Immersion Silver and Immersion Tin
IPC Plating Committee 4-14 Industry Update

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Overview

The development of two new industry specifications – IPC-4553 (immersion silver IAg) and IPC-4554 (immersion tin ISn) are well under way. Following in a tradition started with the development of the 4552 ENIG specification, it is customary for this committee to present an update in the form of a technical paper on the progress of any specification under development.

The acceptance and subsequent release of any technical specification should be based on the data generated to justify it. This committee prides itself on data generation being the backbone for any specification that it works on. This technical report outlines the data generated to date, for both immersion silver (4553) and immersion tin (4554) deposits. Some of the data is from completed tests while other data sets are ongoing.

As with the 4552 ENIG specification it is the intention of this committee to justify all parts of these two specifications currently in progress with a completed technical paper that will be attached to the document in the form of an appendix.

Introduction

The primary use of both the I Ag and I Sn deposits is solderability. As such it was felt by the committee that both specifications could be developed simultaneously and in a relatively short time period. As the specifications began to take form this initial goal of a short time to completion has gone away completely.

For ISn the specter of tin whiskers, initially reported to the industry as NOT being a problem suddenly became a problem, once Bosch Gmbh reported issues with Tin whiskers on immersion coatings kept at room temperature.

For the I Ag deposits the issues pertaining to electrolytic corrosion potentials and accurate measurements of the deposits have been the dominant issues.

While these items are opportunities for the committee to resolve, the successful format from the 4552 specification was again used to help develop these two specifications. To that end the following were identified as the key parameters for research and testing:

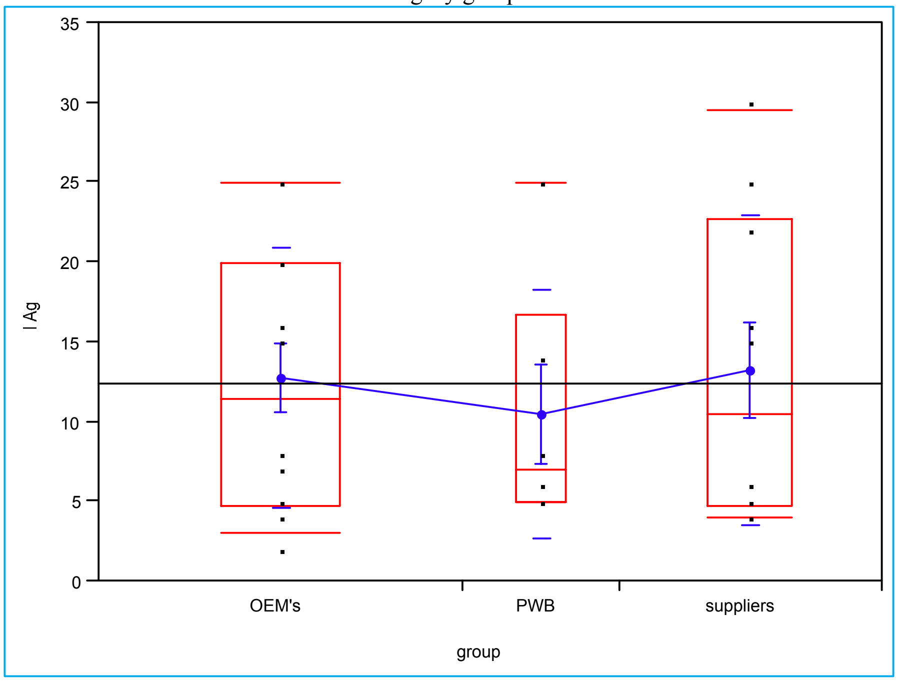
1) Perform an industry survey for deposit thickness
2) Identify the uses of the deposit – single use vs. multi-functionality
3) Define the test plan to validate solderability performance as well as multi-functionality where applicable.
4) Build and measure test coupons for deposit thickness.
5) Commence performance testing.
6) Compile data and insert into the specification.

Industry thickness survey

One of the primary goals for both these specifications is to set thickness limits based on performance characteristics. Since no specification has existed to date, it has fallen on the chemical suppliers in the majority with some PWB suppliers and OEM's in the minority to set the acceptable limits for thickness. Some of these values have good sound reasoning; others have been of 'the more there is of it the better philosophy'. Based on this it was decided to run a quick industry survey on what thickness was recommended or required.

Figures 1 and 2 show the details of the results of the survey.

