure 18: Representative failure mode for bulk solder failure of LGA joints on Cu-OSP PCB surface finish.

all observed. Representative images of each are shown in Figure 19. It is noted that in all the failed LGA joints on ImmAg PCB surface finish, cracks were observed in the PCB laminate under the pad. Partial pad cratering always happened regardless of the crack path producing the ultimate interconnect failure. These competitive cracking modes dissipate additional drop shock energy and may in some instances serve to prolong the drop lifetime of LGA over BGA. For LGA joints failing through the bulk solder (primarily those on OSP), greater solder Ag content was seen to correlate with better drop performance in these SnAgCu based alloys, presumably due to the increased strength of solder (see Figure 20a).

Solder Joint Volume Effects: BGA vs. LGA

The characteristic drop lifetimes of LGA and BGA solder joints are compared in Figure 20 for

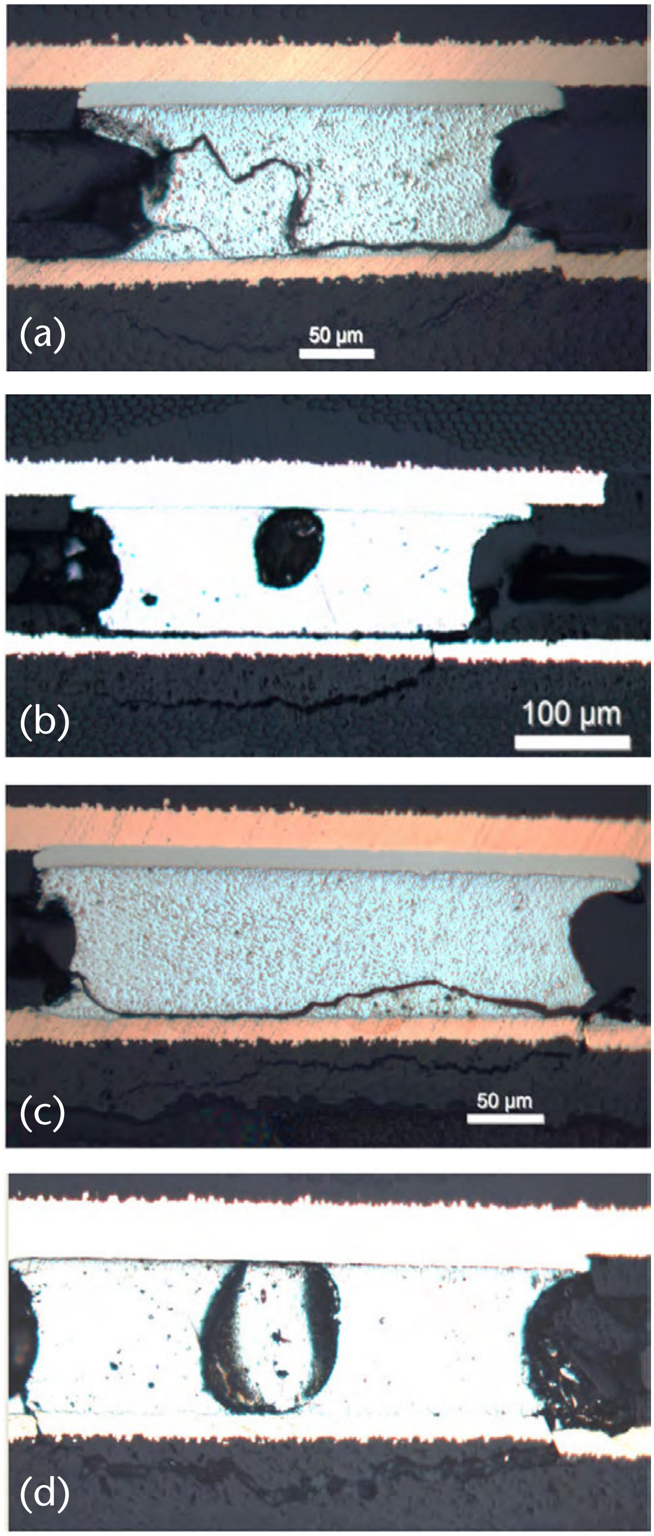

Figure 19: LGA failure modes on ImmAg PCB surface finish: (a) solder bulk failure, SN100C, late (b) IMC failure, SAC305, early (c) IMC/solder mixed failure, SAC105, early (d) pad cratering, SAC305, late.

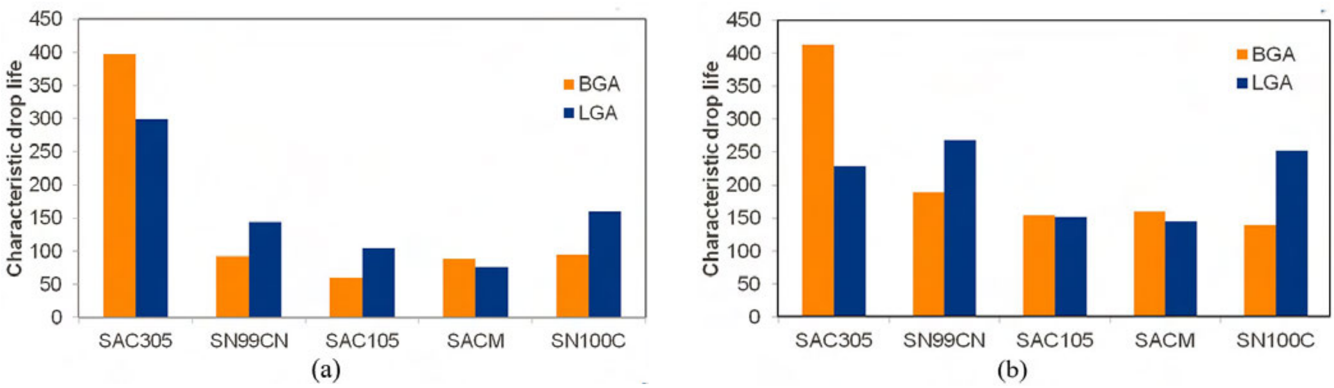

Figure 20: Comparison of characteristic life between BGAs and LGAs on (a) Cu-OSP PCB surface finish (b) ImAg PCB surface finish.

each board finish. No obvious trend in effect of joint type and solder alloy is apparent, although for any given alloy the relative performance between these joint configurations is mostly reproducible across the two surface finishes used. SN99CN and SN100C perform better in the LGA format while SAC305 and SAC-M perform better in the BGA format. SAC105 performs better in the lower volume LGA joints on Cu-OSP finish but is insensitive to solder joint volume on the immersion Ag finish.

Summary and Conclusions

Five Pb-free solder alloys on two PCB surface finishes were evaluated for drop shock reliability with two different solder joint volumes (LGA and BGA). Using a drop test board specifically designed to promote solder joint failures (i.e., solder mask defined board pads), several experimental observations could be made.

Repetitive drop shock testing was seen to produce four distinct interconnect failure modes: bulk solder failure, interfacial IMC failure, mixed IMC/solder failure and laminate pad cratering. Different failure mode trends were observed between BGA and LGA joints. Board surface finish played a role in determining the failure mode. On Cu-OSP surface finish, SAC305 BGA joints showed mainly pad cratering failure while BGA joints of other alloys generally showed mixed IMC/solder failure. On the ImmAg finish, the results were roughly reversed; BGA joints of SAC305 showed IMC/solder failure while other alloys mostly produced pad cratering failures.

LGA joints on the Cu-OSP finish produced mainly bulk solder failures. On the ImmAg finish however, LGA joints produced examples of all four failure modes with the low Ag alloys tending to have more solder bulk failure. For BGA joints on ImmAg, alloys with lower Ag amount tended to have more pad cratering. Pad cratering failure was in general more prevalent on the ImmAg finish.

Of the five lead free solder alloys evaluated, SAC305 performed the best, or nearly so, for all experimental conditions (board finish and solder joint volume). SN99CN was generally the second best drop performer with SN100C performing very similarly. Given the integral involvement of the laminate in the drop shock failure process, these observations and conclusions should for now be considered applicable only to the laminate material and pad design used. If a more robust laminate formulation further suppresses the pad cratering mechanism, more solder and interfacial failures would be observed, perhaps altering the observed relative performance of the alloys. **SMT**

Acknowledgements

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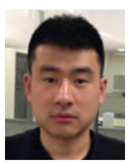
The research described was performed under the auspices of the consortium for Advanced Research in Electronics Assembly (AREA). This industry consortium was established by the Universal Instruments Corporation in the early years of surface mount assembly to address manufacturing and reliability challenges through careful scientific investigation. With a unique operational model wherein shared research is performed on-site in the Universal process laboratory by a professional research staff, it boasts manufacturing scale electronics assembly tools, a full suite of analytical capabilities and a reliability test equipment all run by experienced staff. The AREA consortium continues to stay current and relevant through the active input of its many member companies. As such, it is always open to new members with novel assembly challenges and reliability questions. Contact Denis Barbini at barbini@uic.com for additional information.

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

Jim Wilcox, Ph.D., is consortium manager, Advanced Research in Electronic Assembly (AREA), at Universal Instruments Corp.



Shuai Shao is currently a Ph.D. student at Binghamton University. During these experiments, he was a Graduate Research Associate at Universal Instruments Inc.

Francis Mutuku is a process research engineer at Universal Instruments Inc.

Babak Arfaei, Ph.D. is a materials scientist at Ford Motor Co. and a research assistant professor at Binghamton University.

Controlling Oxidation and Intermetallics in Moisture-Sensitive Devices

by Rich Heimsch
SUPER DRY-TOTECH EU

To avoid the damage of micro-cracks and delamination during the processing of electronic components, appropriate environmental storage is essential. The introduction of lead-free soldering and the associated higher processing temperatures involved makes moisture management even more important. Lead-free reflow increases the consequent saturated vapor pressure within components considerably (up to 30 bars). The same component that could be safely processed before lead-free becomes a moisture sensitive device with limited floor life. The difference is often two sensitivity levels higher classification (MSL) and shorter allowable exposure time ("floor life").

Component suppliers should deliver these moisture sensitive components in effective protective packaging to avoid absorption of humidity during transport and storage. These moisture barrier bags (MBB) are made from multiple layers of plastic and aluminum. Properly prepared and sealed, they are also a protective packaging that can prevent oxidation. ESD bags or zippered plastic bags do not protect against moisture. After opening the package, the time begins during which the components absorb humidity. Depending upon ambient humidity and temperature, the components can be safely used only within a limited time period. This time period is classified by the IPC/JEDEC J-Std 033C.

When a component has exceeded the allowed exposure time the component can be dried and made safe again through a baking process, traditionally done at 125°C. The component should be processed especially carefully after that. A repeated absorption of humidity must be avoided because the baking process should not be repeated.

Even one exposure to baking at these temperatures induces oxidation and inter-metallic growth, which reduces the wetting ability of the connection surfaces. Intermetallic thickness has been shown to increase by approximately 50% when baking at 125°C for four days. Thicker inter-metallic layers can lead to a reduction in solder joint integrity and in extreme cases reduce solderability.

To fight this well-known effect, many suppliers of baking ovens provide an additional reduction of oxygen by means of a nitrogen atmosphere or vacuum during the drying process. Setting the clock back to zero for the component can take in excess of 72 hours, inevitably

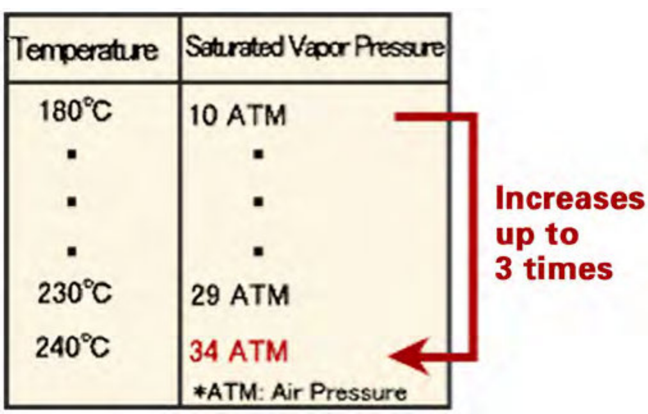


Figure 1: Saturated vapor pressure.

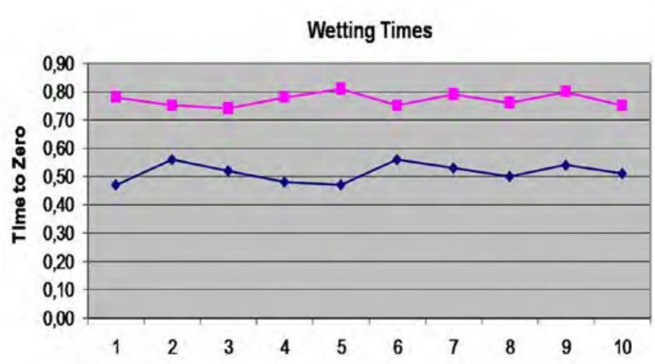


Figure 2: Wetting times.

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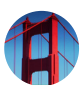

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bringing along considerable costs for nitrogen, and only a low rest-oxygen content of less than 13 ppm stops the oxidation.

Lead-Free Soldering Alloys

Because of the considerably higher content of tin in lead-free soldering alloys, the need to consider oxidation protection during storage has increased in importance. This is caused by higher oxidation tendencies of these alloys and the generally more difficult wet ability and flow properties of lead-free soldering alloys.

The Oxidation Process

The oxygen causing the oxidation originates from two different sources. The first is the oxygen molecule, found world-wide in our atmosphere. However, because of its strong atomic bond it only occurs at temperatures higher than 40°C. The second and in fact more aggressive bearer of oxygen is the water molecule. Here, the oxygen atom weakly connected, and considerable oxidation can be observed at low temperatures. This means that not the content of oxygen, far more the content of humidity is decisive for the oxidation percentage in stored components. Technically, it is possible to solve both problems at the same time. However, it is important to avoid heating above 40°C thereby eliminating the air-oxygen as a reaction partner, and to provide a strong dehumidification of the air at the same time. To achieve this, dry storage systems have been designed that can produce internal atmospheres of below 1% RH. With this extremely low content of humidity it is possible to protect the components against the additional absorption of moisture and also to remove the moisture already absorbed. As the diagram below shows, even storage in very clean nitrogen does not provide actual dehumidification of components as levels under 0.1 Wt % are not possible.

Modern Desiccant Technology

Ultra-low humidity desiccant technology is now available that can sustain a low rest-humidity of <0.5% RH (0.05 grams H20/m3) effectively a "moisture vacuum." The latest technology also provides recovery times (after door openings) of less than three minutes. This provides practical working access throughout the day without raising the average RH above the J-Std-033C specified safe storage level.

Unlike clay or silica, these storage areas (which can be thousands of cubic feet in size) use a crystal known as zeolite. It is a molecu-

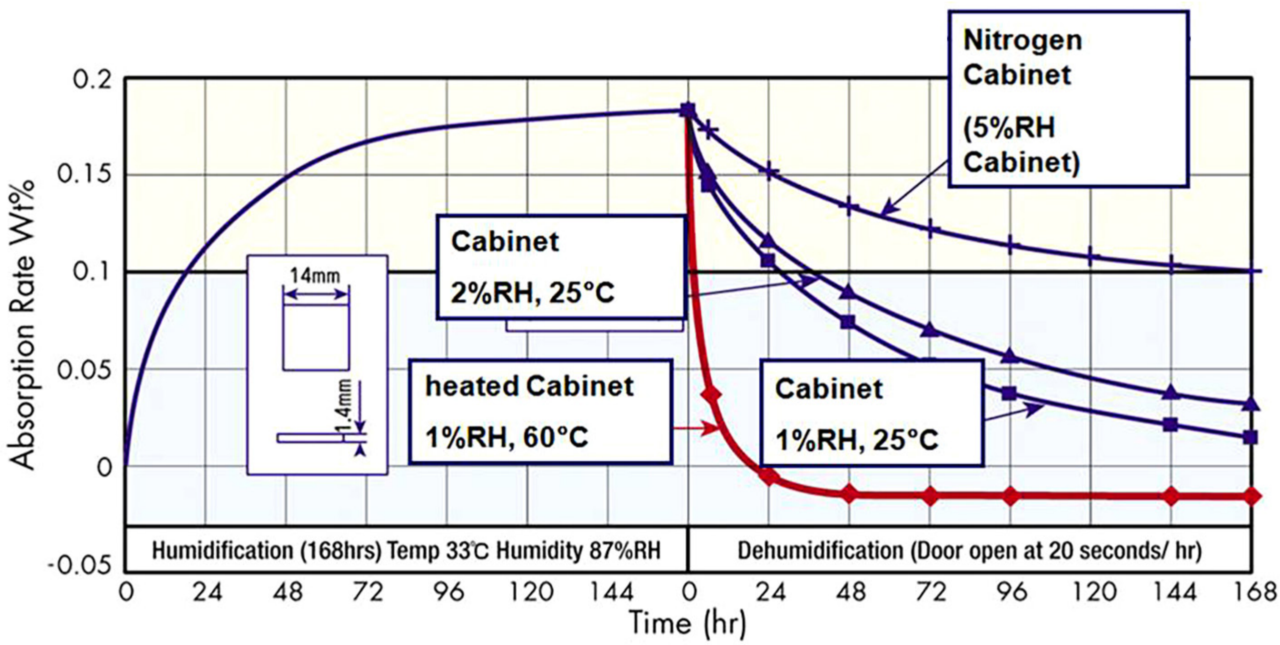

Figure 3: Drying efficiency.

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lar sieve—that is to say, the size and shape of its structural openings are that of H_2O molecules. And those water molecules are literally sifted from the air inside the cabinet. The desiccant is never touched by operators, and it never needs replacing, because the systems have automatic regeneration cycles.

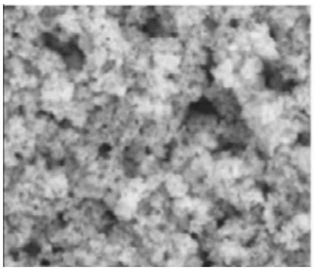
This 0.5% RH enables not just safe storage, but an effective drying of components, even at room temperature. This is impossible to achieve with nitrogen alone. (Disagree? Put an apple in one of each type of cabinet and see what they look like after a day.)

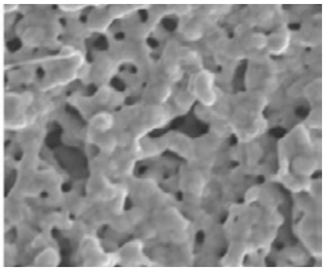
Components stored in ultra-low RH cabinets utilizing such technology are thus dehumidified, even at ambient temperature. Increasing the temperature to 40°C (the point as noted previously, at which most alloys will not oxidize) while maintaining 1% RH can further accelerate the drying time of components without oxidation or intermetallic growth, and at 10% of the operating cost of high-temperature baking.

By virtue of the oxidation protection explained previously, longer periods of storage without the use of moisture barrier bags are also practical. Safeguarding the quality and reliability of electronic assemblies starts with the controlled storage of components and PCBs. SMT

Richard Heimsch is a director at Protean Inbound and for Super Dry in the Americas.

Advance in Intense Pulsed Light Sintering Opens Door to Improved Electronics Manufacturing





Faster production of advanced, flexible electronics is among the potential benefits of a discovery by researchers at Oregon State University's College of Engineering.

Taking a deeper look at photonic sintering of silver nanoparticle films—the use of intense pulsed light (IPL) to rapidly fuse functional conductive nanoparticles—scientists uncovered a relationship between film temperature and densification, which increases the density of a nanoparticle thin-film or pattern, leading to functional improvements such as greater electrical conductivity.

The engineers found a temperature turning point in IPL despite no change in pulsing energy, and discovered that this turning point appears because densification during IPL reduces the nanoparticles' ability to absorb further energy from the light.

This previously unknown interaction between optical absorption and densification creates a new understanding of why densification levels off after the temperature turning point in IPL, and further enables large-area, high-speed IPL to realize its full potential as a scalable and efficient manufacturing process.

Rajiv Malhotra, assistant professor of mechanical engineering at OSU, and graduate student Shalu Bansal conducted the research. The results were recently published in Nanotechnology.

Intense pulsed light sintering allows for faster densification over larger areas compared to conventional sintering processes such as oven-based and laser-based. IPL can potentially be used to sinter nanoparticles for applications in printed electronics, solar cells, gas sensing and photocatalysis.

Products that could evolve from the research, Malhotra said, are radiofrequency identification tags, a wide range of flexible electronics, wearable biomedical sensors, and sensing devices for environmental applications.

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Supply Lines Highlights

Living Up to Their Name at Alpha Assembly Solutions

At SMTAI in October, I-Connect007's Judy Warner spent some quality time with Alpha Assembly Solutions' Jason Fullerton, to discuss Alpha's innovative new products. Fullerton also discussed a paper he was presenting, which compares two lead-free, silver-free alloys in a selective soldering application.

Digi ConnectCore 6UL Creates a Big Buzz at electronica

Guy Volckaerts, director for EMEA embedded sales at Digi, speaks with I-Connect007's Judy Warner about Digi's star-of-the-show at the recent electronica event in Germany—the Digi ConnectCore 6UL—a quick, simple, feature-rich, yet very flexible system-on-module solution for OEMS and developers.

KIC Shows Solutions to Voiding Problems via Optimized Reflow Profiling

At the recent SMTAI event, MB (Marybeth) Allen of KIC speaks with I-Connect007's Patty Goldman about her company, and discusses some of the details of her presentation titled "Optimized Reflow Profiling to Minimize Voiding".

Electrolube Contact Lubricants Extend Switch Lifetime

Electrolube's Contact lubricants have been proven to extend the lifetime of switches by more than 300%, increasing performance in a variety of applications and preventing the need for expensive maintenance.