I Ag By group

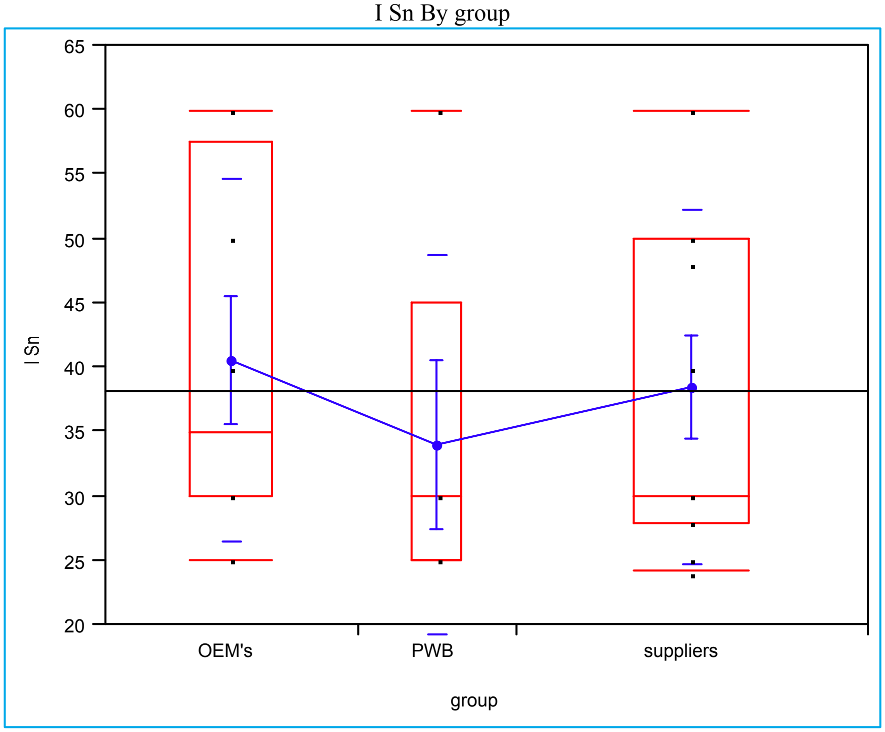


Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
OEM's	14	12.7857	8.22920	2.1993
PWB	6	10.5000	7.86766	3.2120
suppliers	10	13.2000	9.80703	3.1013

Figure 1 - Immersion Silver Industry Survey Results

I Sn By group



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
OEM's	8	40.6250	14.2522	5.0389
PWB	5	34.0000	14.7479	6.5955
suppliers	11	38.4545	13.8084	4.1634

Figure 2 - Immersion Tin Industry Survey Results

For the IAg, with a casual glance at the data, it would appear there is a consensus for thickness around 12 micro-inches; however thickness specifications are not based on casual glances from a survey! From a performance view point to the main function of a solderability preservative to the underlying copper, the answer will be forth coming from the long term solderability testing underway as well as the process capability of repeatedly reproducing the low end value of the thickness range at a statistical level in production. On the upper end value there is the question of tin silver inter-metallic compounds and their potential effect on long term solder joint reliability.

For the ISn deposit there is good agreement on the lower end of the specification with a minimum thickness of 25 micro inches, with the ideal thickness somewhere in the high 30's to 40 micro inches. With immersion tin there was clearly a logic behind a minimum thickness – retarding the mean time of copper migration to the surface and hence loss of solderability. The 25 µinches (based on real life data) would provide upwards of 6 months of shelf life, which matches the category 3 requirement in ANSI JSTD-003A. The upper limit was simply a function of attempting to ensure that all feature sizes on a board would have the minimum deposit thickness necessary to ensure this. Additional tin, while costing more and may have the potentially of the affecting solder mask adhesion to the board due to the increased dwell time in the bath, really had little to no downside.

Based on the above it was decided to test for performance and let the data speak for itself with regard to deposit thickness and solderability performance.

Single use Vs Multifunctional

For the ISn deposit this question was answered easily and rapidly – single use. Soldering surface is the primary application; however it is also suitable for compliant pin, as a mating surface for ZIF connectors and other simple applications.

For the IAg some members believed that the surface has the potential to function as a switch surface for soft contact membrane switch applications such as cell phones. Wire bonding was also cited as another potential use for the surface finish as well as EMI shielding interconnections to the chassis of an electronic module – these other potential uses would give the IAg deposit multifunctionality and would require additional testing.

Test Matrix

Thickness Measurement

Before we get to the actual testing of the solderability of the deposits in question, the potentially larger and more costly subject of measurement capability of the deposits were raised. It has been the experience of the authors to have parts fail solderability testing, especially if the deposit is stressed by heat or moisture due to insufficient thickness being applied inadvertently due to poor measurement capability. Apart from a performance issue how does one specify a deposit thickness if accuracy and repeatability of thickness measurement is not there?

Accurate and repeatable measurements of thin metallic deposit such as IAg and ISn were a big challenge that this group faced. The most accurate method for thickness measurement is XRF. However, when it comes to I Ag and I Sn deposits the challenge is tough and expensive with the potential of making a lot of older XRF units obsolete. As can be seen from the attached figures it has been the experience of this group that what is actually applied (thickness of the deposit) is not what the person applying the deposit thought he was applying! Once the panels were returned from the chemical suppliers and coded, the first task was to measure accurately what deposit thickness was going to be tested for potentially the next year or so. At this point the committee would like to again thank the scientists at ThermoNoran for the use of a solid state XRF – a reference unit costing in excess of $500,000. The results of measuring the deposits are found in Figures 3 & 4.

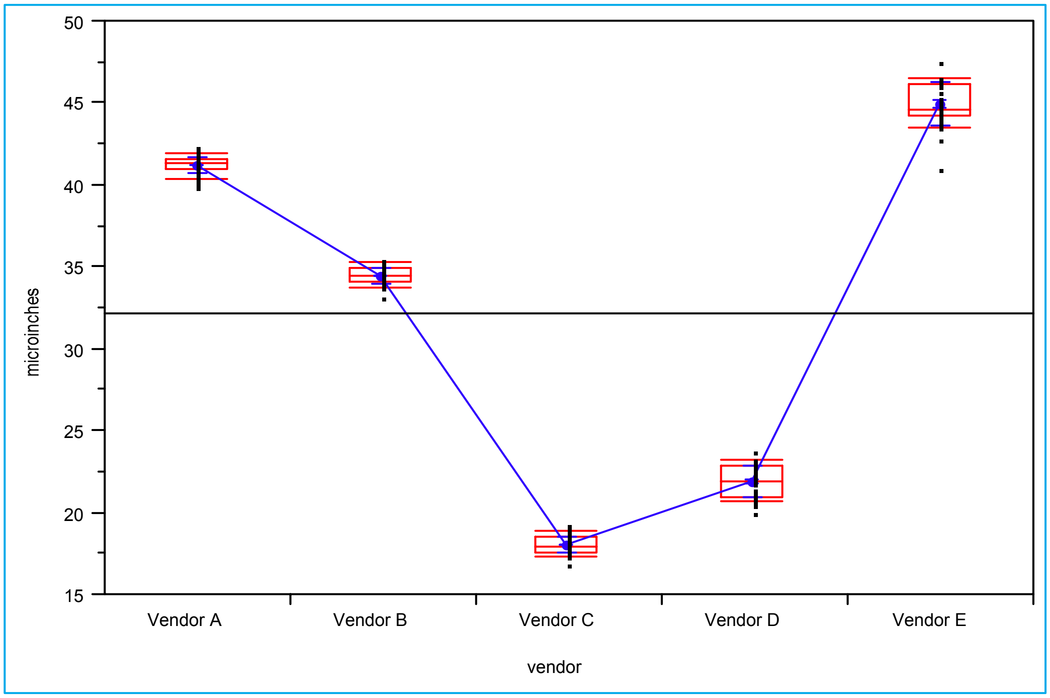


Figure 3 - Immersion Tin supplied for Wetting Balance Testing

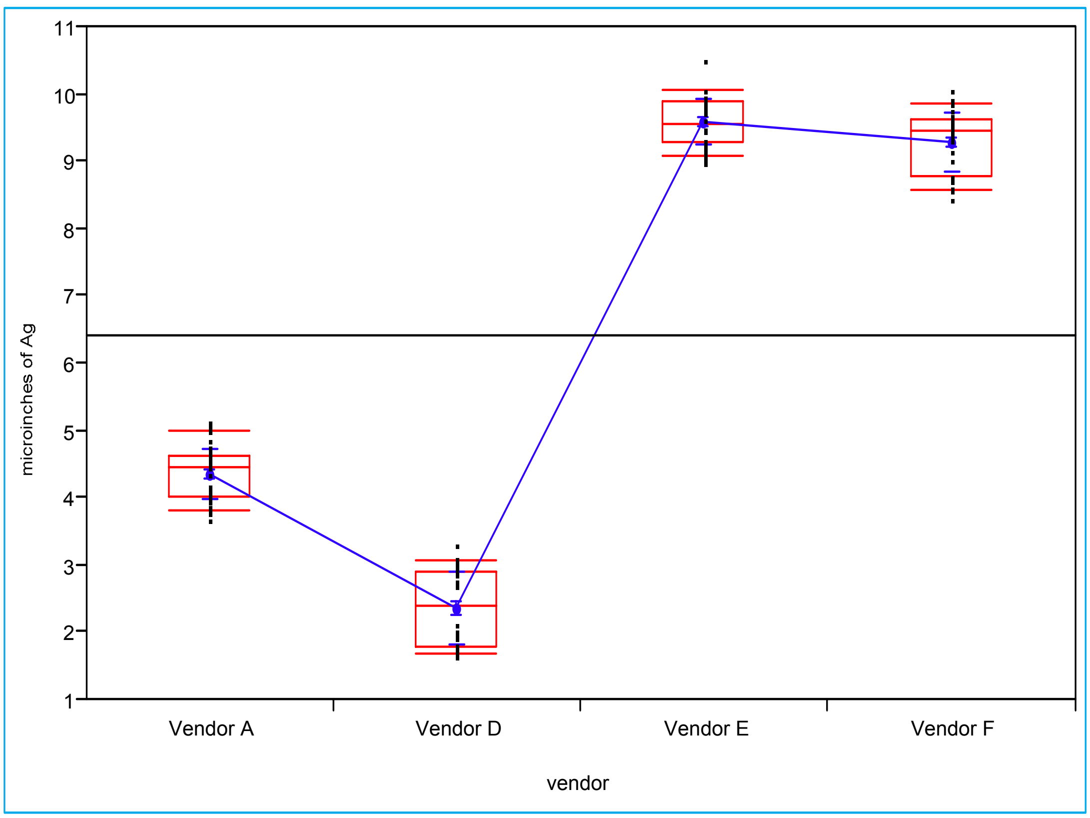


Figure 4 - Immersion Silver Deposit Supplied For Wetting Balance Testing

It should be noted that vendor C for the immersion tin and vendor A for the immersion silver thought they were supplying a much heavier deposit than what they actually sent.