Molex Solder on Polyester Substrate Delivers Flexible, Cost-effective Circuitry

Molex has introduced Solder on Polyester Substrate, a flexible, economical alternative to rigid PCB and polyimide. Surface mount (SMT) components, including fine-pitched integrated circuits (ICs) are attached with low-temperature solder and encapsulated on a polyester substrate.

Alpha's Mitch Holtzer to Present on Minimizing Voiding in Bottom Terminated Components at IPC APEX 2017

Mitch Holtzer, Director of Reclaim for Alpha Assembly Solutions, a part of the MacDermid Performance Solutions group of businesses, will present the paper titled "Minimizing Voiding in Bottom Terminated Components Using Vacuum Assisted Reflow", at IPC APEX EXPO 2017.

SED Systems Chooses ACE Selective Soldering Equipment Once Again

ACE Production Technologies, Inc., a leading supplier of selective soldering systems, is pleased to announce that Calian's system engineering division, SED Systems has purchased a KISS-102 selective soldering machine from ACE.

Super Dry Launches Series of Expandable Desiccant Cabinets

Moisture specialist Super Dry has launched a new series of desiccant storage solutions. Complementing the company's extensive range of ultra-low humidity drying and storage cabinets, the MSD Series features very high performance dehumidification in a modular design that costs 50% less than conventional solutions.

Indium's Karch Wins Best Presentation at IMAPS Autumn Conference 2016

Indium Corporation's Andreas Karch, Regional Technical Manager for Germany, Austria and Switzerland, was recognized for his technical presentation on new solder material technology in the manufacturing process of IGBT modules, at the recent IMAPS Autumn Conference in Munich, Germany. Karch's presentation featured a new method that produces strong, reliable solder joints that resist cracking and thermal fatigue.

Goepel Adds Solder Bead Detection Function in AXI System

The automatic X-ray system X Line·3D from GOEPEL electronic now has a new test function for automated detection of solder beads.


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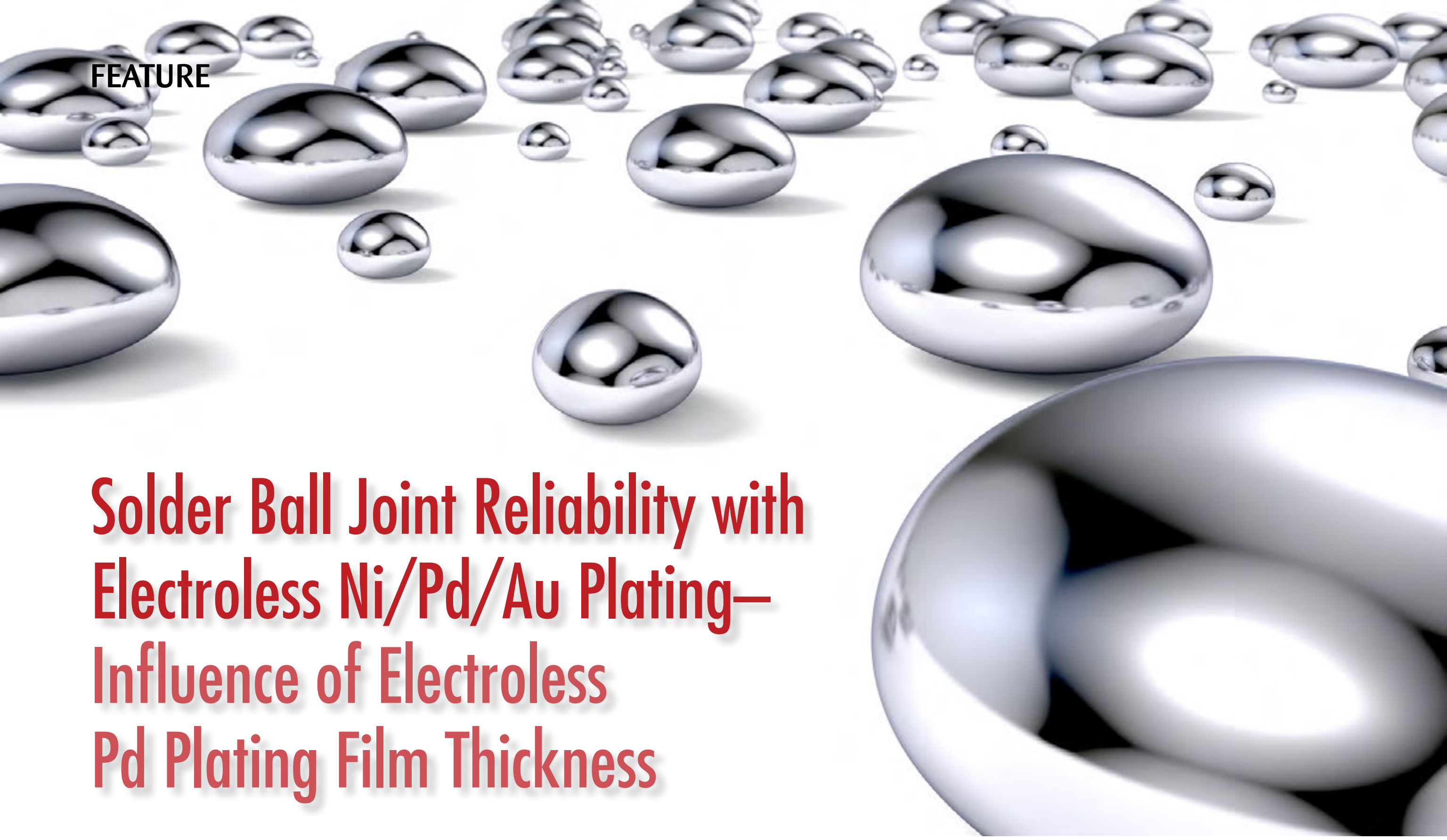

Solder Ball Joint Reliability with Electroless Ni/Pd/Au Plating—Influence of Electroless Pd Plating Film Thickness

by Yoshinori Ejiri, Takehisa Sakurai, Yoshinori Arayama, Yoshiaki Tsubomatsu, and Kiyoshi Hasegawa
HITACHI CHEMICAL CO. LTD

Abstract

The influence of Pd film thickness in electroless Ni/Pd/Au plating on the solder ball joint reliability after reflow cycles and thermal aging was investigated by conducting a high-speed solder ball shear test. Sn-3.0Ag-0.5Cu (SAC305) was used as the solder ball in this study. On the basis of the solder joint reliability obtained after multiple reflow cycles and thermal aging, the optimum thickness of the Pd film was found to be 0.05–0.2 µm.

The covering property of electroless Pd plating film on the electroless Ni plating film was also investigated. We found that an electroless Pd plating film with a thickness of 0.02 µm or more covered the electroless Ni plating film adequately, and the solder ball joint reliability in this case was better than that with electroless Ni/Au plating. We consider that the shape of the intermetallic compounds (IMCs) is one of the factors that influence the solder joint reliability after multiple reflow cycles. Consequently, we inferred that the high adhesion at the dendrite layers of IMCs/solder interface resulted in excellent solder ball joint reliability after the reflow cycles. We consider that the thickness of the IMCs is one of the factors that influence the solder joint reliability after thermal aging. In $(Cu, Ni, Pd)_6Sn_5$ IMCs that contained trace amounts of Pd, the growth of the IMCs is prevented by Pd, resulting in excellent solder ball joint reliability after thermal aging.

Introduction

With the widespread use of portable electronic equipment, chip scale packages (CSPs) and ball grid arrays (BGAs) mounted on high-density printed circuit boards (PCBs) have become popular as semiconductor package assemblies. The CSPs and BGAs are connected to the PCBs using solder balls. Such connection methods require smaller connection areas and no metal leads, thus resulting in a lower ability to resist the stress relaxation than in the case of the traditional methods of connecting the leads of thin small outline packages (TSOP) and quad flat packages (QFPs). The connection methods employing solder balls, therefore, involve many problems related to joint reliability. Several studies on the reliability of solder ball joint connections with CSPs and BGAs are now in progress[1-16].

The conventional electrolytic Ni/Au plating is a mature technology that has long been

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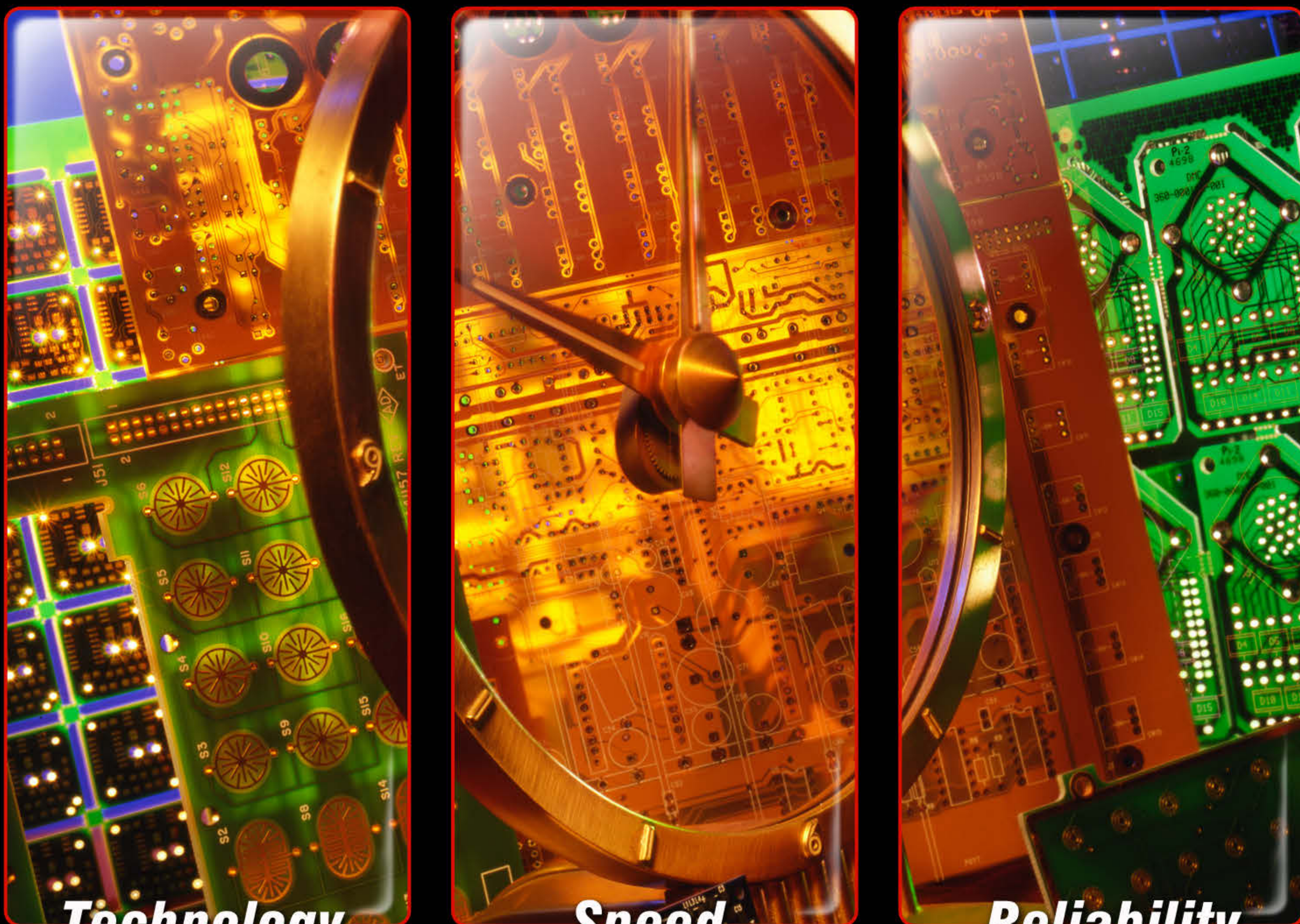

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used for surface finishing of package substrates. However, this technique cannot be applied to high-density package substrates, because it requires bus lines to each terminal and the necessary area for those lines. Therefore, electroless Ni/Au plating was adopted because it does not require bus lines. However, drop tests revealed that the reliability of ball joints prepared by this technique is insufficient. To solve this problem, electroless Ni/Pd/Au plating was adopted for surface finishing of the terminals of package substrates[17-19].

Recently, electroless Ni/Pd/Au plating is being offered as an alternative surface finishing process with high solder joint reliability and wire bondability. In the previous studies, the details regarding the influence of Pd thickness on solder joint reliability and IMC growth have not been provided. In this study, the influence of Pd film thickness on solder ball joint reliability was investigated to clearly identify the optimum thickness of the Pd film in electroless Ni/Pd/Au plating.

Experiments

Sample Preparation

A test pattern was formed on an epoxy resin copper cladding laminate (MCL-E-679F; Hitachi Chemical Co. Ltd) using the semi-additive method. The thicknesses of the board and copper pad were 0.6 mm and 25 µm, respectively. Then, solder resist was formed with a solder mask using a photo-definable type resist. The opening diameter of the ball pad was 0.45 mm. These test substrates were covered with electroless Ni/Au (ENIG: electroless Ni/immersion Au) and electroless Ni/Pd/Au (ENEPIG: electroless Ni/electroless Pd/immersion Au) plating. After applying flux, solder balls (SAC305) were attached to the test substrates and passed through a nitrogen-reflow furnace. The thickness of each plating film and the evaluation conditions are listed in Table 1.

Reliability Test on Solder Ball Joints (High-Speed Shear)

As shown in Figure 1, the distance between the shear tool tip and the package substrate was 50 µm. The shear speeds were 20, 200, and 500 mm/s. A high-speed bond tester 4000HS (Dage Precision Industries, Ltd.) was used (Figure 2). The fracture surface was observed with an optical microscope, and the fracture modes were classified into four failure modes. Typical images of these four failure modes are shown in Figure 3.

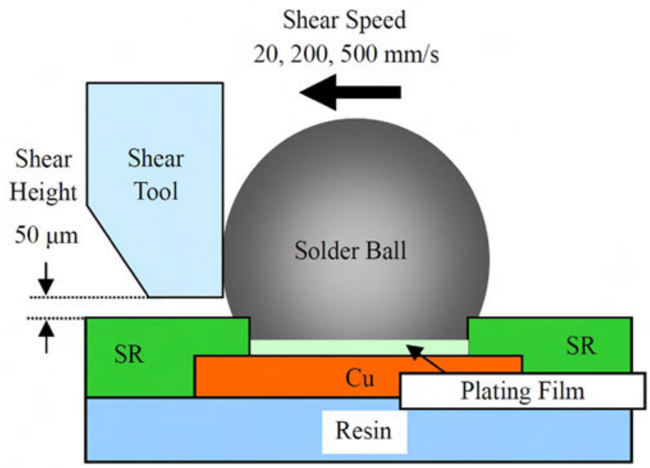

Figure 1: Outline of solder-ball shear test.

Figure 2: Externals of high-speed shear test equipment (DAGE 4000HS Bond Tester).

Method of Evaluating the Covering Property of Pd Plating Film on Ni Plating Film

To evaluate the covering property of the Pd plating film on the Ni plating film, ultrasonic

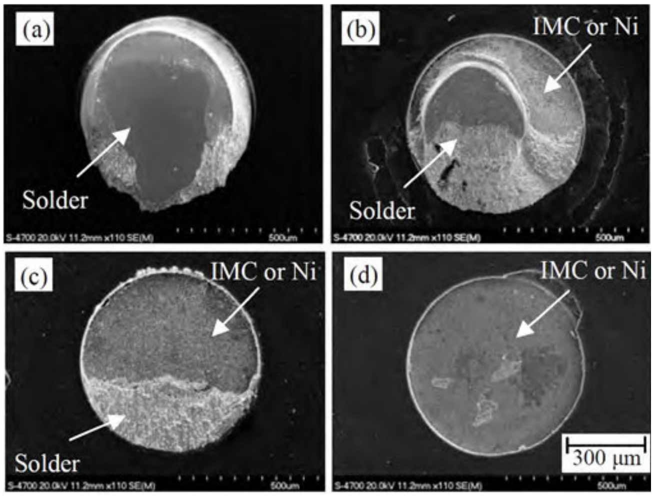

Figure 3: Classification of the fracture mode for solder ball shear test. (a) Mode A: Solder residual rate 100%; (b) Mode B: Solder residual rate 50~99%; (c) Mode C: Solder residual rate 10~49%; (d) Mode D: Solder residual rate 0~9%.

waves (1 min, 20 kHz) were applied to the Pd plated specimens to detect the low adhesion points. The surface of the Pd plated specimens before and after applying ultrasonic waves was observed using a scanning electron microscope (SEM). The cross section of these specimens was observed using a transmission electron microscope (TEM).

Growth of IMCs depending on Pd Film Thickness

The growth of the IMCs, corresponding to different Pd film thicknesses, was observed using an SEM, and the composition of the IMCs was analyzed by energy dispersive X-ray spectroscopy (EDX).

Results and Discussion

Results of High-Speed Solder Ball Shear Test

The influence of electroless Pd film thickness on solder ball joint reliability was investigated. The results of the high-speed solder ball shear test are shown in Figures 4 and 5. Almost all the samples with electroless Ni/Au film (Figure 4a) showed brittle fracture in each evaluated condition. The solder joint reliability with the electroless Pd film having a thickness of 0.01–

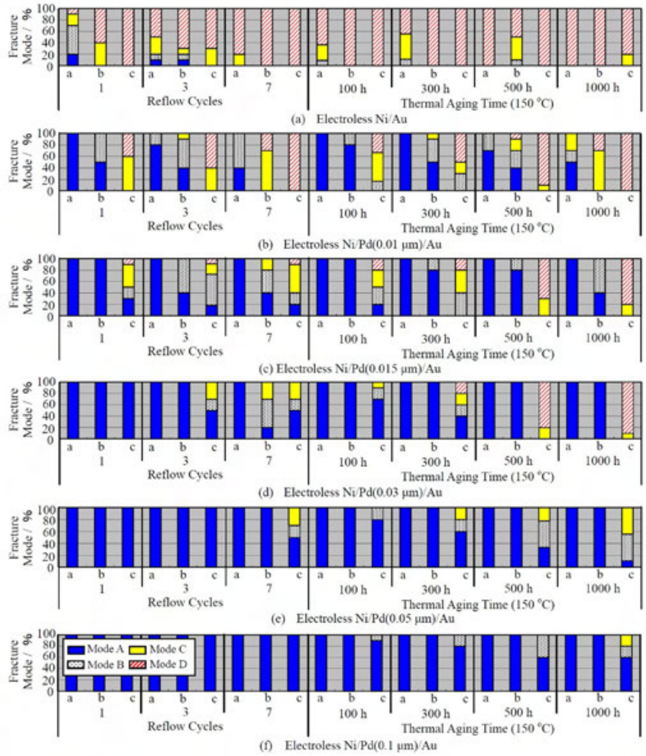

Figure 4: Dependence of fracture modes on Pd thickness. Shear speed: (a) 20 mm/s, (b) 200 mm/s, (c) 500 mm/s.

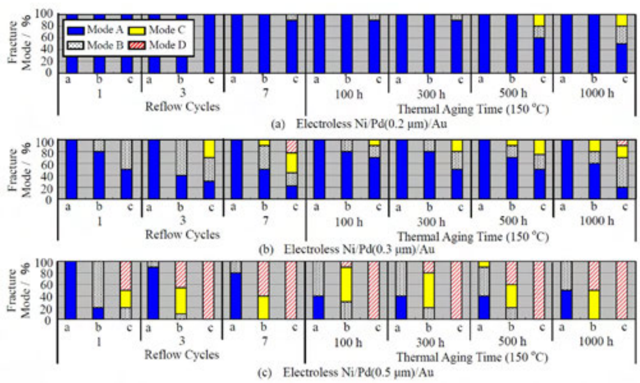

Figure 5: Dependence of fracture modes on Pd thickness. Shear speed: (a) 20 mm/s, (b) 200 mm/s, (c) 500 mm/s.

0.03 μm was higher than that with the electroless Ni/Au films. In the case of electroless Pd films with thickness more than 0.3 μm, the percentage of ductile fracture mode failures (Mode A) decreased with increasing number of reflow cycles and higher Pd film thickness. The reliability of the solder ball joint with a 0.05–0.2 µm thick electroless Pd film was similar to that obtained with conventional electrolytic Ni/Au[19] films. Thus, the optimum thickness of an electroless Pd film for a reliable solder ball joint was found to be 0.05–0.2 µm.

Covering Property of Pd Plating Film on Ni Plating Film

Figure 6 shows the results of SEM observations with different Pd thicknesses before and after applying ultrasonic waves. In the case of 0.01–0.015 µm thick electroless Pd film, pinholes occurred after applying ultrasonic waves. In contrast, in the case of electroless Pd films with thickness more than 0.02 µm, there were no pinholes after applying ultrasonic waves. A model depicting the covering process of Pd plating film on the Ni plating film is shown in Figure 7. The initial stage of Pd deposition on the electroless Ni surface involves a replacement reaction (Figure 7a). Since the electroless Pd plating bath includes a reducing agent, corrosion hardly occurs, because the reduction reaction progresses immediately on the Pd film plated by the replacement reaction (Figure 7b). However, the covering of the Pd film at the replacement reaction points was delayed compared to the other points. Thin Pd plated points existed in the case of 0.01–0.015 µm thick Pd film (Figures 7c and 7d). It is presumed that the thin Pd plated points might be the cause of occurrence of the pinholes.