This opened the proverbial can of worms with regard to measurement capability that the sellers and users of these deposits had. It was decided to run a quick round robin test on the immersion silver deposit. Two groups of test strips, one light deposit, the other heavy were sent to numerous suppliers/users. The results of the round robin testing are in figs 5 & 6.

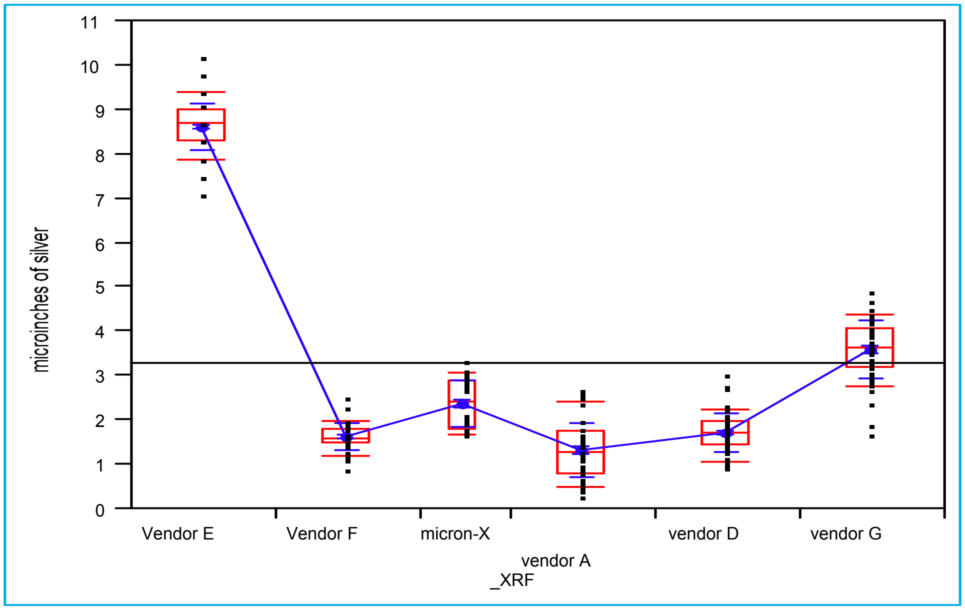


Figure 5 - Thin Deposit of I Ag XRF Results
Note: Micron-X value the correct value with a mean of 2.38 micro inches. Note vendor E's readings for this group!

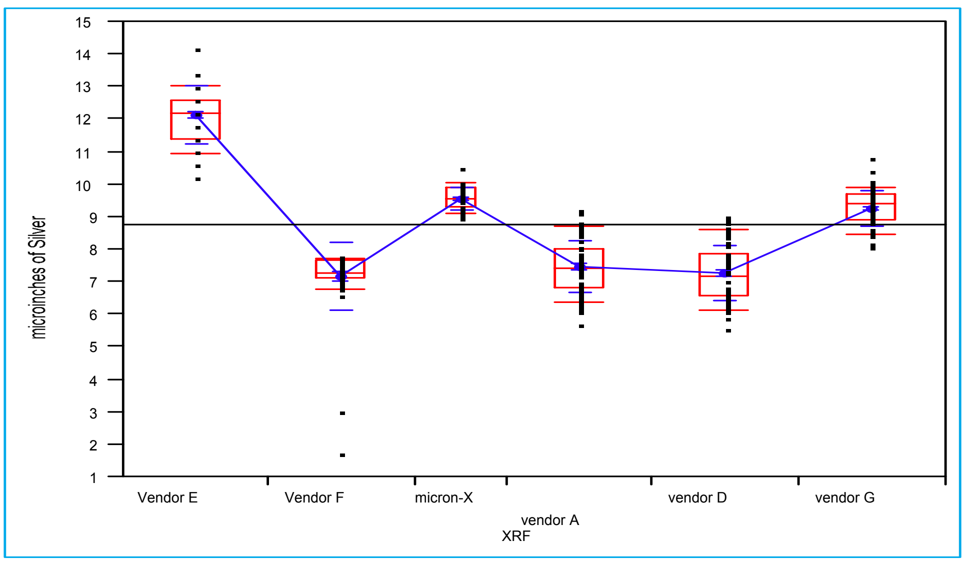


Figure 6 - Thick Deposit of I Ag XRF Results
Note: Micron-X value the correct value with a mean of 9.58 micro inches. Note vendor E's readings for this group! Note also the two outliers from Vendor F at 1.9 and 3.2 micro inches

Solderability
Wetting balance
Now that the deposit thickness for solderability had been documented the testing could commence. The primary function of both deposits is solderability protection of the underlying copper. In order to determine solderability performance over time – no currently accepted stressing condition exists for non-lead containing surface finishes – it was decided to test in real time using a wetting balance, similar to what was run and in fact is still running after 2 years for ENIG.

Panels of acid copper plated wetting balance coupons were sent to five suppliers for ISn and four suppliers for IAg. Due to the variations in process recommendations by the chemical suppliers it was decided to "level" the playing field by running the ISn with 2 g/l of copper buildup in the plating bath and the IAg with one Metal Turn Over (MTO) of bath life. Panels were then returned to Photocircuits Corporation where they were singulated into strips of 14-test coupons/strip and 27 strips per panel. The singulated strips were then placed into a plastic tote bin and tested on a weekly basis for solderability using wetting balance.

The test was a "classic" edge dip with no preheats, immersion time of 10 seconds, immersion depth of 0.5mm and an immersion angle of 90° incident to the solder pot. The flux used for the test was the standard activated flux as per ANSI JSTD-003A –Actiec 2.

One item of note was that the test temperature of 235°C is above the melting point of the immersion tin. It has been the experience of the author that this may provide a false positive result compared to when soldered at the reflow profile peak temperatures of 212-217°C. A secondary group of immersion tin coupons was run at the test temperature of 215°C.

Figures 7-9 are samples of the wetting curves as a function of real time storage.

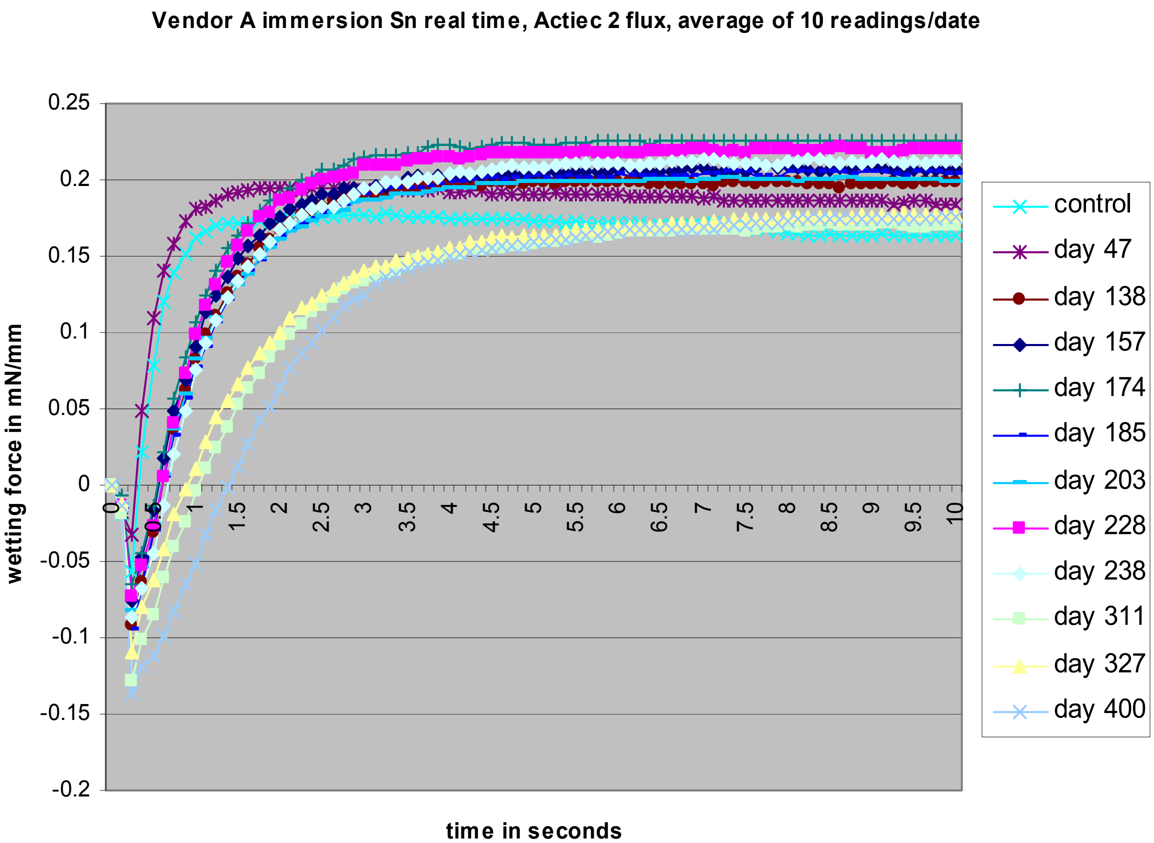


Figure 7 - Supplier A ISn after 400 Days in Storage – Very Good Shelf Life!