All the samples with electroless Ni/Au film showed brittle fracture in each of the evaluated conditions. The SEM images of surface morphology of the electroless Ni film, after the dissolution of Au or Pd, are shown in Figure 8. In the case of electroless Ni/Pd/Au film, no corrosive pits were formed in the Ni layers, as shown in Figure 8a. On the other hand, in the case of electroless Ni/Au film, low reliability was observed, because of the formation of corrosive pits in the layers of electroless Ni, caused by the dissolution of Ni during the immersion plating of Au (Figure 8b)[17]. The TEM images of the cross section of the electroless plating film are shown in Figure 9. In the cross section of the electroless Ni/Pd/Au film with 0.02 µm thickness of Pd (Figure 9a), there were no local corrosive pits at the interface between the electroless Pd and electroless Ni. We found that 0.02 µm thick electroless Pd film can be considered as an effective barrier film to prevent the Ni layer from dis-

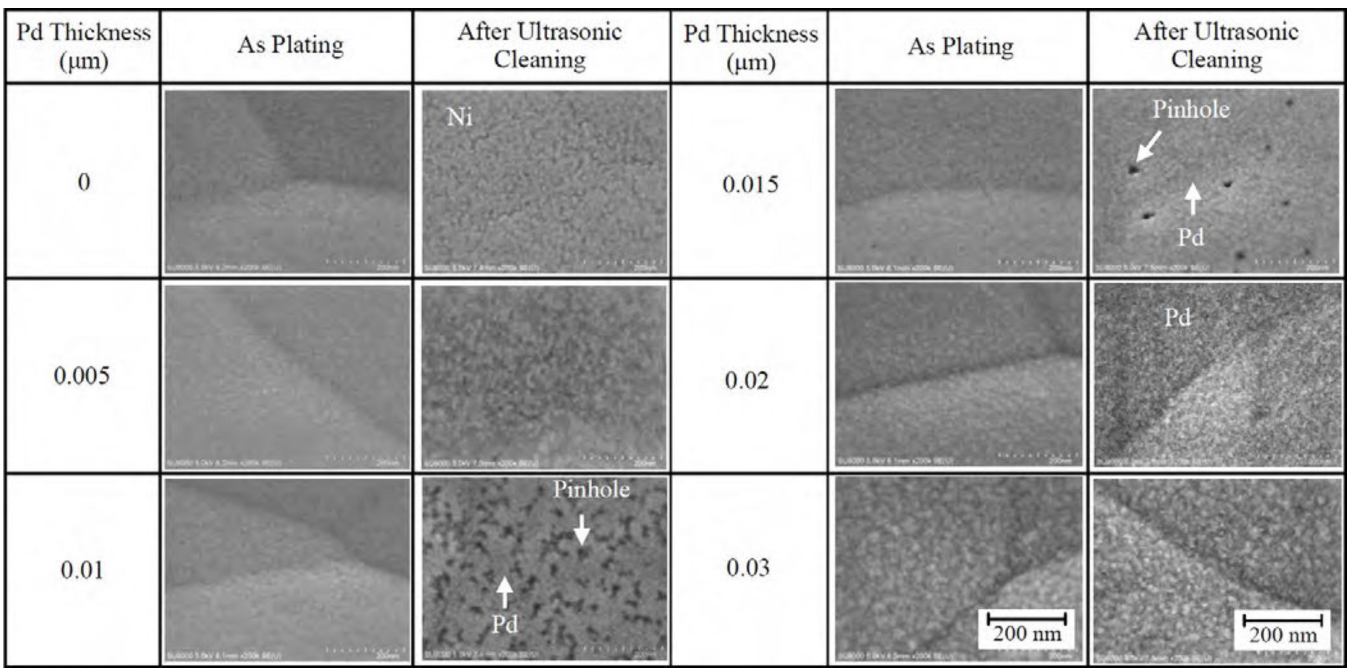

Figure 6: Coverage of the electroless Pd plating film on electroless Ni plating film.

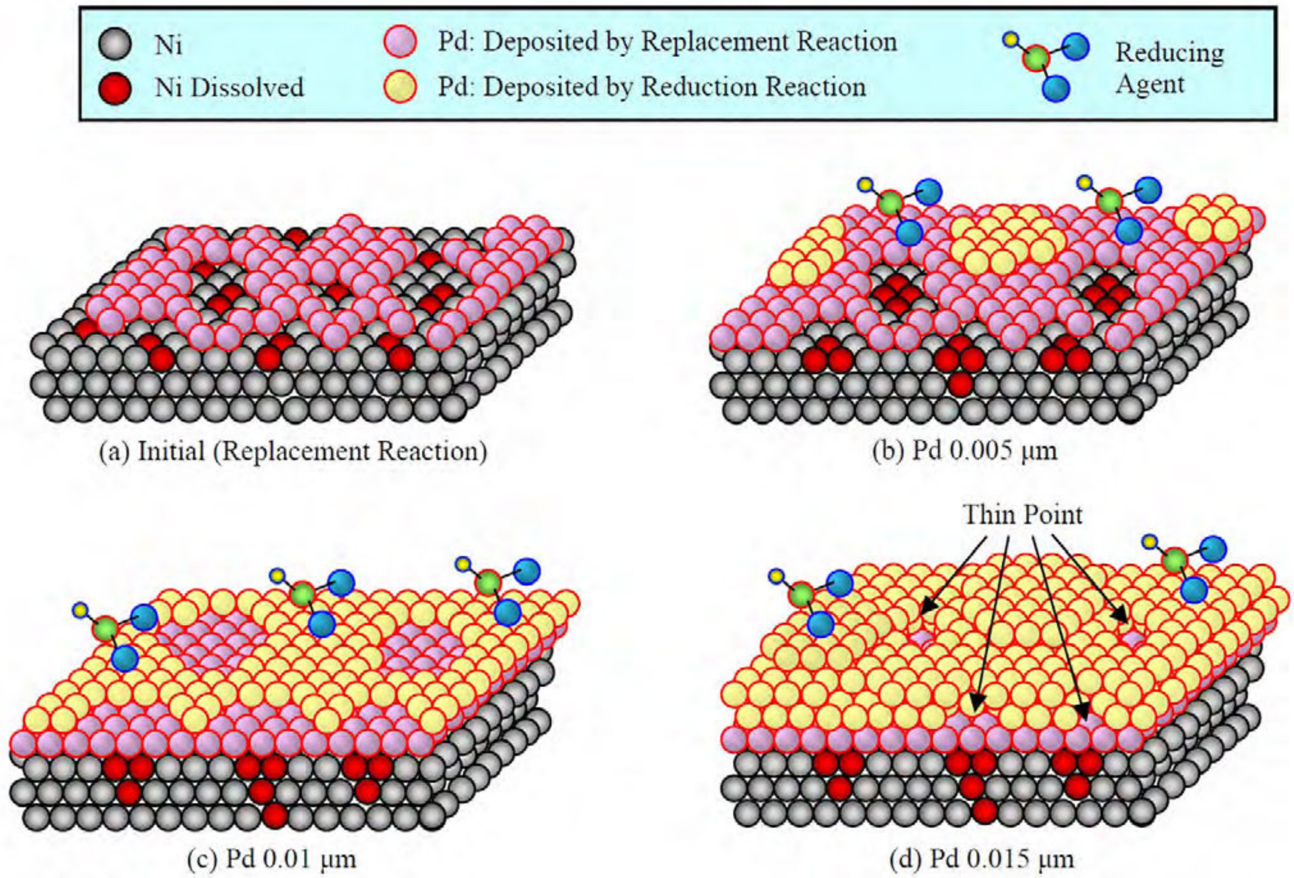

Figure 7: A model depicting the covering process of Pd plating film on the Ni plating film.

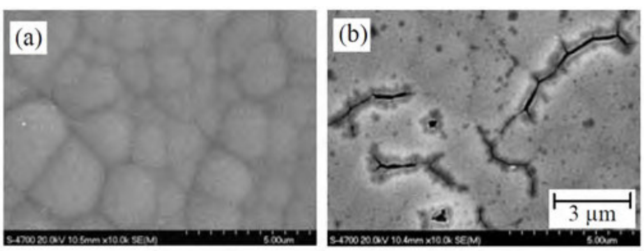

Figure 8: SEM photographs of surface morphology of the electroless Ni after the dissolution of Au or Pd. (a) electroless Ni/Pd/Au; (b) electroless Ni/Au.

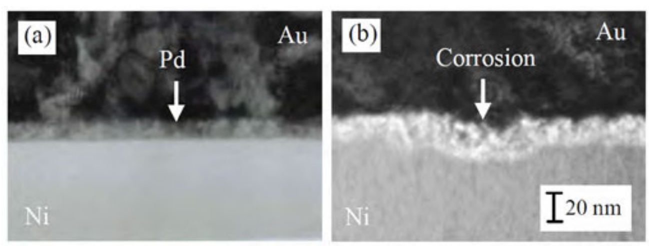

Figure 9: TEM photographs of cross-section of the electroless plating film (a) electroless Ni/Pd/Au; (b) electroless Ni/Au.

solving during immersion plating of Au. However, in the case of electroless Ni/Au film (Figure 9b), the surface of the electroless Ni was found to have dissolved evenly during the immersion gold plating.

The cross-sectional views of the plating film and solder joint interface for various Pd thicknesses are shown in Figure 10. In the case of electroless Ni/Au film (Figure 10a), the surface of electroless Ni was corroded by the immersion gold plating. IMC layers were formed at the interface of solder and the corroded electroless Ni during the reflow process. The corroded electroless Ni layer is the cause of the poor adhesion at the Ni/IMCs interface. Therefore, the brittle fracture may easily occur in the case of electro-

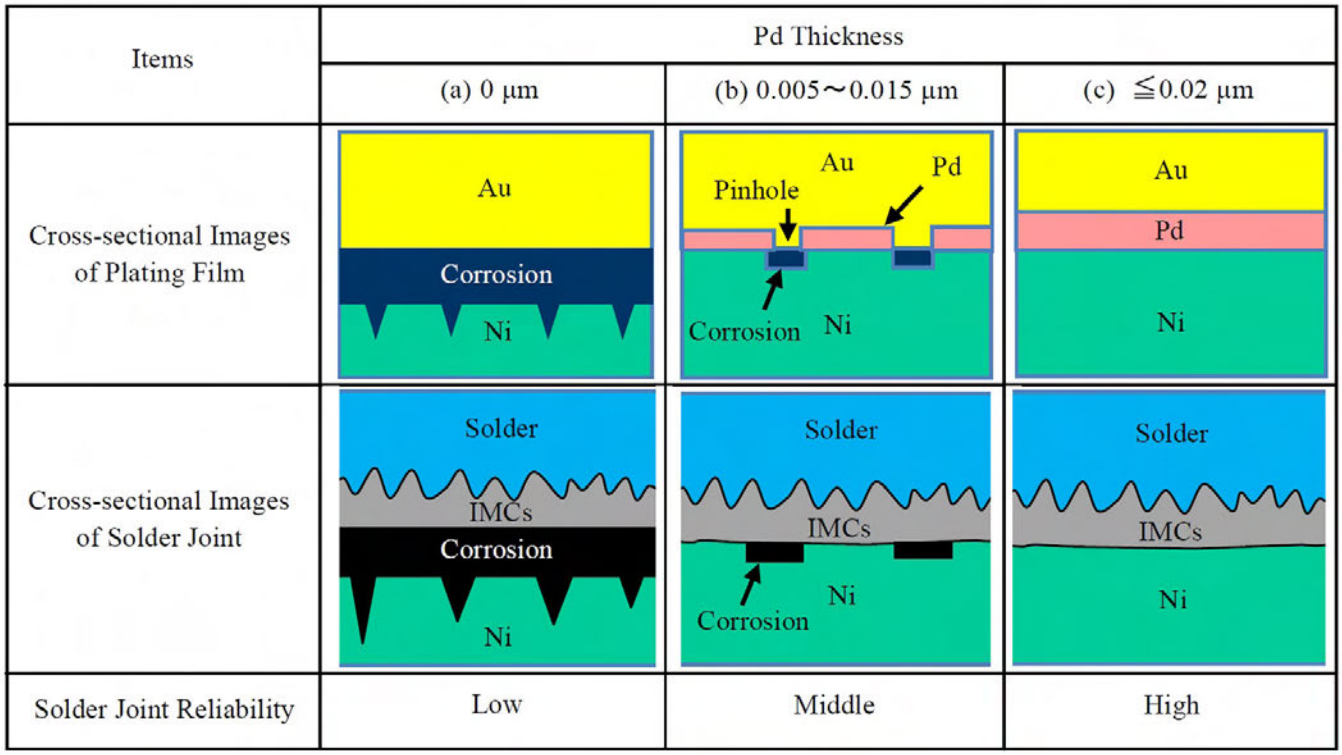

Figure 10: Cross-sectional models of plating film and solder joint interface depending on Pd thickness.

less Ni/Au film. In the case of 0.005–0.015 μm thick Pd film (Figure 10b), the thin Pd plating points were attacked by the immersion gold plating, and there was local corrosion in the electroless Ni layer. The joints with 0.005–0.015 μm thick Pd film were better than those with electroless Ni/Au film. With a Pd film thickness of 0.02 μm or more (Figure 10c), the absence of corrosive pits in the Ni layers might have contributed to excellent solder joint reliability.

Growth of the IMCs at the Solder Ball Joint Interface

(1) Influence of Reflow Cycles

The SEM observations of the cross sections of the IMCs for various Pd thicknesses and reflow cycles are shown in Figure 11. When the Pd thickness was 0.015–0.3 μm, dendrite layers of IMCs were formed at the interface of SAC305 and the Ni plating film. On the other hand, when the Pd thickness was 0.5 μm, flat layers of IMCs were formed.

To investigate the growth of the IMCs in greater detail, the cross section and surface morphology of the IMCs after the reflow cycles were observed on 0.1 μm and 0.5 μm thick Pd films. The results are shown in Figure 12. When the thickness was 0.1 μm, thin dendrite layers of $(Cu, Ni, Pd)_6Sn_5$ IMCs were formed after one reflow cycle. The size of the dendrite layers of the IMCs increased with increasing number of reflow cycles. After seven reflow cycles, thick dendrite layers of $(Cu, Ni, Pd)_6Sn_5$ IMCs [Figure 12 I (Cu : Ni : Pd : Sn=23.5 : 18.1 : 0.2 : 58.2 wt%)] were formed.

In the case of 0.5 μm thick Pd film, two types of IMC compositions were observed: one is $(Cu, Ni, Pd)_6Sn_5$ [Figure 12 II (Cu:Ni:Pd:Sn=23.4:16.5:1.2:59.0 wt%)], and the other is Cu/Ni/Pd/Sn [Figure 12 III (Cu:Ni:Pd:Sn=1.4:3.4:11.1:84.1 wt%)]. The shape of $(Cu, Ni, Pd)_6Sn_5$ IMCs was granular. These results suggested that the Cu/Ni/Pd/Sn IMCs, which included a high concentration of Pd, affected the shape of $(Cu, Ni, Pd)_6Sn_5$ IMCs. After seven reflow cycles, $(Cu, Ni, Pd)_6Sn_5$ IMCs increased in size and showed a more planar morphology [Figure 12 IV (Cu:Ni:Pd:Sn=23.3:16.5:0.8:59.4 wt%)].

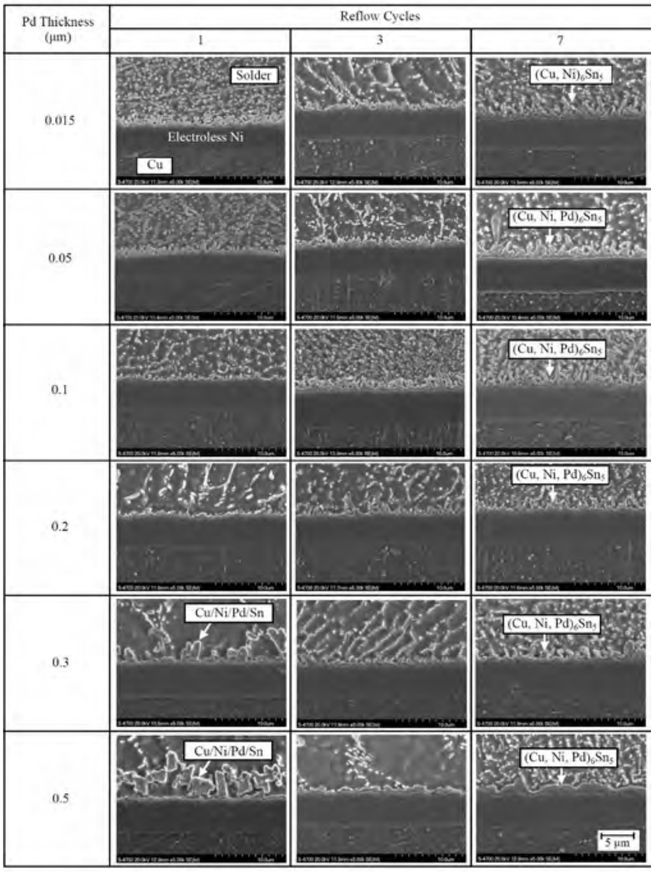

Figure 11: Cross-section of IMCs depending on Pd thickness and reflow cycles.

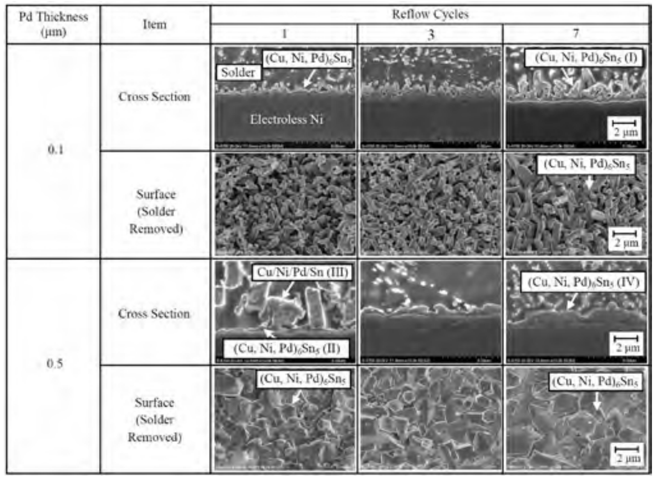

Figure 12: Cross-section and surface morphology of IMCs after reflow cycles with 0.1μm and 0.5 μm thick Pd films.

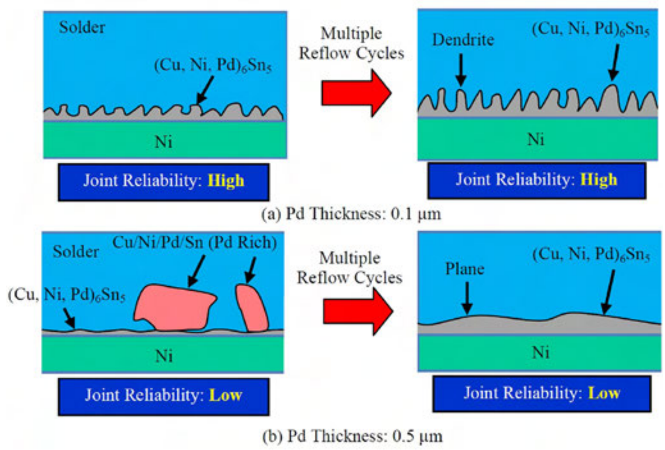

Figure 13: Cross sectional models of the IMCs depending on Pd thickness and reflow cycles.

The cross-sectional views of the IMCs for various Pd thicknesses and reflow cycles are shown in Figure 13. In the case of 0.1 μm thick Pd film, the size of the dendrite layers of IMCs increased with increasing number reflow cycles. We considered that the high adhesion at the dendrite layers of IMCs/solder interface resulted in an excellent joint after multiple reflow cycles. In the case of 0.5 μm thick Pd film, the IMC phase growth showed a more planar morphology after multiple reflow cycles. The poor adhesion at the plane IMCs/solder interface may be the reasons for the decrease in solder joint reliability.

(2) Influence of Thermal Aging

The level of reliability of the solder ball joint with a 0.1 μm thick electroless Pd film (Figure 4f) was better than that obtained with a 0.03 μm thick electroless Pd film (Figure 4d) after 1000 h of thermal aging. Therefore, the root cause of excellent solder joint reliability with a 0.1 μm thick electroless Pd film after thermal aging was investigated. The cross section and surface morphology of the IMCs after thermal aging were observed with 0.03 μm and 0.1 μm thick Pd films. The results are shown in Figure 14. The IMC phase growth after thermal aging showed a more planar morphology than that after multiple reflow cycles. The IMC layers with 0.1 μm thick Pd film were thinner than those observed in the joints with 0.03 μm thick Pd film. The composition of the IMCs with 0.03

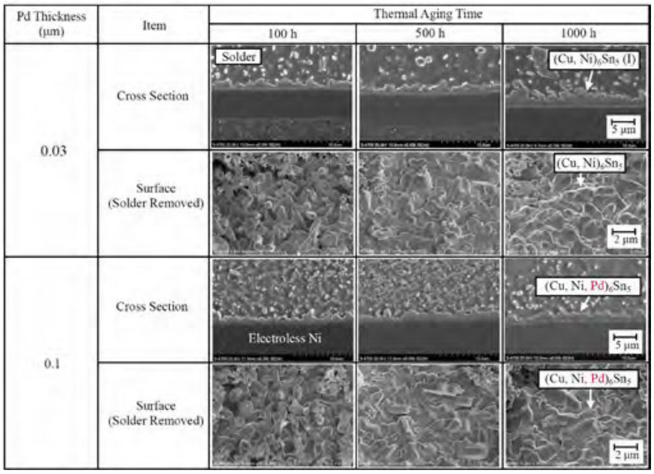

Figure 14: Cross-section and surface morphology of IMCs depending on Pd thickness and thermal aging time.

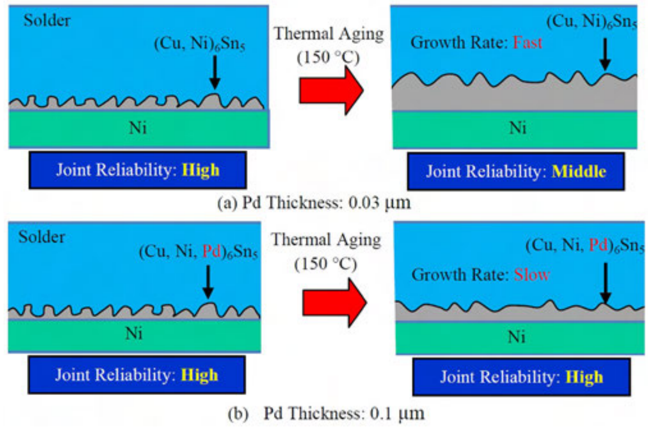

Figure 15: Cross-sectional models of the IMCs depending on Pd thickness and thermal aging.