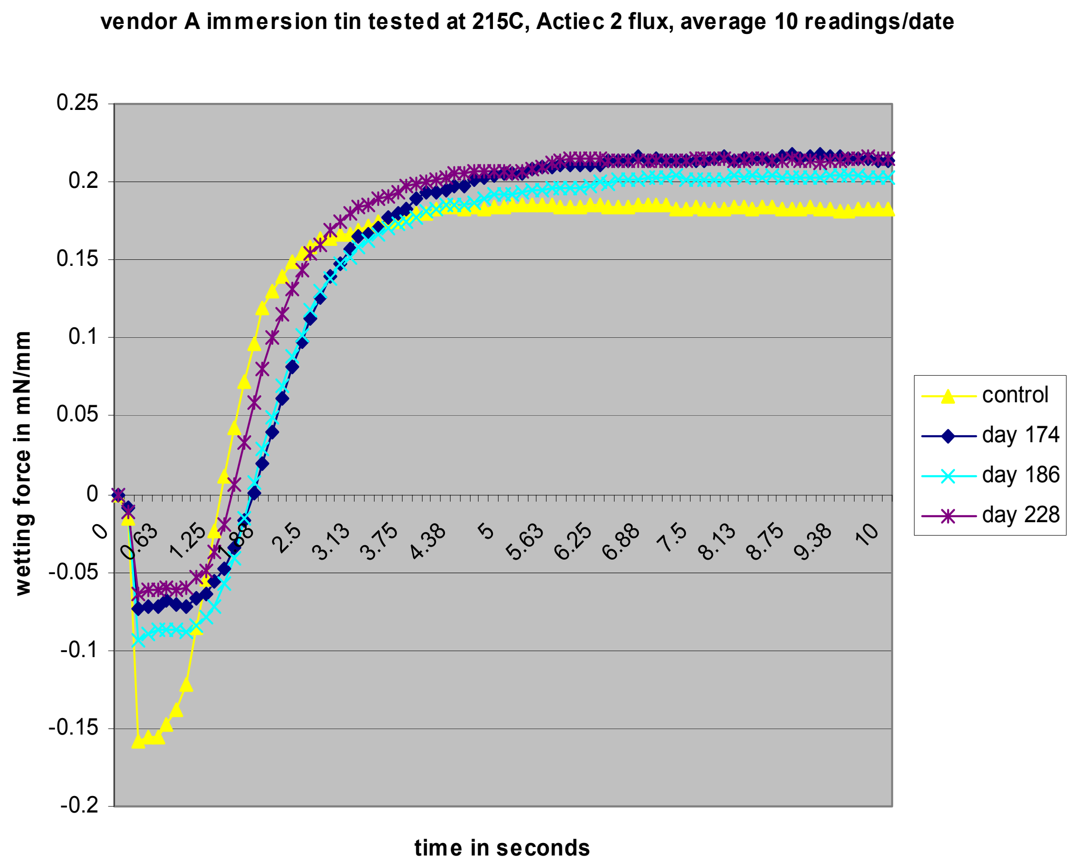


Figure 8 - Supplier A I Sn but Tested at the Lower 215°C Test Temperature

Notice the increase in time to cross the zero line compared with the values obtained in Figure 7.