μm and 0.1 μm thick Pd films were (Cu, Ni)6Sn5 [Cu:Ni:Sn=23.5:18.1:57.4 wt%] and (Cu, Ni, Pd)6Sn5 [Cu:Ni:Pd:Sn=24.1:17.4:0.2:58.3 wt%], respectively.

The cross-sectional views of the IMCs for various Pd thicknesses after thermal aging are shown in Figure 15. In the case of 0.1 μm thick electroless Pd film, (Cu, Ni, Pd)6Sn5 IMCs were formed at the solder joint interface, and the growth rate of (Cu, Ni, Pd)6Sn5 IMC layers was less than that of (Cu, Ni)6Sn5 IMCs with thermal aging. We inferred that the trace amounts of Pd prevented the growth of the IMCs. The IMCs are generally more brittle than the base metal, and it is reported that thick IMCs decrease solder joint reliability 20-22). We estimate that the thin layer of (Cu, Ni, Pd)6Sn5 IMCs with 0.1 μm thick Pd film after thermal aging is the cause of excellent solder ball joint reliability.

Conclusion

The influence of Pd film thickness in electroless Ni/Pd/Au plating on the solder ball joint reliability was investigated. The following conclusions were obtained:

(1) Based on the solder joint reliability obtained after multiple reflow cycles and thermal aging, the optimum thickness of Pd film was found to be 0.05–0.2μm.

(2) The shape of the IMCs is considered to be one of the factors that influence the solder joint reliability after multiple reflow cycles. We estimated that the high adhesion at the dendrite layers of IMCs/solder interface resulted in excellent joints after multiple reflow cycles.

(3) The thickness of the IMCs is considered to be one of the factors that influence the solder joint reliability after thermal aging. For (Cu, Ni, Pd)6Sn5 IMCs that contained trace amounts of Pd, the growth of the IMCs is prevented by Pd, resulting in excellent solder ball joint reliability after thermal aging. **SMT**

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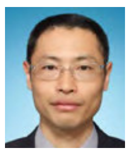

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Reducing Warpage on BGAs During Rework

by Bob Wettermann
BEST INC.

One of the challenges associated with BGA rework has to do with effects of device warpage, which can cause undue shorts or opens post rework. The impact of a lead-free rework process, the continuous "thinning" of the BGA package as well as continued turnaround time pressures of rework all have led to increased propensity of this phenomenon to occur. While most of the failures in the rework process can be captured via visual or x-ray inspection, or some escapes in test can occur. For example, head-in-pillow defects can be caused by the process of the ball being "pulled" out of the oriented paste during the reflow profile. Too much warpage can also create stress on the solder ball joints and lead to reliability failures of the packages (Figure 1).

Outside of opens and shorts in the reflowed and reworked BGA, there is a widely accepted analytical technique for measuring the degree of warpage. These measurements are made by coating the part with reflective paint and placing a sheet of low expansion quartz glass etched with equally spaced parallel lines parallel to the sample. A beam of light is then directed onto the quartz glass and the lines create a shadow on the top of the BGA package. When the package becomes warped a Moiré pattern is produced by the geometric interference between the lines on the quartz and the shadow of the lines on the surface. These fringe patterns then can be calibrated and are displayed as 3-D topographical part "map." A typical Shadow Moiré warpage output, from a modern measuring instrument, can be seen below (Figure 2). This method tries to emulate the behavior of the package through a thermal cycle.

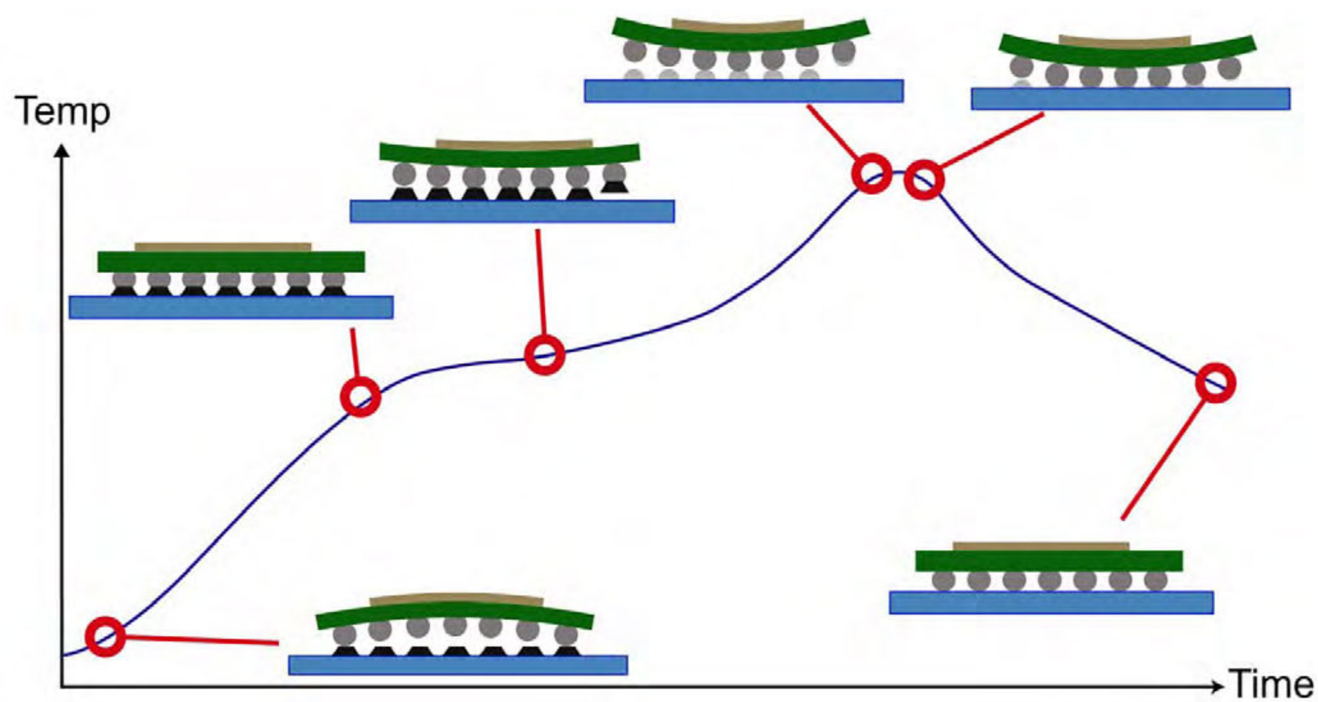

Figure 1: Typical rework profile and the potential impact of warpage at differing points.

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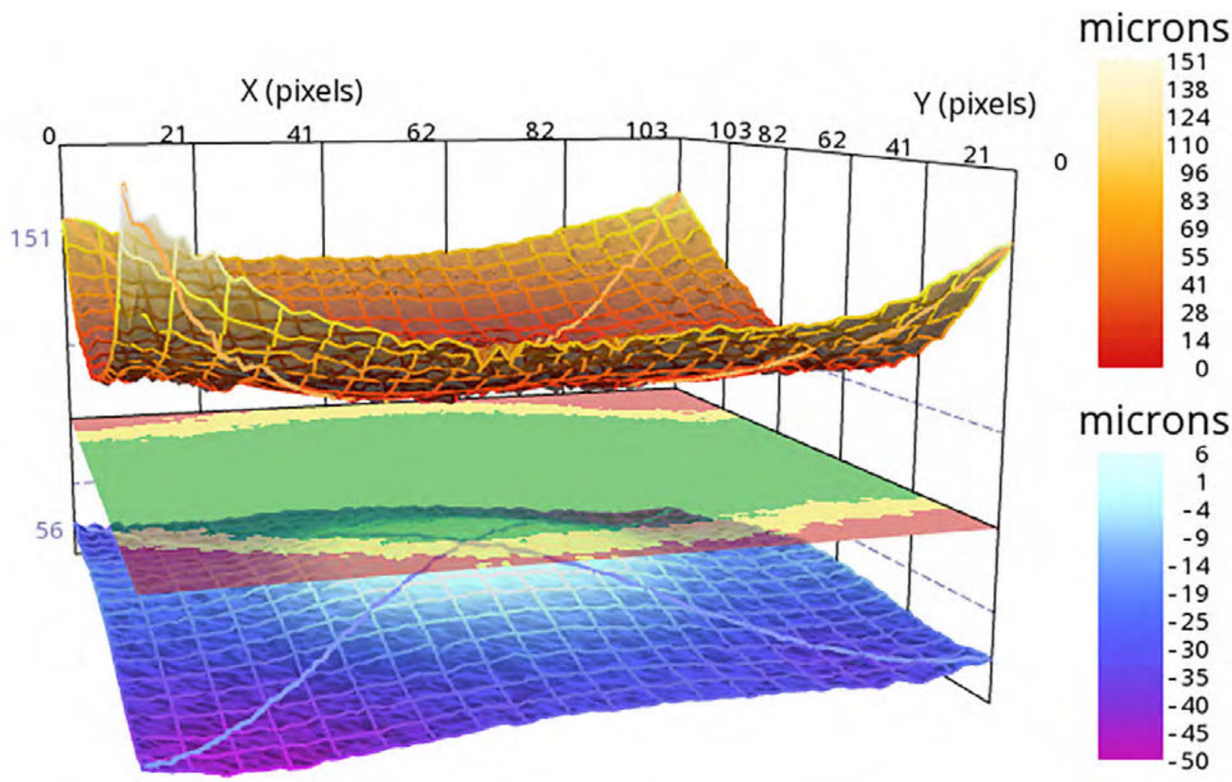


Figure 2: Shadow Moiré output showing device warpage. (Courtesy: Akrometrix)

The difference among the components in the BGA (silicon die, the molding compound, substrate, etc.) causes thermal stresses due to the thermal expansion mismatch between the various components. A major reason for warping in area array plastic package is this coefficient of thermal expansion (CTE) mismatch. Using low-CTE advanced thermal materials, it is possible to tailor CTE, reducing this problem. Sometimes underfill is used to provide mechanical support and protection for the dieto-package interconnects. This can minimize thermal stress on the die due to CTE mismatch with the substrate materials.

As a result of the higher lead free processing temperatures in rework, device packages, initially constructed for lead bearing solders are subjected to greater thermal stresses and exhibit a greater propensity to warp. Some research [1] has demonstrated that the impact of a higher processing temperature, versus the molding temperature, of the package material is a direct causal link to the amount of device warpage. As the device packaging for lead free products have

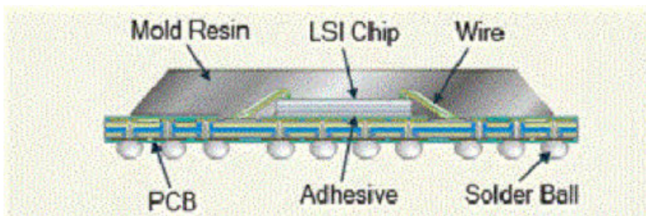
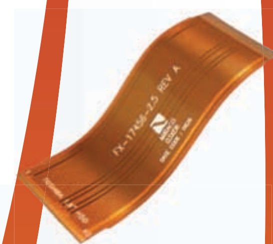


Figure 3: Typical BGA package cross section. (Courtesy: Socionext)

become more stable, this impact has been lessened through material changes in typical BGA packages.

The thinning of area array packages, due to the increasing demand to make end devices more portable, has brought the average moisture sensitivity of device packages up. This makes devices more susceptible to thermal damage based on a given heat exposure time. The purpose of the MSD standard is to identify the moisture sensitivity level at a fixed reflow temperature (Figure 4). The user can then properly store and handle the devices, avoiding subse-

Engineering And Providing Balanced Interconnect Solutions



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Level	Description	Preconditioning Followed by Three Cycles of VPR or IR Solder Shock	Expected Floor Life (at 30°C / 60% RH)
1	Not moisture sensitive	168 hours at 85°C/85% RH	Unlimited
2	Limited moisture sensitive	168 hours at 85°C/60% RH	One year
3	Moisture sensitive	192 hours at 30°C/60% RH	Seven days
4	Moisture sensitive	84 hours at 30°C/60% RH	Three days
5	Highly moisture sensitive	168 hours at 85°C/85% RH	One day
6	Extremely moisture sensitive	168 hours at 85°C/85% RH	Six hours

Figure 4: JEDEC Standard Qualification Levels for Moisture Sensitivity.

quent thermal/mechanical damage, during the assembly reflow attachment and/or repair operations. The thinning of the device bodies has moved them to higher MSD levels and shorter floor life, thereby exacerbating the warpage problem.

JEDEC Standard Qualification Levels

Time-to-market pressure for repair depots, as well as leaner inventories, have caused additional turnaround stress on PCB rework departments. Many times, this time pressure on BGA rework means taking short cuts when using hot air rework systems. Matching nozzle size to the BGA is important in minimizing the part warping during rework. Using too small of a nozzle requires all the heat to pass thru the part and into the solder joint. This can cause large temperature differentials and result in BGA warping.

There are several process conditions which need to be controlled in order that warped device packages do not become a problem. The greatest areas to control include: profile development, MSD controls and solder paste volume adjustments made during printing.

Good reflow profile management, in terms of extending the heating/cooling profiles longer, will minimize the impact of device warpage. Although this will impact throughput. During the cool down process, if you go too slowly, it will create coarse-grained structures in the solder joint. Additionally, the proper control of temperature differential, across the part during reflow by using a multizone bottomside heater, will reduce the warpage impact.

A properly sized nozzle, approximately 2mm larger around the periphery of the package, will allow heat to flow directly onto the PWB and reduce the intensity of the profile. A less "intense" profile, one with lower maximum temperature and lower flow rates, will help to prevent the temperature differentials that can cause the BGA to bow downward creating corner shorts. Using an infrared heating source for BGA rework will reduce, or eliminate, the long lead time for custom nozzles. Multizone bottomside heating will also help mitigate device warpage problems by keeping the temperature differential on the part surface to a minimum.

Control of the parts with respect to moisture sensitivity control guidelines will keep the warpage impact of moisture absorbed by the package to a minimum. The to-be-reworked boards will need to be baked out in order to reduce the chance for MSD damage. In addition, the parts that will be placed back on to the board will need to be kept in dry boxes or a moisture barrier bag which has been properly sealed. Close tracking of "floor time" will help insure that moisture ingress is limited throughout the process.

If during the development of the rework process you are discovering opens and shorts and have optimized the other parts of the rework process, then solder volumes for different areas of the array may be in order. For example, if shorts are being noted at the corners of the reworked BGA—then print volume may need to be reduced at those locations. This can be accomplished by using either smaller balls at the corners or shrinking the aperture sizes of the stencil. Sometimes limiting collapse height of the solder balls at the corners can be accomplished through the use of standoffs (at the corners which can be removed) after fellow.

There are numerous other ways to mitigate the problem of warpage on BGA rework in addition to the above noted. The solder paste formulation, the type of flux, and its activation level will determine how forgiving the BGA rework profile will be. Changes in tooling, soldering methods, and preheating of component methods can affect the impact and degree of the BGA rework process yield warpage. **SMT**

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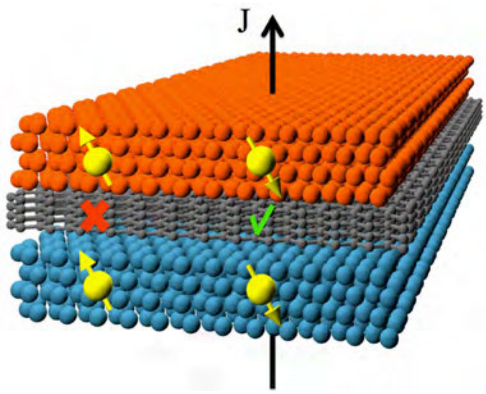
Bob Wettermann is the principal of BEST Inc., a contract rework and repair facility in Chicago.

Spin Filtering at Room Temperature with Graphene

An interdisciplinary team of scientists at the U.S. Naval Research Laboratory (NRL) have reported the first demonstration of metallic spin filtering at room temperature using ferromagnet-graphene-ferromagnet thin film junction devices.



"The spin filtering had been theoretically predicted and previously seen only for high-resistance structures at cryogenic temperatures," said Dr. Enrique Cobas, principal investigator, NRL Materials Science and Technology Division. "The new results confirm the effect works at room temperature with very low resistance in arrays of multiple devices."

The thin film junctions demonstrated low resistance, and the magnetoresistance characteristic of a spin filter interface from cryogenic temperatures to room temperature. The research team also developed a device model to incorporate the predicted spin filtering by explicitly treating a metallic minority spin channel with spin current conversion, and determined that the spin polarization was at least 80 percent in the graphene layer.

"Graphene is famous for its extraordinary in-plane properties, but we wanted to look at conductivity between stacked graphene sheets and how they interact with other materials," said Cobas.

To do so, NRL researchers developed a recipe to grow large multi-layer graphene films directly on a smooth, crystalline nickel alloy film while retaining that film's magnetic properties, then patterned the film into arrays of cross-bar junctions.

"There is room for improvement as theory suggests the effect can be increased by an order of magnitude by fine-tuning the number of graphene layers," said Dr. Olaf van 't Erve, research scientist, NRL Materials Science and Technology Division. "However, current models do not include the spin-conversion that happens inside the ferromagnetic contacts. Once we account for those effects, we're already close to the ideal case of 100 percent spin polarization in the graphene layer, enabling us to revise our device geometry and materials to maximize the effect."

Electronics Industry News
Market Highlights

Display Panel Makers Increase Fab Utilization Rate to 90% in Q4

The overall utilization rate at fabrication plants used for display panel production is expected to reach 90% in the fourth quarter of 2016, up 7 percentage points from the same period in the previous year, and up 1 percentage point from the previous quarter, according to IHS Markit.

Average Contract Price of PC DRAM to Go Up 15% Sequentially in Q1 2017

The latest research from DRAMeXchange finds that the global DRAM market in the first quarter of 2017 will benefit from the stock-up activities ahead of the Chinese New Year holidays and the widespread expectations of tight supply.

4G Smartphones to Surpass 1 Billion Mark in Shipments for 2016

Worldwide smartphone shipments are expected to reach 1.45 billion units with a year-over-year growth rate of 0.6% in 2016, according to the IDC Worldwide Quarterly Mobile Phone Tracker.

IoT: Soaring Demand for Smarter Devices to Bring Lucrative Opportunities in Market

The global Internet of Things market stood at $237.77 billion in 2014 and is predicted to touch $924.86 billion in 2021, expanding at a whopping 21.4% CAGR between 2015 and 2021.

Global Smartphone Production Volume to Grow 4.5% Annually in 2017

Market research firm TrendForce has lowered the projected annual growth rate of smartphone production worldwide for 2016 to 2.5%.

Strong Growth Expected for the Wearable Technology Markets

The wearable technology market is worth $28.89 billion in 2016 and expected to reach $71.23 billion by 2021, growing at a CAGR of 18.9% from 2016 to 2021, according to a new report by Scalar Market Research.

Indian Smartphone Market Crosses 30-Million-Unit Shipment Milestone

The smartphone market in India has crossed the 30-million-unit shipment milestone for the first time ever in a quarter in CY Q3 2016, maintaining its healthy traction with 11% year-on-year growth.

Worldwide Sales of Smartphones Grew by 5.4% Year Over Year

Three Chinese vendors — Huawei, Oppo and BBK Communication Equipment — together accounted for 21% of the smartphones sold to end users worldwide in the third quarter of 2016. They were the only smartphone vendors in the global top five to increase their sales and market share during the quarter, according to Gartner Inc.

Biometric System Market Worth $32.73 Billion by 2022

The future growth of the biometric system market is expected to be driven by rising use of biometric technology in financial institutes and healthcare sectors, government initiatives in adoption of biometric system, and increasing use of biometric systems in criminal identification.

Global Tablet Market to Recover in 2018

Worldwide tablet shipments are expected to decline by 12% in 2016, rounding out the year at 182.3 million shipments, according to a new forecast from the IDC Worldwide Quarterly Tablet Tracker. IDC expects the market to rebound in 2018, though growth will remain in the low single digits as detachable tablets slowly gain traction.