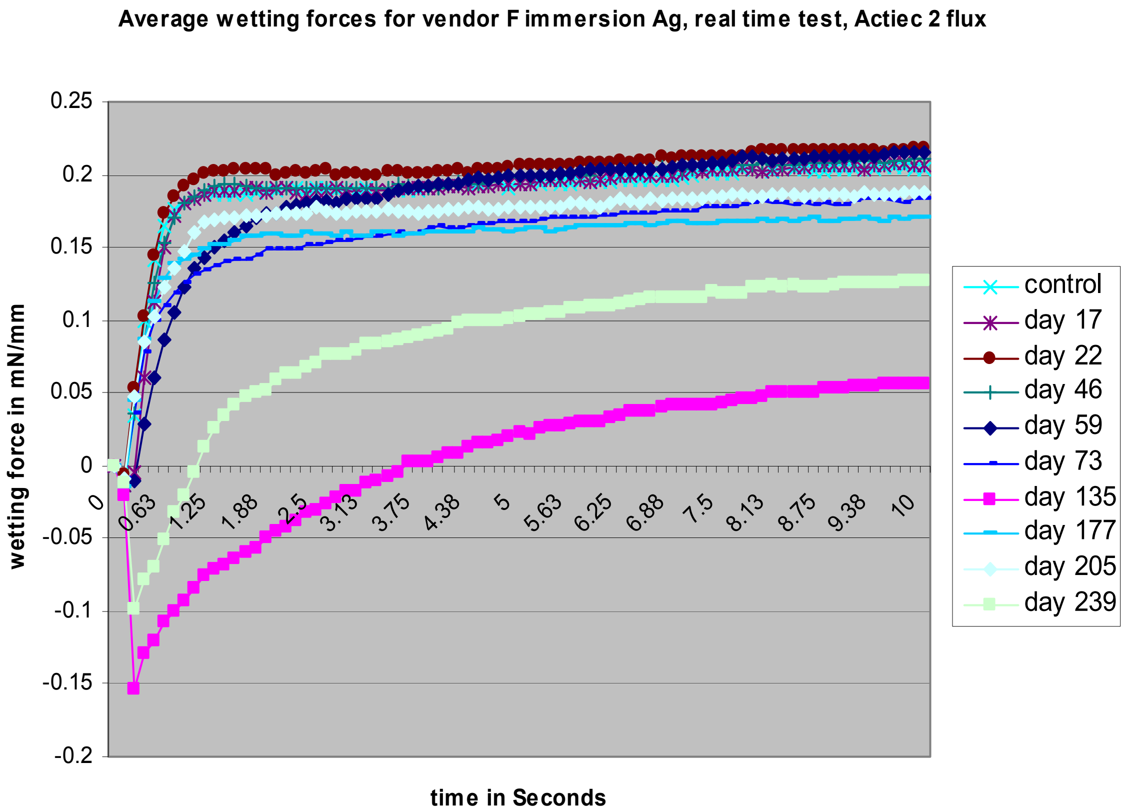


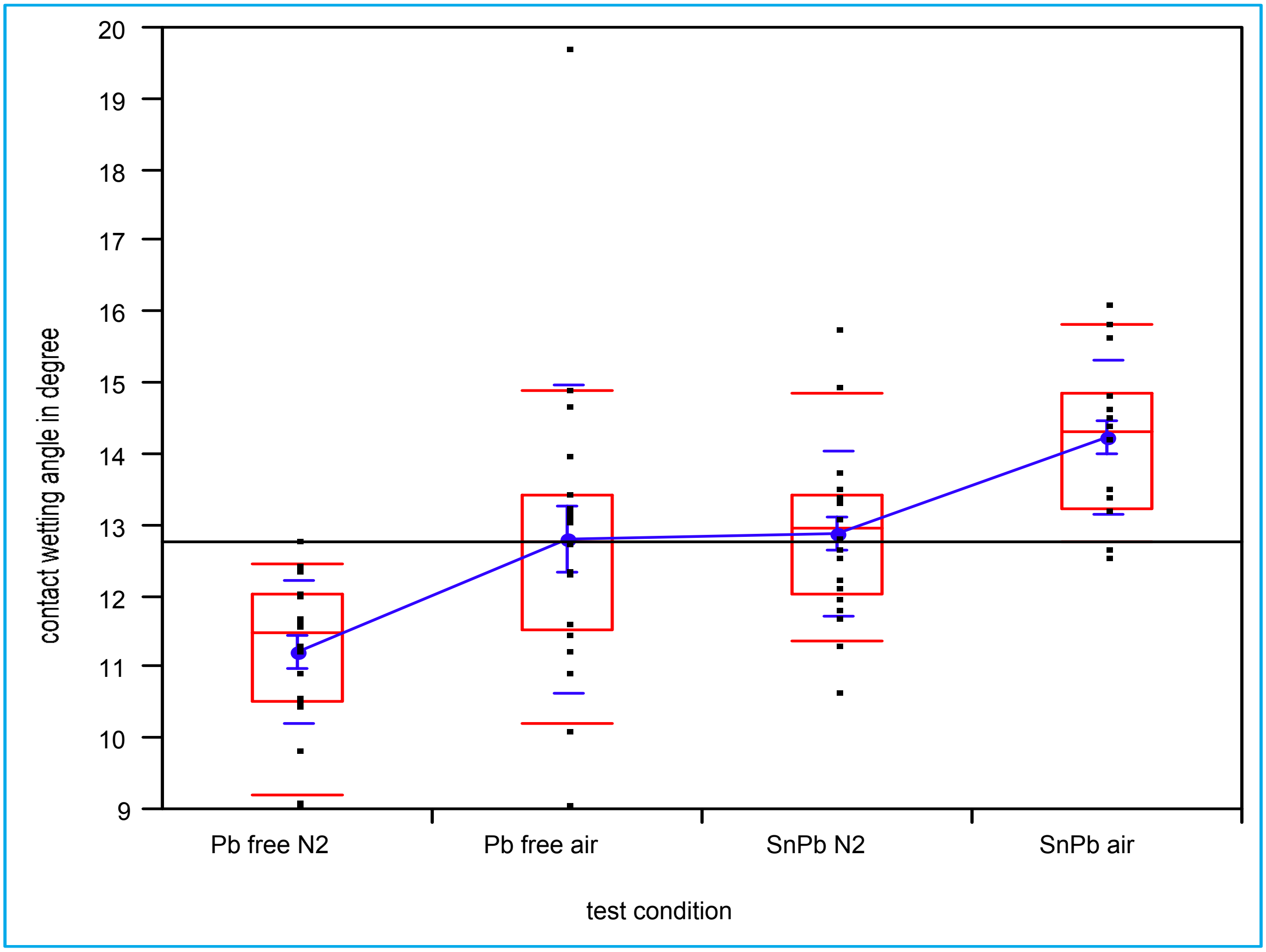
Figure 9 - Supplier F IAg

Inconsistencies in the results (day 135 lower than Day 205) are directly impacted on the relative position of the test strip in the tote bin. If exposed to the air then it tarnishes and produces lower results. If protected by it neighbor then the solderability is maintained. It is NOT recommended to store IAg coated PWB's in this manner. They should ALWAYS remain wrapped in their original packaging if possible!

Solder Spread Test

The second series of solderability tests were solder spread tests, run at two locations – Celestica in Toronto and Rockwell Collins in Iowa. Only I Sn was tested. Testing was run with both SnPb and Pb free alloys as well as testing in Nitrogen Vs Normal atmospheres. Due to production time constraints by both locations, the test coupons actually saw some real time storage of upwards of 9 months from the time they were coated with ISn to the time the test was run. In both cases the deposits exhibited excellent solderability and produced in the majority contact wetting angles below 15° - the lower the contact angle the better the solderability.