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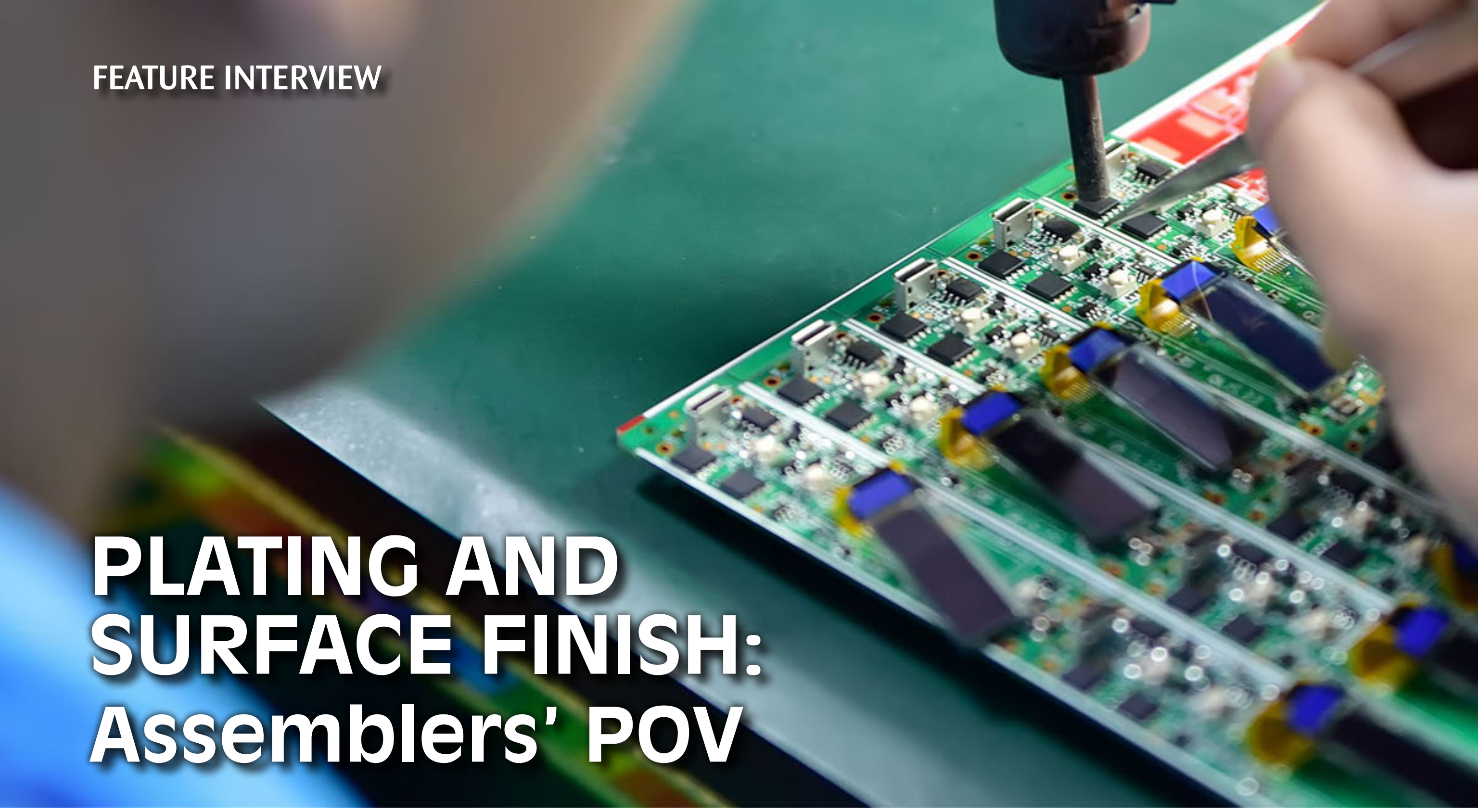

PLATING AND SURFACE FINISH: Assemblers' POV

by Stephen Las Marias
I-CONNECT007

Joemar D. Apolinario, manufacturing engineering manager, and Dnichols R. Dulang, process engineer at EMS firm Integrated Micro-Electronics Inc. discusses with *SMT Magazine* the impact of plating and surface finishes on electronics assemblies. They highlight the impact on solderability, the problems with complex components and packages, as well as parameters to consider when it comes to surface finish selection.

***Stephen Las Marias:** From your perspective, what are the greatest challenges when it comes to plating and surface finishing*?

Joemar Apolinario: The greatest challenges that we face include obtaining good connectivity between the PCB and the component, and having good solder joint reliability; proper selection of the surface finish that will satisfy the product application requirements, cost, reliability and compliance to ROHS; proper handling and storage; and signature defects such as visual cosmetics (exposed copper), plating thickness integrity (especially high-value materials such as silver and gold) from the PCB manufacturer.

Dnichols Dulang: The greatest challenges are the problems due to visual cosmetics and solderability, both for TH and SMT pad surfaces.

***Las Marias:** What are the most common plating and/or surface finishing defects?*

Apolinario: Common defects include discoloration (oxidized pad), corrosion, contamination, and exposed copper. These PCB defects normally results in solderability problems, and affect product reliability.

Dulang: Other defects are de-wetting, black pad defect, and tin/silver whiskers.

***Las Marias:** How do surface finishes affect your assembly process?*

Apolinario: If the surface finish is not properly determined based on the product component and application, it will impact solderability. Solder wetting is not good for the oxidized pad. Some characteristics of various surface finish are not compatible with some components like fine pitch ICs due to planarity issues. Some finishes, such as OSP, also require extra sensitivity in handling. One critical point is that we should understand how we handle the different surface finish, so that we can put appropri-

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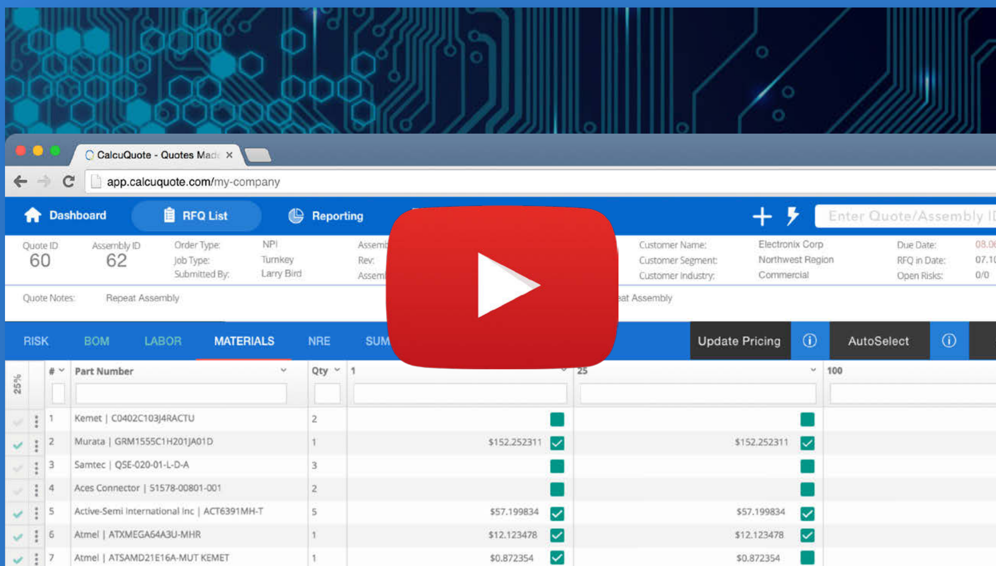

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Joemar Apolinario

ate controls and parameters that will fit the product applications.

***Las Marias:** What about plating? How does plating affect your assembly process?*

Dulang: Plating is one of the critical parameters. If plating does not comply with the specifications, then there is a strong possibility to encounter assembly problems. Plating can cause functional test failures due to connectivity issues. The worst reliability failure is the intermittent failure due to cracks. Compatibility of surface plating to solder paste and component plating are very critical points.

***Las Marias:** Are there parameters to consider when it comes to plating and/or surface finishing that will help optimize your assembly process?*

Apolinario: The parameters are the right selection of surface finish, then PCB pad cleanliness. Plating thickness should be considered to optimize the assembly process and testing, as well as handling and shelf life.

***Las Marias:** How do surface finishes impact solderability?*

Apolinario: Solder finishes have a significant impact on solderability, most especially on those fine-pitch lead and more complex components such BGAs, LGAs, and flip chips. That's why the selection of the surface finish is not easy; the surface plating should be determined based on the product application and complexity. First, the planarity of surface finish should be properly assessed; an uneven surface is not fit for complex components such BGAs. Then, the handling sensitivity—exposed surface finish might create contamination that will impact solderability. And lastly, the reliability of assemblies.

***Las Marias:** What about shelf life?*

Apolinario: The PCB shelf life depends on the type of surface finish and thickness. Proper packaging should be considered to prevent any excess moisture and ensure prolonged shelf life. There are standards written on how to treat the PCB if it exceeded the shelf life; more often, customers decide and recommend actions on how to handle end of shelf life. The quality and integrity of the solder and connection slightly varies as the shelf life nears its expiration.

Dnichols Dulang

***Las Marias:** How do you and your customers determine which surface finish would be best suited to your needs?*

Apolinario: In most cases, customer requirements depend on the product application, standards regulation, manufacturability or complexity of process, cost, reliability, rework, and the environment where the product will most exposed.

Dulang: The overall product assembly process must be considered. For example, does the product have COB process? Some surface finishes are wire bondable while others are not. Therefore, what wire to use, aluminum or gold? The environment upon where the product will be applied also needs to be considered as it can affect reliability.

***Las Marias:** What trends do you see in surface finishes?*

Apolinario: As the complexity of surface-mount components increases, we see the trend toward ENIG finish. Even though it is expensive, it has the advantage of being able to handle more complex surface-mount components such BGAs, flip chips, and LGAs. ENIG is compliant with ROHS and WEEE, which are now standard requirements for the industry, especially in the automotive and industrial sectors. However, given the challenges on productivity, cost and quality, most industries are also considering alternative finish such immersion silver, which has the same advantages as ENIG but not as expensive.

***Las Marias:** Thank you, gentlemen.*

Apolinario: Thank you, Stephen. **SMT**

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A New Organizational Model Using Logic, Cost Effectiveness and Customer Service, Part 2

by Tom Borkes
THE JEFFERSON PROJECT

Words mean something, it seems, unless you are a politician.

No matter what your political views, it is hard to dispute that the recent U.S. election was unique and certainly not in a way that makes us want to stand up and cheer. Before the email deluge begins, let me make it clear that I'm talking about the election *process*.

Speaking truth to power has a romantic and compelling draw. However, this campaign was no *Mr. Smith Goes to Washington*. I have often counseled young engineers that being right on a technical point is not enough—that the *package* you put your information in is as important as the information itself. In team dynamics we call this *aligning constituencies,* and it is an important element in influencing other team members. It's hard to gain the support of others after you've used your command voice—or worse, called them the devil's spawn.

On the other hand, there is an attractive and refreshing quality to being direct when making a point, and calling one out when it is warranted—remember the child on the parade route screaming: *the emperor has no clothes on!* The art of rhetoric—persuading one to agree with your position on an issue—is walking the sometimes very fine line between the two approaches.

Production Volumes Take Off

Our corporate production organizations have been in place since Henry Ford created the assembly line in the early 20th century. Each line worker was given a small, repetitive task to perform in the overall assembly of an automobile. This reduced production costs and correspondingly, automobile prices. More and more of the population were able to afford this product. Production volumes skyrocketed[1]. With the exploding volumes, more workers were needed. As the technology became more complex the workers developed areas of specialization. These workers had to be managed, so they were


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grouped in departments based on common skill sets and job responsibilities. A manager was assigned for each department in order to coordinate, assign and measure the activities of the group.

Management's objective became one of maximizing the output and quality of the workers by controlling them—planning their work, reviewing their performance and keeping their nose to the grindstone. It was the Hamiltonian worldview that the workers (masses) were the beast and the beast must be controlled. See Fritz Lang's *Metropolis* (1927), or on the lighter side Lucy and Ethel working on the chocolate assembly belt in the episode, *Speed it Up!*

"So, we became chained to a production organizational model that was hierarchical and laden with supervisors whose goal was optimizing worker productivity."

So, we became chained to a production organizational model that was hierarchical and laden with supervisors whose goal was optimizing worker productivity.

There have always been areas of specialization such as wheelwrights, blacksmiths, plumbers and later soldering, welding, etc., but mass production for the first time brought many of these skills under one roof—working for one employer and grouped in departments.

Even before Henry Ford, in the 18th and 19th centuries, workers were employed in ever increasing capital-intensive industries such as textiles. Customer demand for these products caused workers to leave their cottage operations and join together in factories. Replacing water mills and other equipment with those that were steam-driven, permitted the factories to be located anywhere, not just near a source of running water.

It sounds counterintuitive, but in the early days of the new republic as this transition of the workforce took place, "[the] primary reason for the rapid industrialization of the United States was very high labor costs...American wages were high because employers had to compete [for employees] with the exceptional opportunities of self-employment in order to attract adequate numbers of qualified workers[2]."

This competition in production still exists today. Because of the high levels of automation now required to deal with very small components in electronic products, companies that do their own product assembly have thought they could hire cheap labor to just push the buttons and let the machine do the hard stuff. Developing, programming and maintaining the automation was relegated to others with the necessary skill sets. This fit nicely in the hierarchy and organizational power pyramid[3].

However, now with sources of low labor rates that the global economy has ushered in, high production wages become a convenient excuse to offload the manufacturing and assembly of their products. Companies are finding that producing their products remotely to take advantage of these lower rates can have some serious drawbacks. To me there are only two reasons to produce your products remotely:

1. You want to sell them into that remote marketplace (a good reason)
2. You can't compete with those remote sources of production (a bad reason)

In previous columns, we have talked extensively about the one of the controllable components of labor cost: the counterweight to competing against low labor rates—using automation to reduce labor content. Over the next few months we will drill down into the other controllable component of labor cost: indirect labor.

Why Do We Do Things This Way? Because We Always Have.

Does art imitate life or does life imitate art?

Is product production a result of our organizational structure, or is our organizational structure a result of the needs of product production?

It seems we have hierarchical, pyramid shaped organizational structures because they are rooted in the past, not because they are necessarily best. They certainly cost more than alternatives. If the traditional structure is not the closest to perfection, what alternative is?

Plato believed we are born out of perfection and true reality—the World of Ideas. As we begin our human existence, all we have is a quickly fading memory of that perfection. It's as if we're tied up in a cave, watching only shadows flit about on the wall in front of us, projected from the World of Ideas. The shadows. We mistake the shadows for reality. They ultimately become our reality.

Aristotle, Plato's student, believed we start with a *tabula rasa,* a blank slate. What we think and perceive become impressed on that slate (our mind) and we are quickly corrupted by the reality of our surroundings. Pick your philosopher.

So, many things have changed in our technological world. One thing that hasn't changed is how we organize the personnel in high tech production operations. Our production *reality* is formed by centuries of doing things a certain way. Breaking this organizational paradigm is a daunting challenge.

The Greek theater was therapeutic for the people (polis). It permitted all the bad human impulses to be cathartically dealt with, and reinforced noble, virtuous behavior. Do we have a comparable, lesson-teaching method today? Most of the entertainment I see today has things blowing up or people rolling around together—art, I guess.

In Plato's world, juries were formed with an average of 501 members to ensure justice. Why? Because it is difficult to bribe that many people when conspiring to rig a jury verdict. Back then, if the Greek laurel wreath didn't fit, you must acquit.

However, pure democracy could often result in mob rule, so in Plato's mind the people should find a wise philosopher-king to rule absolutely. This person would be given total control and the people must comply. Ideally, infants would be taken away from their families and raised by the government in camps. This was the way to ensue equality—no one getting a head start because they came from a wealthy family.

In fact, it was the mistrust of the people that caused the founders not to elect the president by popular vote, but have an electoral college establish who would be President.

Political campaigns have always been savage. The election of 1800 resulted in an electoral tie between Aaron Burr and Thomas Jefferson and was filled with intrigue. Each of the 16 states had one vote as the election, according to the Federal Constitution, was to be decided by the states voting in House of Representatives. This would determine the third President of the United States. It took 36 separate votes of the 16 states to decide in Jefferson's favor.

Even though political campaigns could be brutal, one's honor meant something. In those days, having one's honor challenged would sometimes result in a dual—witness Alexander Hamilton and Aaron Burr in 1804 that resulted in Hamilton's death.

It seems we don't have that push-back today. Lying for many has become a way of life. Politicians lie with conviction. It's become a prerequisite for the job—a job that the Founders never thought of as a lifetime occupation. For them, serving their country was a drudge, a sacrifice—although a necessary and honorable one. Getting back to private life was their objective.

Today, lying is only wrong if you get caught—and then, not really wrong because everybody does it and what do right and wrong mean anyway in a relativistic (not, Einstein's relativity), deterministic world? My DNA made me do it!

Win at all costs is the message. Winning is the only option. The end justifies the means. What happened to using, *It's not winning or losing it's how you play the game* as the pole star that guides us on how best to compete?

As mentioned above, Henry Ford helped establish the current organizational hierarchical model through the practice of assembly line specialization. Our educational system reinforced the model by offering majors in engineering, economics, political science, anthropology, history, etc. based on the current state of thinking for each discipline. However, the laws of physics don't change. Our understanding of them changes, from believing the earth is at the center of the universe to Newton's laws of motion to Einstein's theory of relativity.

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As mentioned last month, academia has been able to adjust their educational offering to our changing *understanding* of the general laws. What they haven't done very well is adjust to the constantly changing practical application of these laws in product production—what we call Industrial Engineering.

Professors try to interpret the real world's needs and adjust, but those without practical experience continue to fail in the *learning for earning* part[5]. They are always playing catch up.

Sometimes we may have noble strategic objectives, but fail to develop or carry out a tactical plan to meet those objectives—the words are easy. Academia always has good intentions for industry, but seldom achieve good results. An academic institution has an objective of giving their students a firm understanding of the classical subjects. Part of the tactical plan that schools use to achieve this objective in technical subjects is to confront students with closed-form problems. Students that can demonstrate success in solving these problems are thought to have grasped an understanding of the underlying subject matter.

“In the real world, critical thinking is an invaluable tool to solve the open-form problems that, more often than not, we are confronted with.”

In the real world, critical thinking is an invaluable tool to solve the open-form problems that, more often than not, we are confronted with. Even with the best intentions, the academic classroom is a difficult environment to teach this important judgment tool.

The real world has had to comply with academia, rather than demand that academia meet their needs for qualified graduates. Lofty thinking and the ability to solve non-linear differential equations, while important, are not critical to success on the production floor.

How are We Going to Pay these People?

Last month, I introduced a fictional electronic product assembly company, *Chips and Dips,* or what we affectionately call C&D[6].

For space considerations, we present only two of the organizational charts for C&D.

There are about 20 more. All of these departments, sections and groups are managed and nested into those above them until we reach the top level organizational chart where they ultimately reside in one of six directorates, hence, the term hierarchical:

1. Operations
2. Engineering
3. Business Development
4. Finance
5. Quality
6. Human Resources

Adding the total cost of this top-level chart alone results in $1.285 million in salaries (this does not include the cost of each employee's benefits [average of 40% of salaries, or $514,000] and incentives). This adds up to a general and administrative cost of about $1.8 million + of indirect cost that MUST be absorbed by the direct labor rate when we quote a job—say, to build electronic home alarm security systems for an OPD (original product developer).

Add to this the indirect labor expended by the Operations directorate, about $2 million more. This causes us to load the average direct labor rate (the average salary with benefits) of machine operators, hand assemblers, test personnel, hand soldering, etc., typically hourly employees used for the direct assembly of the product with about $3.8 million. But, that's just part of the indirect cost iceberg—there are five more directorates!

All the department managers and some entire departments in the other five directorates are indirect labor sources as well, and must be absorbed by selling direct labor. This brief discussion makes it clear why the volume of direct labor that we sell is critical. As striking as these indirect costs are, the organization's departments also create natural *silos*. This results in an employee's sense of working for operations or engineering or quality assurance first, not C&D!

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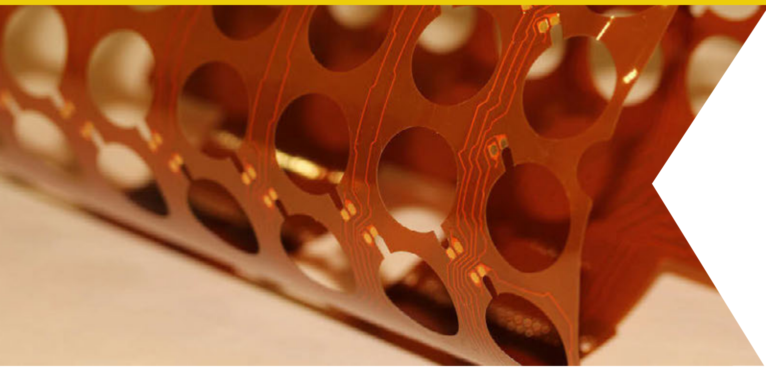

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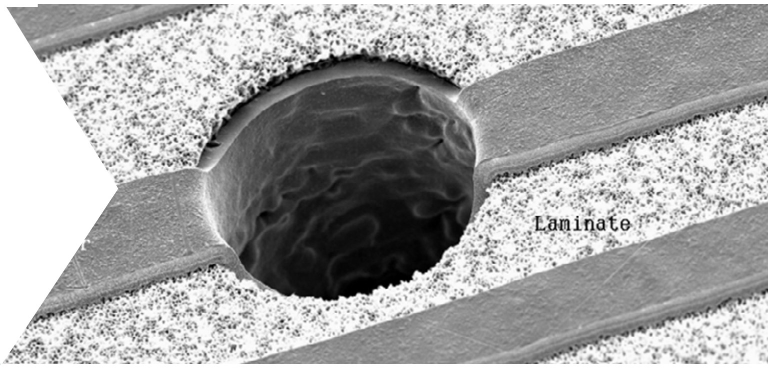

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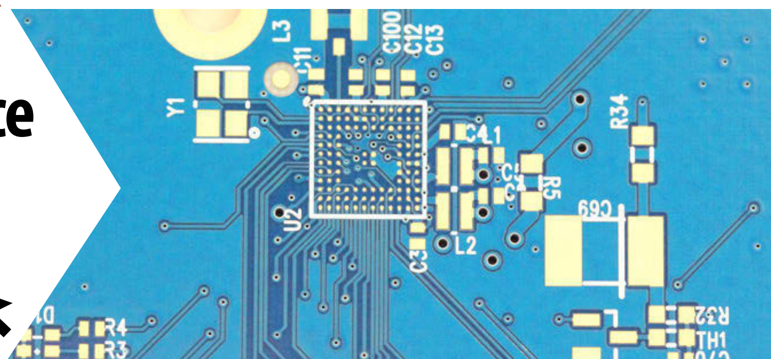

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Unless we have very strong leadership and managers who put the welfare of the company ahead of their own departments, decisions are often made in the best interest of a department, not C&D. And, let the warfare begin as the hunt for the root cause of a bad company result is fought on an organizational battlefield that pits department against department, using weapons of denial, blame and finger pointing. I've seen it many times; maybe you have as well. It's not a pretty picture.

The tentacles that tie the employees together across departments in the power pyramid are projects and/or new products. Good company leadership is essential to have personnel who reside in their department silos and are matrixed into a project *team,* work solely for the benefit of the project. The lesson here is that an organization should try to maximize direct labor and minimize indirect labor to the extent possible.

Toward that end, a hierarchical, power-pyramid organizational structure biases labor in the opposite way, creating fractionalization built upon job specialization. This model in effect creates many *towns,* each town requiring a mayor and town council. But, where towns can operate in a quasi-autonomous fashion within a county, most departments in a product production company are intimately connected and each one's performance is dependent on their neighbors.

Isn't it amazing that we hire people to create and shorten an assembly process that reduces direct labor, but often don't give the indirect labor, labor paid for by direct personnel, the same scrutiny and academic treatment—maybe that's because many in these management ranks are academics.

New Model Considerations

I hope you recognize by now that it's a bit ironic that indirect costs are only paid for with direct labor. If we reduce direct labor content through automation, we can support less indirect labor.

Maybe even more than a bit ironic and more of a way of protecting indirect labor, was keeping direct labor. So, box build assembly and other labor intensive processes were valuable. This worked, whether conscious or subconscious, until production companies in high labor rate markets were thrust into a global manufacturing marketplace. Alarmingly low labor offshore rates being available caused enormous pressure to reduce labor cost. Most companies took the easy route as they knee-jerked their production to the low labor rate sources.

Next month, we'll continue our discussion on organizational structure labor costs. Then we will introduce an alternate organizational structure—one that permits a more efficient and cost effective way to manage electronic product assembly.

Hey, what do YOU say? I'd like to hear your thoughts and experiences. **SMT**

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Tom Borkes is the founder of The Jefferson Project and the forthcoming Jefferson Institute of Technology. To reach Borkes, click here.

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Breaking Down the Long, Complex Sales Cycle in the EMS Industry

by Jake Kulp
MC ASSEMBLY

The EMS industry is still considered a young industry, with roots based in the early contract manufacturing days of small harness and PCBA shops. Some folks credit Huntsville, Alabama, as the "birthplace of EMS" when IBM began outsourcing in earnest while others have differing opinions of when this industry really took root. The intent of this article is not to argue the anthology of the industry but since its birth around 30 or so years ago, discuss how the demand creation process has morphed into what we might consider as typical today.

Even the statement "typical today" is a bit misleading as no two new business engagements follow the exact same path and timeline. So please excuse the generalizing when we "new business development" (NBD) professionals have countless examples where this is not exactly how the process flowed. Since both the OEM and EMS should have the same desired outcome, awarding or winning the outsourced available market to a company where the relationship has a good possibility of lasting for many years going forward, the elements of the process should be followed to minimize decisions that both the OEM and EMS may regret. I have broken down the sales process into both phases as well as time frames for each phase, for a better appreciation of the path these deals tend to travel.

Discovery Phase

This is an on-going phase with no end for the NBD professional. The beginning of any sales funnel must have an appropriate investment of time and all aspects of the individual's network must be utilized. Lead generation is critical for anyone making their livelihood in any sales profession; the EMS industry is no different. New prospects, or leads, can come from a wide variety of sources including: past relationships, leads from executive management's past, manufacturing representatives (MC Assembly has had positive results with this model), current happy clients, public domain information (local announcements), supplier referrals, trade shows, EMS web site inquiries, networking with channel partners, trade affiliations, and targeting specific industry leaders, to name just a few ways the EMS industry knows who to call on. The timeline on this phase of the sales process can be rather fast for opportu-






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nistic leads to many years of work for the NBD individual.

Qualification Phase

The qualification phase is one of the more difficult phases of the sales cycle for the NBD professional as they must always remember they are a business person first, a sales professional second. In this phase, MC Assembly NBD has the responsibility to uncover the possible manufacturing, technical support and business model "fit" between the OEM and the EMS company. What are the real needs of the OEM and does the OEM value the service offerings supplied by the EMS? At MC Assembly, this phase determines if we will invest the company's time and resources in trying to complete a successful sales cycle. Additional considerations usually addressed at this stage should include questions such as financial viability, the outsourcing strategy employed by the OEM, and timeframes needed to invest in the outcome, as just a few examples. This is the time to decide if the EMS and OEM pursuit of each other is really in both parties' best interests and that answer can only be uncovered if both parties engage in very honest and mature discussions of all the aspects of the potential business relationship. If either party is not convinced this is a good fit for them, it's best to professionally step out of the sales process and move on to other options. If both parties are satisfied this is worthy of the heavy investment of each other's time and resources, the EMS has to select the targeted manufacturing facility (possible facilities) they will compete for the OEMs business at. This qualification process takes between three to sixteen months in the current environment we operate in.

"What are the real needs of the OEM and does the OEM value the service offerings supplied by the EMS?"

Pursuit Phase

During this phase, major time and resource investments are usually made by both the OEM and the EMS. Requests for quotes (RFQs), formal / detailed requests for information (RFIs) disclosures, formal self-audits completed by the EMS, factory audits conducted by the OEM at the EMS targeted facility, and formal pricing and business support proposals are made with preliminary terms and conditions discussions being addressed at a high level. Key leadership from the targeted EMS site and various corporate team members of the EMS engage with the leadership and decision makers at the OEM, as well. Since we all know that people do business with people and not a company brand, this personal leadership investment should not be overlooked if long term relationships are to endure. The time involved in this phase of the decision process seems to run from three months to eighteen months, depending on the decision process the OEM is using to pare down the possible EMS companies to a manageable number for the eventual outsourcing decision.

Re-Qualification Phase

During this time, final negotiations of the OEMs terms and conditions happen and the initial group of EMS bidders have been down-selected to a small, manageable number for the OEM to make final decisions on. Best and final bids are entertained, key executive leaders are usually very involved at this stage and any final de-bugging of the cost models the EMS has deployed are finalized.

In this phase, it is critical to reconfirm all the facts and assumptions that have been discussed during the long process preceding this late stage of the sales cycle. Even though the current investments both the OEM and EMS have made in each other are substantial, there is still time to avoid bad decisions if any of the facts changed or assumptions the companies have been making turn out to be faulty and the parties determine that the business fit between the two companies is not optimal. The goal is to avoid engaging in a sub-optimal relationship and short-term partner; as this can be excessively painful and costly for both parties when this occurs.

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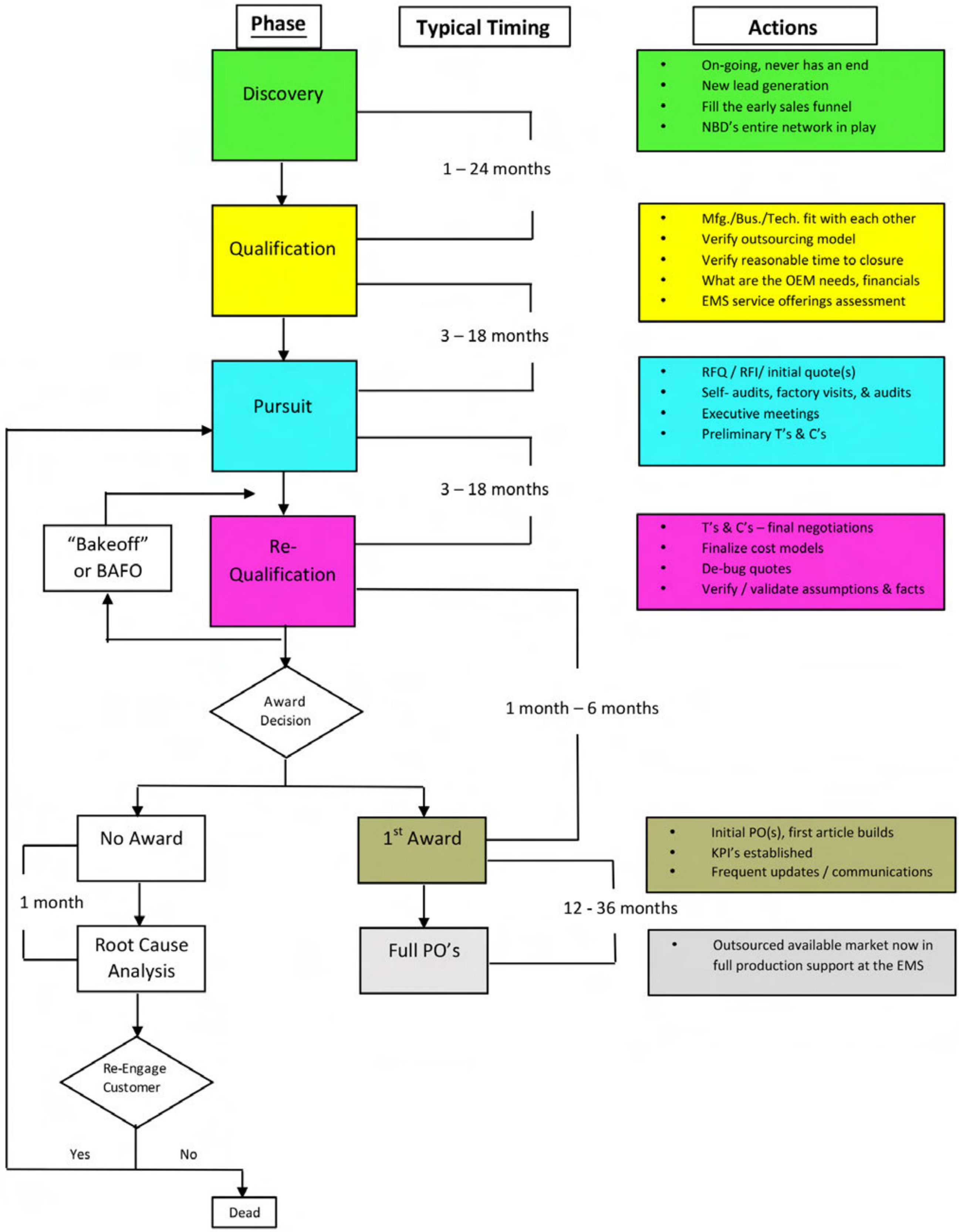

Figure 1: The sales cycle in the EMS industry.

This timeframe tends to run a little quicker than the previous phases, usually lasting one to six months. I have seen protected negotiations run much longer than necessary at times though. From my perspective, three terms that seem to be most coveted by the EMS community are the FOB point for revenue recognition, the expected payment terms and coming to an agreement on the timeframe that raw material is deemed excess or obsolete so ownership and cash exchanges can occur. I know there are many pages of additional elements always negotiated but these three, along with factors affecting the cash to cash cycle of the EMS and terms that overlook the fact that this is a build to the OEM specification, AVL and print relationship; tend to be the sticking points on protracted negotiations.

Award Phase

Once an OEM awards an EMS a job, the sales process now morphs into one of execution for the winning EMS. It remains critical for frequent, honest and open communications but now key performance indicators (KPIs), better known as metrics, are tracked and analyzed to assess the health of a sustaining relationship. From the time the initial orders are placed with the EMS to when the outsourcing is completed, the EMS community has experienced a dramatic lengthening of this phase over the years. What used to take six to 12 months to fully load the EMS with the desired outsourcing of the available products, now may take two to three years for full ramping. Nobody I talk to, in either the EMS or OEM communities, seems to be able to offer sound reasoning for this phenomenon, other than we all seem to be "doing more work, with less people."

When you start to accumulate the times the EMS NBD person spends on each opportunity brought to a close, it can easily add up to one to three years of time; and even then, there is no guarantee they will become the chosen source of supply to that OEM. Since time is one asset nobody has figured out how to recoup, it is imperative that the fit between the OEM needs and the ability of the EMS to serve those needs be vetted as completely as possible. The sooner a misalignment of those two aspects of any deal can be uncovered, the less time will be wasted by both the OEM and the EMS with each other.

Here is the summary of the entire process that completes with a win or a loss for the EMS company (Figure 1).

My final thoughts to recap the five phases of the typical EMS sales cycle are that while no two outsourcing deals have the exact footprint or timeframes, the discussion and flowchart above accurately reflect the process much of the time and the difficulty for both the OEM and the EMS to make the appropriate decisions throughout this entire process. The discovery and qualification phases are arguably the most critical as the fit between the OEM and the EMS determines not if an award is made; rather if an award occurs, how probable it is that the relationship will endure. No EMS wants to frequently churn new clients and no OEM wants the risk and cost to once again move their electronics manufacturing. The pursuit phase is really where the sales side of new business development is deployed. It is usually characterized as being the most expensive phase as far as EMS resource utilization goes. In the final re-qualification and award phases, deals that are a good fit are won or lost. Years of investment by both the EMS and OEM can be lost, so the art of closing the sale can't be overstressed. SMT

"No EMS wants to frequently churn new clients and no OEM wants the risk and cost to once again move their electronics manufacturing."

Jake Kulp is VP, New Business Development, at MC Assembly.

Got Whiskers?

by Keith M. Sellers
NTS-BALTIMORE

The tin whisker phenomenon is an issue that has plagued the electronics industry for many years now; however, with even more sectors of the industry now looking to shift or go lead-free—eliminating or limiting lead—in their processes and products, focus on this potentially devastating issue appears to be on the rise once again. A topic that was a huge concern within the industry a decade or so ago, appeared to have waned in recent years, only to be re-establishing itself again from where I sit in the independent test laboratory world.

The phenomenon itself has been studied by many for years now and the question—why do whiskers form—has many answers and theories. In this column, I'm not focusing on the hows and whys of whisker formation, which can be an exhaustive discussion, but more so the testing side of things—more specifically, the testing that has been established to test your mitigation strategy or strategies. To that point, there is no single, perfect strategy for preventing tin whisker formation—other than putting lead in it, which kind of defeats the purpose I suppose—so don't assume that one strategy fixes everything. For background, mitigation practices include all sorts of strategies, from heat treatments/annealing to conformal coatings/potting to matte versus bright tin finishes to many others.

As you may already know or have heard about, trying to control, influence, or predict the growth of tin whiskers is difficult to accomplish. With that, testing of your mitigation practices is critical and prudent for those truly doing their due diligence in the development of a reliable product. Various passages on tin whisker mitigation strategies can be found in industry magazines, scholarly journals, reference books, etc., so be sure to do a little research before you get too deep. As discussed in my October 2016 column, experience is everywhere and you can learn a lot of dos and don'ts by just doing a little homework.

An easy place to start when it comes to the testing of whichever mitigation strategy or strategies that you've implemented is a group of documents that are well-established in the tin whisker testing world. Specifically, the Joint Electron Device Engineering Council (JEDEC) has established two test standards that are very commonly used for tin whisker testing or are

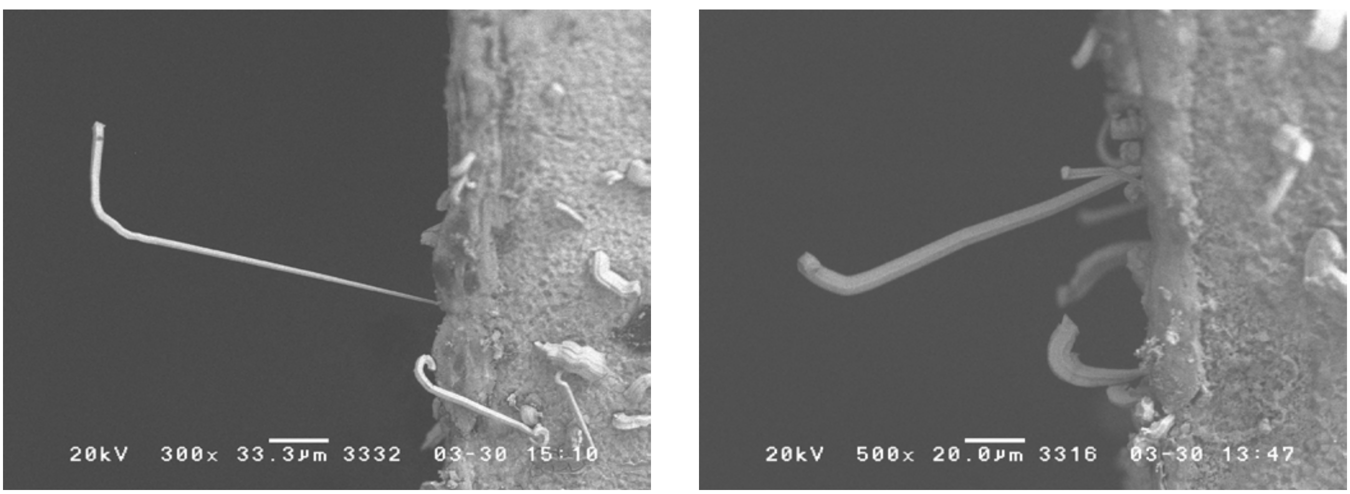

Figure 1: Trying to control, influence, or predict the growth of tin whiskers is difficult to accomplish.

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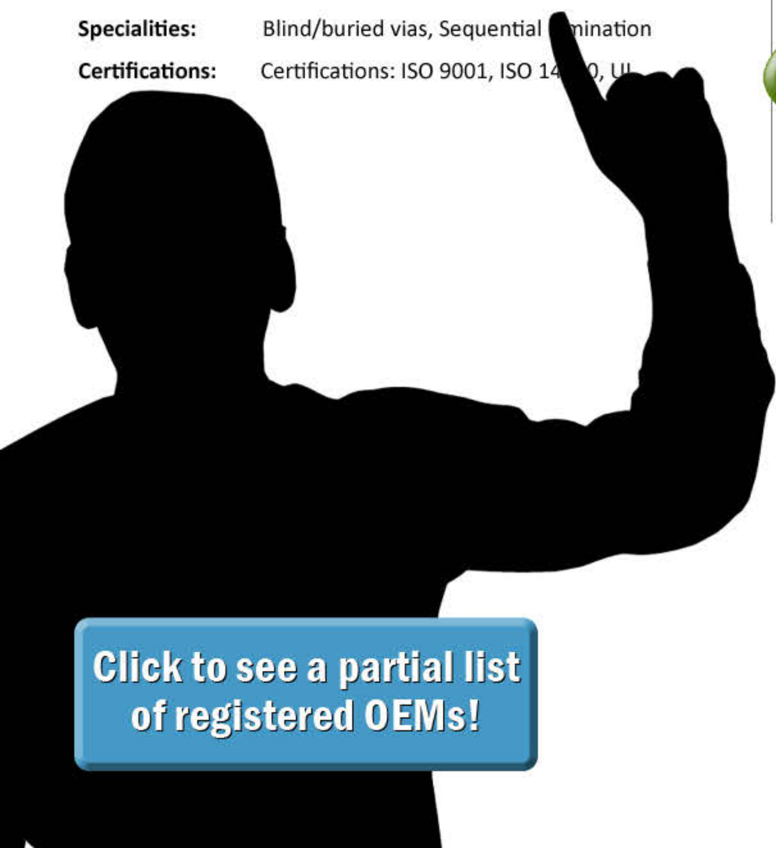

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used as a basis for the establishment/development of your own tin whisker test. For reference, these documents are:

- JESD201A—Environmental Acceptance Requirements for Tin Whisker Susceptibility of Tin and Tin Alloy Surface Finishes[1]
- JESD22-A121A—Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes[2]

Within these standards, the testing protocols call out three different environmental exposures: high temperature/humidity storage, low temperature/humidity storage, and thermal cycling.

Given the nature of tin whisker formation, which is slow and incremental, the testing typically performed is long, relatively speaking, to other common environmental exposure tests. For example, a common duration for the storage tests is 4,000 hours, which is almost 24 weeks, and 1,500 cycles for the thermal cycling test. Additionally, the specific test conditions—temperatures and humidity levels—can vary dependent on the exact test method being followed.

Supplementing the environmental exposure tests themselves, visual examination is a critical part of the evaluation process. Stereomicroscopes and scanning electron microscopes (SEM) are common tools of the trade for this type of inspection, as whisker formations can easily range from the micron level up to millimeters.

Of interest, in addition to the JEDEC documents, other groups have provided information on the whisker phenomenon, most notably iNEMI[3]. Also, others have developed additional test methodologies. The automotive and commercial electronics industries have had interest in the topic of tin whiskers for many years now as the RoHS directive's ban on lead forced manufacturers to make the change to Pb-free materials, most notably solder as it pertains to the printed circuit assembly sector of the industry. Currently, the more traditional high reliability sectors of the industry—aerospace, medical, military…to name a few—are beginning to make some transitions for various reasons. Supply chain issues are a key factor in this more recent shift as component level manufacturers scale back their Pb-containing operations.

Ultimately, as with any process change for whatever the reason might be, a solid test protocol is crucial to ensuring that your product can meet your customer's expected level of reliability. **SMT**

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2. JEDEC, JESD22-A121A
3. www.inemi.org

Keith M. Sellers is operations manager with NTS in Baltimore, Maryland.

Meeting Current and Future Requirements of the Automotive Industry

While at electronica in Munich recently, I-Connect007 Technical Editor Pete Starkey spent time in Electrolube's booth with Phil Kinner, technical director of the company's Coatings Division. As the resident expert on conformal coatings, Kinner explained the role of conformal coatings in various applications of the automotive industry. They discussed some of the things that the automotive industry is demanding from the solutions people in terms of the right conformal coatings for the right applications, and how Electrolube is helping customers to address those applications.

Kinner also elaborated on the condensation testing work that Electrolube is doing with the National Physical Lab, which he said he hope could lead to a standardized test that everyone on the supply chain should use.

Read the interview here.

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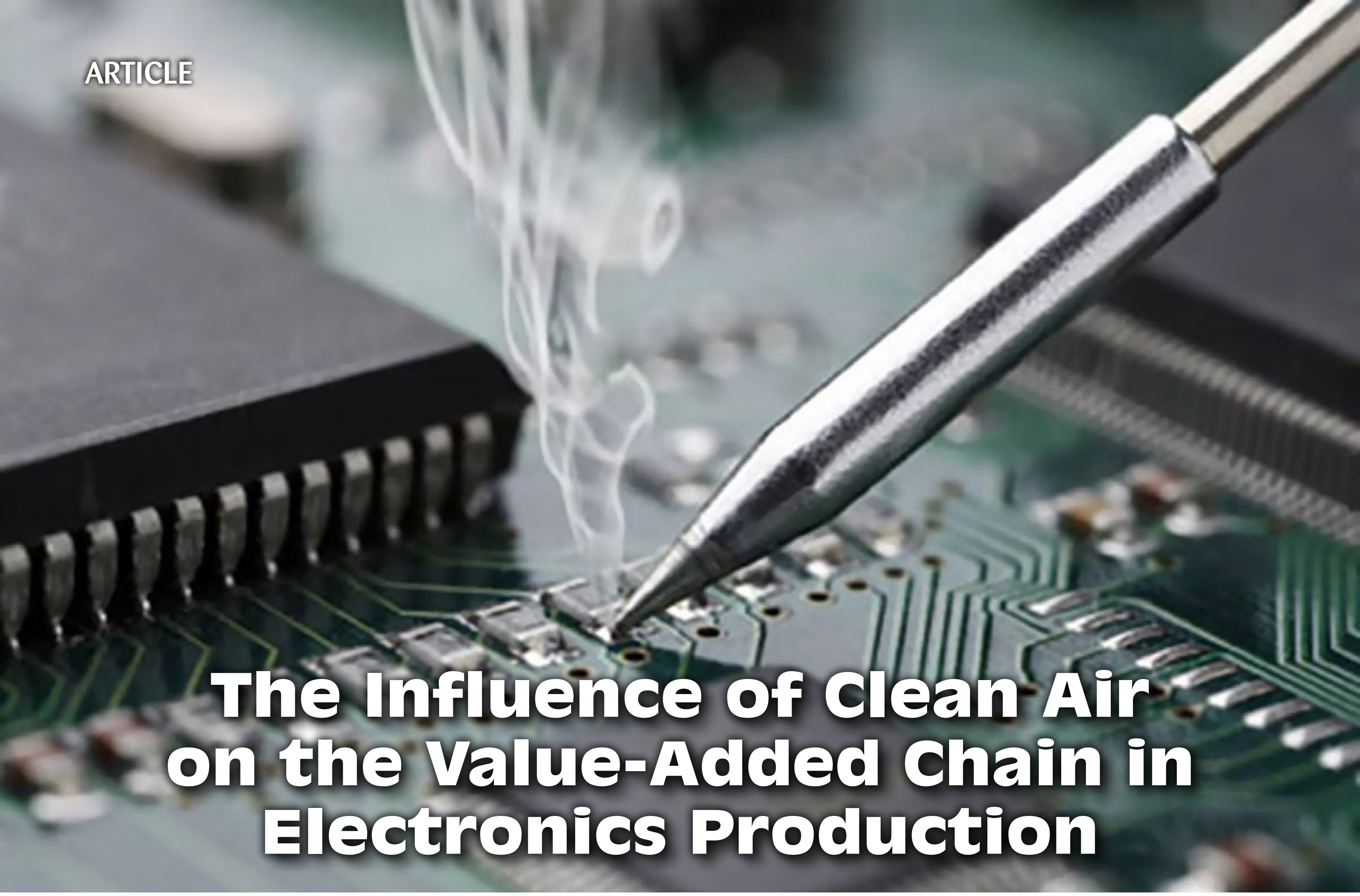

The Influence of Clean Air on the Value-Added Chain in Electronics Production

By Stefan Meissner
ULT AG

The Value-Added Chain—What Is It?

"The idea of the value chain is based on the process view of organizations, the idea of seeing a manufacturing (or service) organization as a system, made up of subsystems each with inputs, transformation processes and outputs."[1] The definition of a value-added chain by Michael E. Porter is one of many that can be found in reference books, works and on websites. In principle, it involves a sequence of activities, executed by a manufacturing company to develop, produce, sell, ship and maintain products or services.

Three main parameters essentially influence a value-added chain:

- Direct activities: research, development, production, shipment, etc.
- Indirect activities: maintenance, operation, occupational safety, environment, etc.
- Quality assurance: monitoring, test/inspection; quality management, etc.

In particular, indirect activities and quality assurance generate a greater part of the costs in product manufacturing. This article principally focuses on the indirect activities.

The indirect activities within a value-added chain comprises of three subdivisions:

- Maintenance: production resources and rooms as well as the entirety of all systems and plants
- Product quality: precision of manufacture, accuracy, functionality and cleanliness
- Occupational safety: work clothing, ESD protection, injury potential and clean air

All three issues have one common factor: They depend on clean air in the production rooms. How is this the case?

In modern electronics production, there is a multitude of different processes: from connection and separation technologies, surface processing such as marking, drilling, sintering and milling, the utilisation of fluxes, up to production processes such as 3D printing or rapid prototyping by means of laser, soldering, welding

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and gluing; all these processes generate harmful substances that might have extreme health impacts.

The Impacts of Airborne Contaminants

Briefly, all airborne pollutants have negative effects on employee health but also on production plants and products.

In principle, airborne pollutants are classified due to particle sizes. This classification primarily focuses on the influence of emissions on the human body. In addition to the possibilities of brain damages, neurotoxic effects or airway injuries, they are differentiated in terms of being inhaling (E fraction) or alveolar (A fraction).

The capture of contaminants is regulated by law in various countries. These regulations determine categories of danger for specific hazardous substances, e.g., in terms of fire and explosion risks, or in types of health damaging effects (cancerogenic, mutagenic or toxic for reproduction).

Airborne contaminants may additionally have negative impact on production systems and products. Depending on technology (laser, soldering, welding, etc.), they consist of various inorganic and organic substances, which might have partly dramatic effects based on chemical reactions.

Soldering fume, for instance, mainly consists of fluxes, soldering material and detergent residues, which often join up to adhesive aerosols. They also compromise machinery and products—and finally product quality—as they create firmly attached dirt layers.

Contamination of electronic assemblies with tacky dusts may lead to conductor track corrosion, which can lead to partly or complete functional failure. Product quality suffers from the impact of hazardous emissions in the long term.

Extraction and Filtration Technology and its Support

The early removal of airborne pollutants prevents their impact. Extraction and filtration systems provide an effective solution. The variety of systems on the market is high.

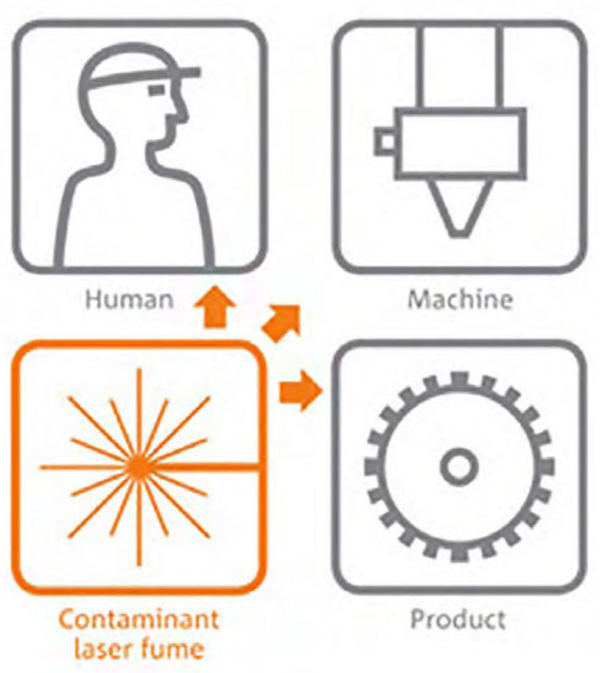

Figure 1: The threefold damaging effect of laser fume on humans, machines and products.

Figure 2: Mobile extraction and filtration system for larger amounts of soldering fume, the LRA 1200 from ULT.

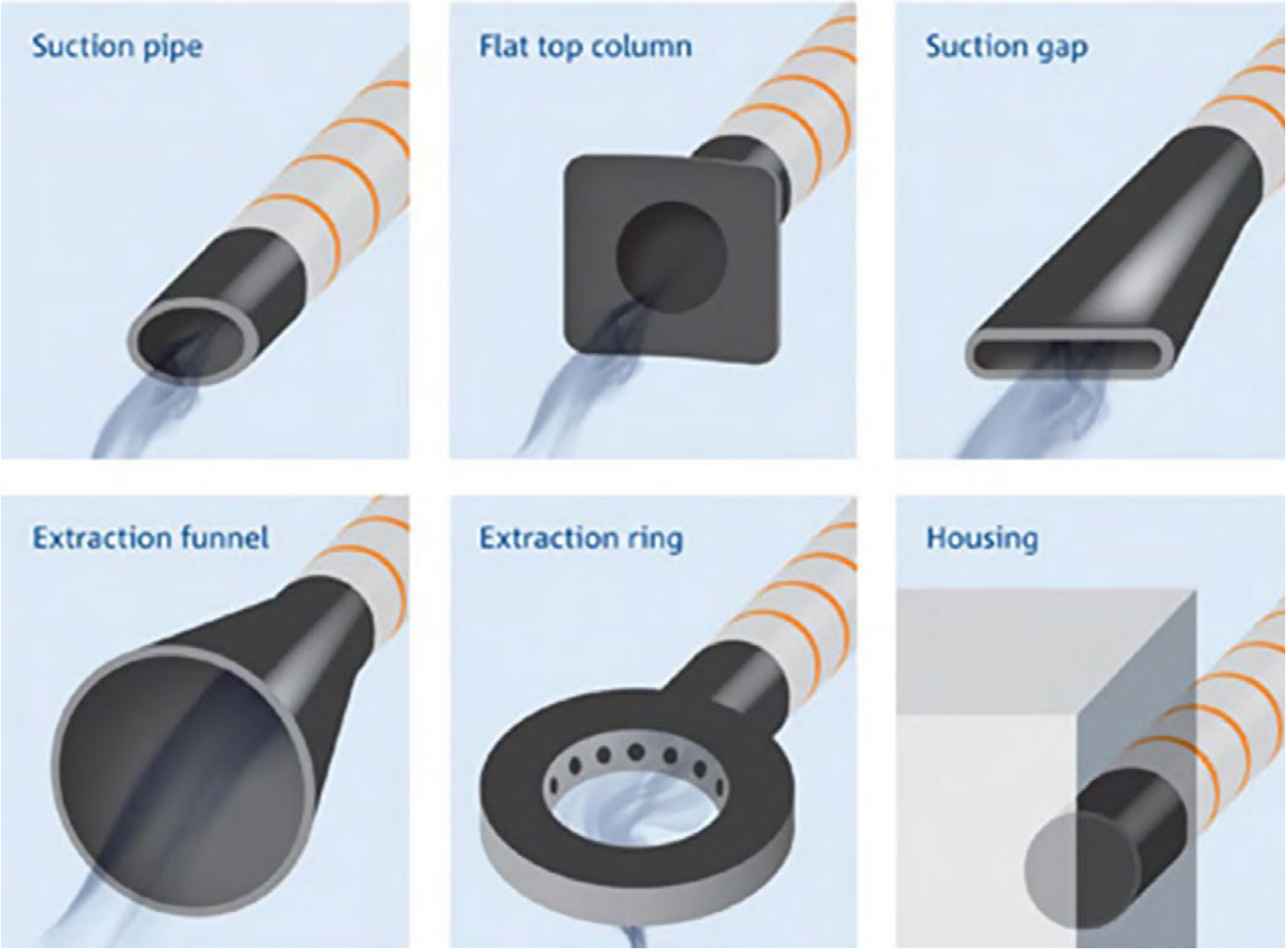

Figure 3: Selection of capturing elements.

Extraction and filtration units are determined by type, composition and amount of pollutants; system utilisation in automated, semi-automated and manual production as well as mobility or flexibility.

Modern extraction and filtration systems clean process air to such a high degree that the purified air can be moved back to the working area. This is based upon innovative filtration concepts, which can additionally be configured to special requirements.

The capturing of airborne pollutants is another decisive aspect in air purification. Closest proximity to the source of pollution is of critical importance—the closer, the better. Not only to capture the majority of all particles but to minimise economic efforts.

A general rule says that twice the distance between emission source and capturing element requires four times the exhaust performance in the extraction and filter system. Capturing elements are nozzles mounted on extraction arms. They guarantee the ideal capturing of airborne contaminants.

Due to pollution amount and type as well as airflow principles, they are available in various versions—up to complete housing solutions.

Basically, the appropriate capturing element can deliver a substantial contribution to the quality of the extraction and filtration device. The degree of capture rate forms the basis for subsequent high-grade filtration, finally providing high overall efficiency and low residue in the returned clean air.

Figure 4: Soldering fume extraction at manual workplace—utilization of a suction pipe mounted on an extraction arm.

The Value-Added Chain and its Dependence on Clean Air

Analysis of possible impacts of airborne pollutants on indirect activities within the value-added chain shows that all three subdivisions are concerned.

- Production resources and rooms must not be polluted
- Product quality and cleanliness must be guaranteed under all circumstances—restricted functionality is intolerable
- Employee protection is of highest importance—regulatory bodies determine the demands to be achieved

Extraction and filtration in electronics production goes far beyond the vacuum cleaner principle. It is not just a case of dirt removal but to eliminate hazardous substances in the air that may have negative impacts on humans, machines and products, and consequently on the entire value-added chain. **SMT**

Reference

1. Porter, Michael Eugene, Competitive Advantage, Free Press, New York 1985.

Stefan Meissner is the head of corporate communication at ULT AG.

Millennials in Manufacturing 101: How to Get Millennials to Join Your Electronics Manufacturing Company

Step 8: Integrate a gamepad in your equipment for control and monitoring.

To know more about the challenges of dealing with millennials in manufacturing, and, of course, the unique advantages that they bring to the table, read Davina McDonnell's column Millennials in Manufacturing.

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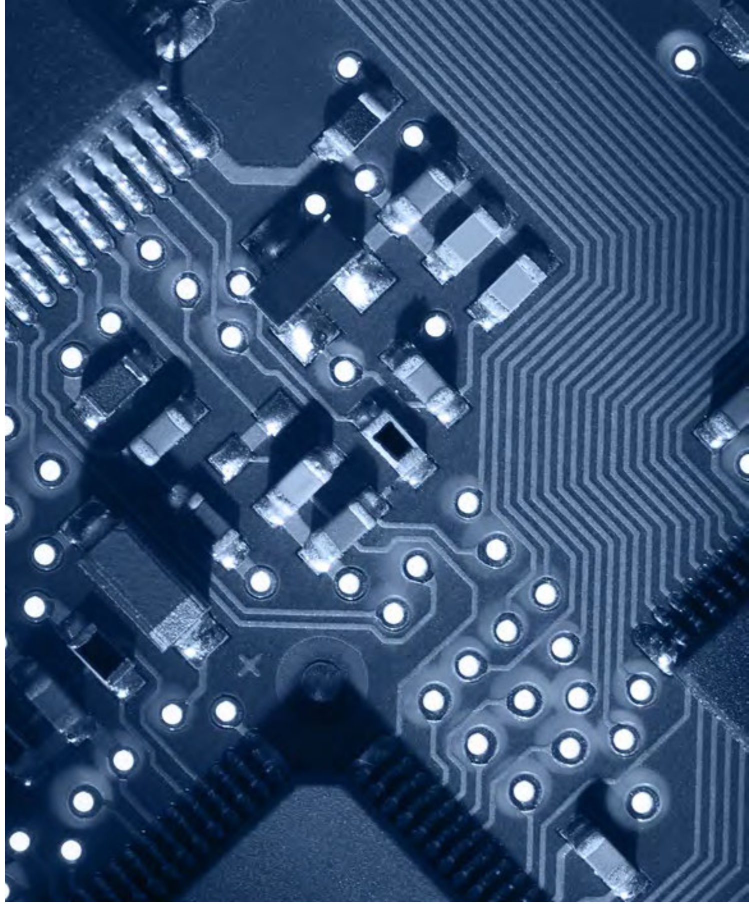
ARTICLE

Choosing the Correct Flux — Advantages/ Disadvantages



by Eddie Groves,
SELECTIVE SOLDERING ACADEMY,
and Jonathan Wol,
PILLARHOUSE USA INC.

While often overlooked, the flux chosen for the selective soldering process has a great impact on solder joint quality, long term reliability and overall selective soldering performance. This article outlines the critical factors of commonly available selective soldering fluxes and how they impact the soldering quality, reliability and equipment performance.

Fluxes essentially fall into three basic categories or flux types:

- Low-solids/no-clean fluxes
- Rosin fluxes (full/high-solids rosins)
- Water soluble fluxes

When discussing fluxes for the selective soldering process, we are generally referring to low-solids/no-clean fluxes, and it is the most commonly used flux type in selective soldering.

If a company is using a full rosin or water soluble flux in their selective soldering process, they are usually mandated to use them by their customer, or industry, and are usually producing a legacy product with a legacy reliability standard. From a flux performance standpoint, both of these flux types solder very well, and there is little to evaluate. But most companies using selective soldering avoid them because of the need to install expensive cleaning processes as well. After all, one of the benefits of selective soldering is the ability to selectively flux so that cleaning can be eliminated.

NOTE: If you are required to use a rosin or water soluble flux in your selective soldering process, then you should consult with your equipment manufacturer to make certain you have the appropriate options or materials for handling these types of fluxes.

Low-solids/no-clean fluxes breakdown into a few other categories:

- Alcohol-based, rosin or resin containing
- Alcohol-based, rosin or resin free
- Water-based, rosin or resin free (VOC-free); rare occasions will contain rosin or resin

In this category, there are a variety of manufacturers and many more flux choices. So how do you decide? Even if your customers, corporate management, or your available manufacturing processes dictate the flux you use, it is

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important to understand if the flux you are using is a help or hindrance to your selective soldering process.

Low-solids/no-clean fluxes in general, have less active chemistry and are more challenging to solder with than rosin or water soluble. Some fluxes are made to overcome particular issues—issues you may not have; while others may be weak in an area that is an issue for you. Frequently the type of products you manufacture can impact the flux that is best for your process. Or, simply the variety of products you manufacture can influence your choice of flux—and it may even require using different fluxes for different products.

One issue is that many of the available fluxes being used in selective soldering were originally intended for wave soldering. Regardless of the product or application, the wave soldering process was relatively the same across the industry and easier to adapt for these different fluxes. Only recently have flux manufacturers started producing fluxes specifically for selective soldering, recognizing that it is a distinctly different process than wave soldering.

However, among these various flux options, the rosin/resin containing, alcohol-based, low-solids/no-clean fluxes are usually the best option for the selective soldering process. They work well across various surface finishes, have a relatively wide process window, handle a wider range of time at high temperature, work with leaded and lead-free solders, and burn-off well, generally leaving safer residues.†

Understanding the Flux Types

There are three key attributes for a flux that determine the flux categories. These attributes also govern whether you need to clean your boards after soldering. However, the level of acceptability is not necessarily universal and depends on the requirements of the product.

- Activity
- Solids content
- Material type

With that in mind the three basic flux types can be simply distinguished in this way:

- Low-solids/no-clean fluxes (2-8% solids content)
  - Solvent based – with or without rosin/resin
  - Water based (VOC-free) – no rosin/resin (rare exceptions)
  - Low to medium activity
  - "Short life" (in process)
  - May or may not require cleaning
- Rosin fluxes
  - Full/high-solids rosins with 15-45%
  - Solvent based
  - Can be low activity, but normally medium to high activity
  - "Long life" (in process)
  - Typically, always cleaned
- Water soluble fluxes
  - Generally, high solids (11-35%)
  - Solvent based (occasionally water-based)
  - Always highly active
  - Very "long life" (in process)
  - Always cleaned

Activity and solids content are usually the two key attributes that determine whether the product will require cleaning of the flux residues after soldering. And from a material type and solids content perspective the fluxes break-down further, as shown in the tree diagram below.

The table below breaks down fluxes as having a high solids content or low solids content, whether it contains rosin or not, and whether it is water based or alcohol based (solvent based). You will also notice four-character designator starting with RO, RE, OR, etc. The IPC instituted this designator system to more clearly classify, or identify, the activity of fluxes as low, medium or high, based on tests outlined in IPC-J-STD-004. All flux manufacturers perform these tests and identify each flux with the appropriate designator. How the designator applies is illustrated in the table below.

Flux manufacturers include this designator on the technical datasheet for every (recent) flux. However, fluxes are rarely referred to by these designators alone. Most fluxes are still referred to as Low-solids/no-clean, rosin and water soluble fluxes. The designators alone do not tell you exactly what type of flux you are dealing with. For example, ROL1 could either be full

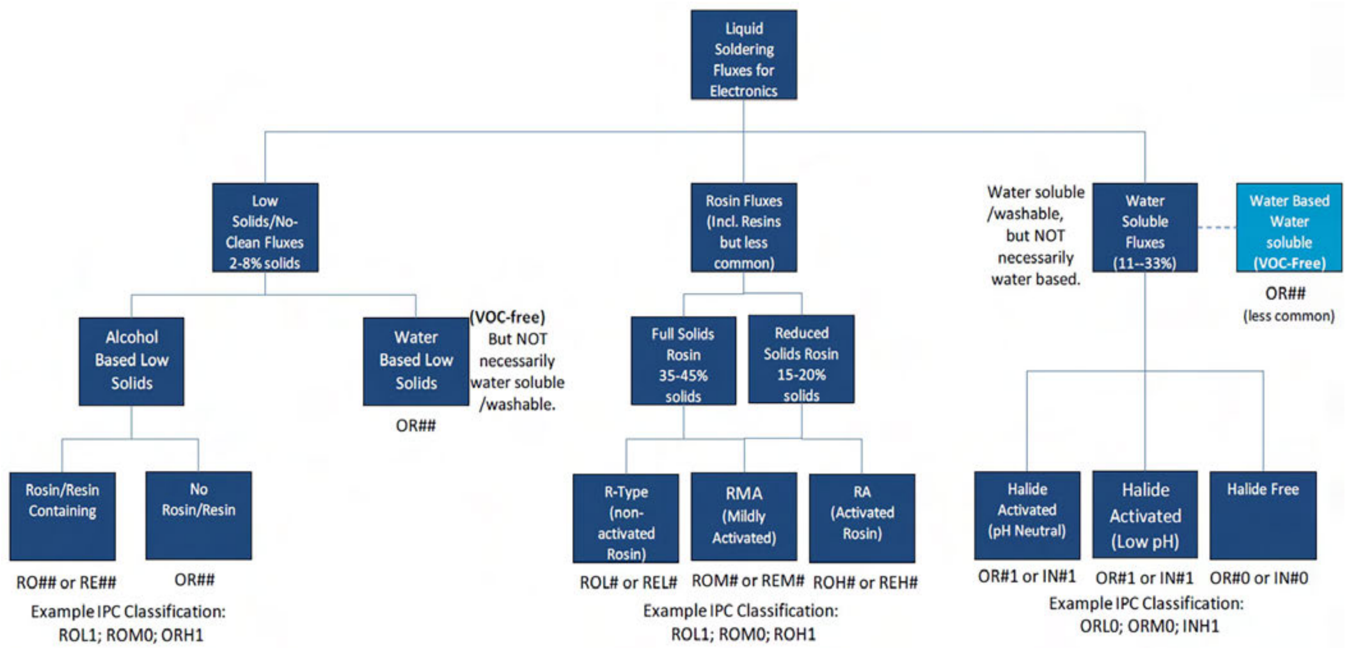

Figure 1: Liquid flux and classification.

Flux Composition	Partial Designator	Flux/Residue Activity	Partial Designator	Complete Designator	
				Containing Halides	No Halides
Rosin	RO	Low	ROL	ROL1	ROL0
		Moderate	ROM	ROM1	ROM0
		High	ROH	ROH1	ROH0
Resin	RE	Low	REL	REL1	REL0
		Moderate	REM	REM1	REM0
		High	REH	REH1	REH0
Organic	OR	Low	ORL	ORL1	ORL0
		Moderate	ORM	ORM1	ORM0
		High	ORH	ORH1	ORH0
Inorganic	IN	Low	INL	INL1	INL0
		Moderate	INM	INM1	INM0
		High	INH	INH1	INH0

Table 1: Flux designation.

rosin or no-clean with some rosin. ORM0 could be an alcohol-based no-clean, a water-based no-clean (VOC-free), a standard water soluble, or a water-based water soluble.

But the information on the datasheets with the designator, the solids content and the description of the flux should provide you with good idea about what kind of flux you have. However, you may have to either consult with the manufacturer or the MSDS to determine the solvent, usually alcohol or water. If a flux contains rosin, you can be quite certain that it is an alcohol based flux, as rosin is not naturally soluble in water.

Flux Type	Flux Composition	Partial Designator	Solvent	Solids Content (most commonly)	Designator Containing Halides	Market Presence/Availability
Low-Solids/No-Clean	Rosin	RO	Alcohol	2%-8%	ROL1/0	Most Common
					ROM1/0	Rare
					~~ROH1/0~~	Never
	Resin	RE	Alcohol	2%-8%	REL1/0	Most Common
					REM1/0	Rare
					~~REH1/0~~	~~Never~~
VOC-Free Low-Solids /NC	Organic	OR	Alcohol (non VOC-Free) Water (VOC-free)	1.5%-6%	ORL1/0	Most Common
					ORM1/0	Occasionally
					~~ORH1/0~~	Uncommon

Table 2: Low-solids/no-clean fluxes correlated to IPC designators.

Since low-solids/no-clean fluxes are the more common flux used in selective soldering, we have correlated them to the IPC designators in the below table.

The point of the designator system, is so that a user can make a more informed decision about the activity and suitability of their flux and understand whether post soldering cleaning is required (or at least investigated). Full rosins and water soluble fluxes both have to be cleaned after soldering because of the high amount of solids and residues, and/or because of high activity of their residues.

NOTE: It is best to consult with the manufacturer of the flux to discuss its performance and behavior. Some fluxes can have tendencies perform better, or worse, in certain aspects even though they appear virtually the same "on paper," which only the manufacturer or rep will know.

CAUTION: Be cautious, not only about water soluble fluxes, but about any flux with low pH. In a number of cases, the pH on a datasheet can be misleading, as all fluxes are designed to become more active as heat is applied. But low pH at room temperature can prove to be detrimental to equipment. Also, because of some clever chemistry, some fluxes are actually more active than they appear with IPC classification, which only the manufacturer knows. It is always best to consult the manufacturer about its characteristics prior to using an unfamiliar flux.

About the Fluxes: The Pros and Cons

One of most important aspects of flux is its activity and ability to form a good solder joint—wetting the lead, the hole and the land quickly, completely and leaving a strong solder joint. Usually the more activity, the better the soldering and the bigger/better the process window. Full-solids rosin and, particularly water soluble fluxes, are well known for excellent soldering performance, largely due to their activity and abundance of chemistry that give it great endurance throughout the soldering process.

Low-solids no-clean fluxes do not remove oxides as well, or as completely as water soluble and full rosin fluxes. And they do not have nearly the chemistry to last as long throughout the soldering process. And as such, they generally have a dramatically smaller process window.

Water Soluble Flux

Water soluble fluxes are excellent for soldering, and provide the best soldering possible. They have a great amount of activity that readily cleans the metals to be soldered, and virtually never burn off during the soldering process. However, these chemistries are generally very aggressive, corrosive, persistent and will continue to react after soldering. They are virtually always classified as ORH, or INH, and must be cleaned from soldered circuit boards thoroughly by a machine wash process, and one that has to be monitored very closely. Any remaining

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Figure 2: Water soluble corrosion.

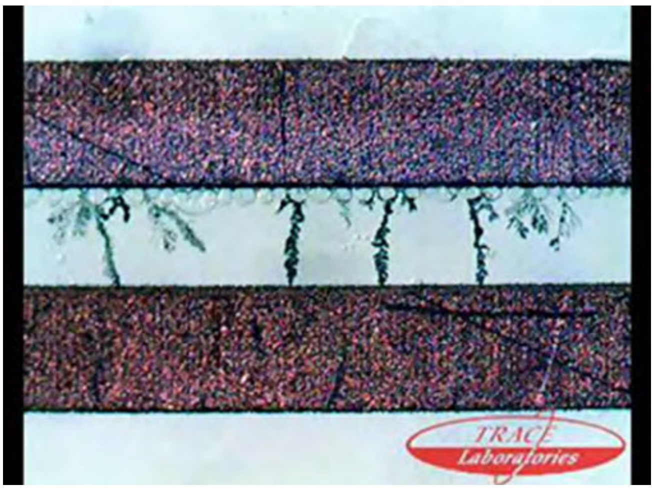


Figure 3: Dendrites. (Courtesy: Trace Labs)

ionic contamination could easily result a disastrous field failure, so the cleaning process has to be extremely thorough. Normally, boards coming out of the wash are periodically tested for ionic contamination, usually using some type of ionograph or omegameter.

The detrimental effects of corrosion can even happen in the manufacturing facility if residues are not cleaned off in a timely manner. Below is a photo of water soluble flux corrosion only after sitting for two hours. Another potential failure mode of water soluble residue contamination is dendritic growth, which is metallic, hair-like growths that can develop between and short adjacent conductor paths.

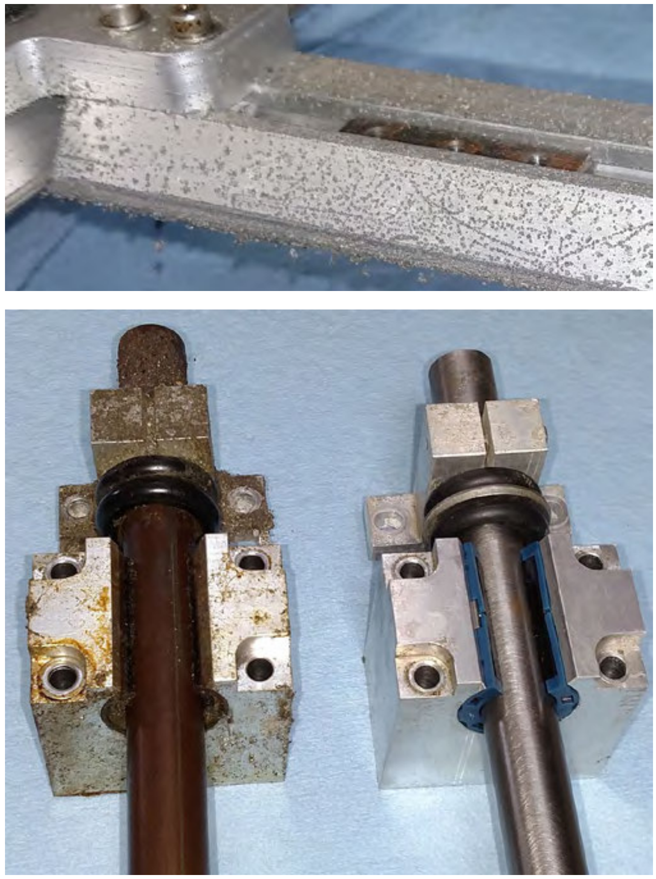


Figure 4: The aggressive chemistry of water soluble fluxes requires corrosive resistant fluxers, and attacks the equipment—which is more difficult to keep clean.

To be clear, the washing systems for water soluble fluxes have proven to be completely effective for decades, but are expensive to operate and take up valuable floor space. However, the aggressive chemistry of water soluble fluxes requires corrosive resistant fluxers, and attacks the equipment which is more difficult to keep clean.

For these reasons, many do not use, and we do not recommend using water soluble flux, whenever possible.

Rosin Flux

Full rosin fluxes also provide excellent soldering, with an equivalent ability to clean the metals to be soldered and to last throughout the process. But, they do not have the same propensity as water soluble to corrode and damage product. In fact, instead, the rosin has the

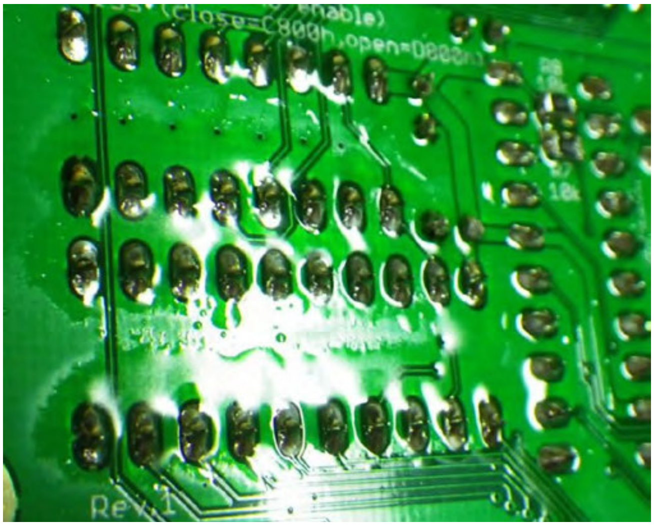


Figure 5: Flux residues after soldering.
(Source: www.lo-tech.co.uk)

benefit of acting as protective barrier during soldering and after soldering can entrap ionic residues, preventing them from being mobile and reacting in a destructive manner.

However, rosin leaves a residue on the board and can contaminate manufacturing equipment—which serves as the main motivator to cleaning this kind of flux from circuit boards, more so than the reliability issues of water soluble fluxes. Although, with the high demands of today's electronics, rosin residues can also lead to failures as well in harsh environments.

The cleaning process for rosin can also be an expensive process to operate, but also usually requires a solvent that brings its own complications. However, the benefits of rosin were enough to carry it over into low-solids/no-clean fluxes.

Low-Solids/No-Clean Fluxes

As most realize, these types of fluxes were employed so that cleaning could be eliminated. As the name implies, these fluxes have less chemistry and activity, and make soldering with the same results more challenging.

Alcohol-based, Rosin Low-Solids/ No-Clean Fluxes

Initially, low-solids/no-clean fluxes were essentially rosin-like fluxes, just less of it. Today, these fluxes are much more sophisticated. But, the principle is that with less chemistry, there will be little to no active chemistry left on the board after the soldering process thus eliminating the need to clean the board. So rather than the 35% solids in a full rosin flux, the low-solids fluxes range from 1.5–8%. With less chemistry, the issue now becomes having enough active chemistry to be an effective flux.

NOTE: Low-solids fluxes are not necessarily no-clean for everyone or every application. The same flux and residues in one application may be perfectly safe, while in another application they may be harmful. It is up to the customer, the product designers, etc., anyone who understands the demands of the end-use environment for that product, to dictate whether a low-solids flux is actually a no-clean flux for them.

Even in small amounts, rosin in effect, is used as a way to avoid simply adding active chemistry to improve performance. It is a key ingredient in many of these low-solids fluxes, as it helps protect the cleaned metal and the little chemistry in these fluxes during the soldering process. It allows the flux to withstand a longer, hotter exposure to heat than without it. With rosin in the flux, you may see slightly more residue, but the idea is again that any remaining chemistry will be contained by the rosin. Even so, some customers find any residue visibly undesirable or potentially more unsafe to leave on the board. In these cases, many end up cleaning, or are asked by their customer to clean the low-solids flux residues from the boards.

Not only are these fluxes good in long heat/preheat exposures or higher heat processes, they work well in low heat applications, or short processes, as the alcohol evaporates very quickly allowing the soldering to begin almost immediately.

Alcohol-Based, Non-Rosin, Low-Solids/ No-Clean Fluxes

To partially address this issue, most flux manufacturers offer low-solids fluxes with no rosin at all, which tends to allow the active flux to volatilize more completely during soldering and leave the least amount of residue. However, as a result, these fluxes tend to not last as long because they are not shrouded by rosin. For selective soldering this can be a problem, as time exposure to elevated or high heat can be relatively long in some cases. These fluxes can potentially be depleted by the time they are soldered in the selective soldering process. Leaving a little rosin in the flux helps combat the heat issue as well as encapsulate remaining ionic residues. For this reason, most low-solids fluxes have some small amount of rosin, or a synthetic equivalent.

These fluxes work best if you have a fairly homogeneous product type and typically run short programs, or don't require a lot of preheat—and require minimal residues. You can dial the process in to get very good results.

VOC-free, Low-Solids/No-Clean Fluxes

VOC-free low-solids fluxes are similar, in that they do not have rosin, but because they are water based they do handle more exposure to heat and can tend to be a little more active. However, the issue with fluxes can be that they are water based—they require more heat to evaporate the water, and can force you into a longer preheat cycle than you would not otherwise need, increasing your overall cycle time.

If you primarily run heavy boards and a high heat programs/processes, VOC-free may work best, as the water takes longer to evaporate and they can be a little more active.

Water Soluble Flux	
PROS:	Excellent soldering—wide process window Excellent to very good for high reliability applications—depends on cleaning process and product demands Good for high heat applications
CONS:	Requires more preheat Residues must *absolutely* be cleaned—process and floor space expensive Cleaning process must be closely monitored with ionic testing Cleaning must occur within time recommended by flux mfr. Increased machine maintenance - chemically attacks equipment Contaminates carriers, totes, other work surfaces Requires optional fluxer upgrade, and/or material upgrade Slight residues can cause field failures

Table 3.

Rosin Flux	
PROS:	Very-good to excellent soldering—wide process window Very good to excellent for high reliability applications Very good to excellent for high heat applications Long process "Life"
CONS:	Requires more preheat Residues must be cleaned—process and floor space expensive Requires more machine maintenance & can pose difficulty for downstream processes, ICT, AOI, etc. Often requires optional fluxer upgrade In some scenarios/applications residues can be reliability concern

Table 4.

Low Solids/No-Clean	
PROS:	Good to very-good soldering Less post-soldering residue-may allow for no cleaning† Can allow for lower preheat processes (vs. wave & non water based) Variety of flux choices and can work well on variety of applications Easy on equipment
Non-Rosin, Alcohol	Burn off very cleanly
VOC-free	No volatile solvent; can be more active and have longer process "Life" vs. Non-Rosin, Alcohol flux
CONS:	Less activity and smaller process window vs. Rosin or Water Soluble fluxes Can pose difficulty and have reduced process window with high heat applications Residues still may need to be cleaned by edict, or flux amount required leaves undesirable or unsafe amount of residues. Water-based (VOC-free) can require more preheat
Non-Rosin, Alcohol	Short process "life"
VOC-free	Requires more preheat, can increase cycle time unnecessarily Can not necessarily as clean as Non-Rosin, Alcohol flux

Table 5.

Pros & Cons Summary

For these reasons, low-solids/no-clean flux with some small amount of rosin, or synthetic equivalent, is usually the better choice for selective soldering. They have a wider process window and offer better success when you have a variety of products and programs that require a range of heat or time at elevated temperatures.

†Safety regarding residues is not universal across all products or applications. The allowable residues depend on the demands of the product, its end-use environment and tested according to the design requirements. **SMT**

Eddie Groves is the Director of the Selective Soldering Academy.

Jonathan Wol is the President of Pillarhouse USA Inc.

*Real Time With...*HKPCA & IPC Show 2016: IPC Hand Soldering World Championship in China

During the recent HKPCA and IPC Show 2016 in Shenzhen, China, IPC President John Mitchell speaks with Editor Stephen Las Marias about the highlights of this year's IPC Hand Soldering World Championship, which was held in China for the first time.

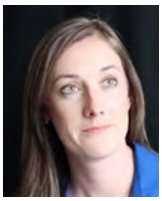
He discusses why it was held in China this year, and how IPC has managed to keep the event so popular and successful for such a long time.

Mitchell also talks about the IPC Design Competition, which is now in its fourth year.

Watch the video here.

Recent Highlights from SMT007

1 Millennials in Manufacturing: Cathy Cox – Multiple Approches to Solving Problems



Next in our Millennials series is Cathy Cox, a process engineer at Lectronics, who is in charge of all the first-time build customers, where she manages the entire assembly process figuring out the perfect assembly plan for each product, and the best schedule to deliver each customer the best product. Find out what she has to say about the challenges of the job.

2 Millennials in Manufacturing: Mike Scaparrotti – A Different, yet Rewarding Career Path

Our next millennial to be featured is Mike Scaparrotti, a purchasing agent at Lectronics. As a millennial, Mike said that majority of the younger generation do not want to be micromanaged. For him, having a valued opinion and being able to influence change when needed are what motivates him in his job.

3 An EMS with a Nimble Global Footprint Makes a Big Splash at electronica

At the recent electronica trade show in Munich, Alwyn Rea, director of business development for non-automotive products at ALL CIRCUITS, a French-based EMS company, speaks with I-Connect007's Judy Warner about his company, their capabilities, and what makes them different from their competitors.

4 SMTA Tech Expo Panel Session: It Takes a Village to Discuss Proper Cleaning Solutions

An expert in cleaning processes, Barbara Kanegsberg is known as "The Cleaning Lady." She moderated the technical session "Ask the Experts: Meeting the Challenges of Effective Cleaning, Defluxing in Southern California." Here Barbara discusses the myriad of challenges regarding cleaning PCBs (particularly in heavily regulated California) and what transpired during the open forum technical session.

5 K-One Reports 53% Drop in 3Q Revenues

For the third quarter ended 30 September 2016, Malaysia-based EMS firm K-One Technology Berhad saw its revenue declined by 53% to RM19.4 million ($4.36 million) from RM41.6 million ($9.36 million) in the previous corresponding quarter, primarily impacted by the programmed shifting away from the mobile phone accessories' business since the beginning of 2015.

6 Milwaukee Electronics Merges with San Diego PCB

EMS firm Milwaukee Electronics is merging with San Diego PCB. "San Diego PCB Inc. is a best-in-class engineering PCB layout design service. We see it as a great fit for our engineering-driven focus in the EMS market and we have chosen to refer to this transaction as a merger to better reflect the collaborative environment it is creating," said P. Michael Stoehr, Milwaukee Electronics' president and CEO.

7 IPC: Connected Factory Initiative Subcommittee's Progress on Machine Data Interface Standard

Representatives of industry's leading manufacturers, machine, device, sensor and software companies that comprise IPC's 2-17 Connected Factory Initiative Subcommittee have made significant strides in developing a machine data interface standard, "Connected Factory Exchange or CFX" that would enable manufacturers, equipment, device and software suppliers to achieve Industry 4.0 benefits.

8 NEO Tech Invests in New Capabilities and Expands Capacity at Otay Mesa Site

NEO Tech continues to invest in infrastructure, equipment, processes, and personnel at its Otay Mesa manufacturing site in Tijuana, Mexico.

9 Zollner's Karl Berger to Present at IPC APEX 2017

Zollner Electronics is pleased to announce that Karl Berger, Vice President of the Americas, has been accepted to present at IPC APEX 2017 in San Diego, California on February 13, 2017.

10 Turn Inspiration into Innovation through IPC APEX EXPO 2017 Educational Programs

The latest technical research, industry best practices, trending topics, ground-breaking technologies and forward thinking innovations will take center stage throughout the IPC APEX EXPO 2017 technical conference and professional development courses, which will take place February 11–16 at the San Diego Convention Center in San Diego, California.

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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.

Printed and Flexible Electronics China
January 11–13, 2017
Shanghai, China

46th NEPCON JAPAN
January 18–20, 2017
Tokyo Big Sight, Japan

Rocky Mountain Expo & Tech Forum
January 19, 2017
Denver, Colorado, USA

DesignCon 2017
January 31–February 2, 2017
Santa Clara, California, USA

EIPC Winter Conference
February 2–3, 2017
Salzburg, Austria

MD&M West
February 7–9, 2017
Anaheim, California, USA

IPC APEX EXPO 2017
February 14–15, 2017
San Diego, California, USA

China International PCB & Assembly Show (CPCA)
March 2017
Shanghai, China

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

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

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

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

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