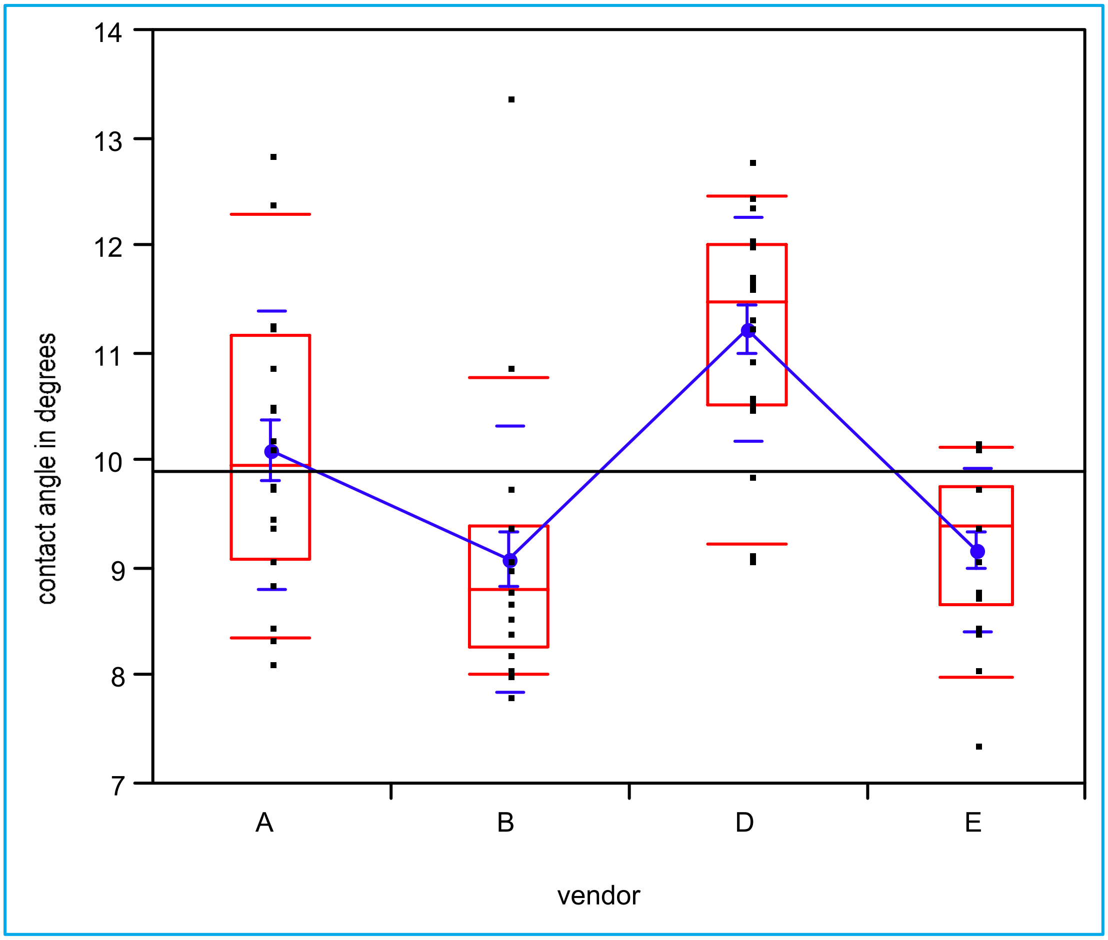
Below are two graphs from the Celestica spread test – One shows the contact angles for Supplier D for all test conditions, the other shows ALL suppliers tested with Pb free in Nitrogen atmosphere.



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
Pb free N2	20	11.2187	1.04411	0.23347
Pb free air	20	12.8050	2.17799	0.48701
SnPb N2	20	12.8938	1.17984	0.26382
SnPb air	20	14.2377	1.09607	0.24509

Figure 10 - Contact Wetting Angle for Supplier D Tested with SnPb and Pb Free Alloys in both Normal and Nitrogen Atmospheres



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
A	20	10.0965	1.30063	0.29083
B	20	9.0824	1.23776	0.27677
D	20	11.2187	1.04411	0.23347
E	18	9.1770	0.77388	0.18240

Figure 11 - Contact Wetting Angles for ALL Suppliers Tested with Pb Free Solder Reflowed in Nitrogen

Solderability Summary

For the most part the deposits are performing as expected.

The ISn deposits are showing very good consistency test to test as they age naturally. One group – C – is however showing a black deposit on the surface post soldering; this only began to appear after 140 plus days into the test.

For the IAg, the group has very specific recommendations pertaining to storage of this deposit. These recommendations were not adhered to for the purpose of this testing. The effect of exposure of the IAg surface to the air has an adverse effect on solderability. What is very significant is that supplier D who has the thinnest deposit, with a mean of 2.3 µinches is performing equally well as supplier E & F who have a mean above 9 µinches. The testing indicates that 2 µinches is an acceptable lower limit for IAg where solderability is the only functionality.

Contact Resistance

The possibility for using immersion silver as a switch pad material for soft touch membrane switch pads – such as cell phones etc was raised by members of the committee. A similar test was run for such an application when drafting the ENIG specification and that test vehicle design was re-used here. With the generous co-operation of SG Industries, it was possible to determine if the immersion silver was a suitable surface for such an application. After discussion within the group the goal of 100,000 cycles were set. Testing commenced. A 100,000 cycles were easily achieved with no issues – it was decided to continue on. Finally at 1 million cycles the test was stopped. The graph below details the contact resistance in ohms Vs number of switch actuations for one of the switch designs – interlocking round contact. Similar results were achieved with the interlocking square.

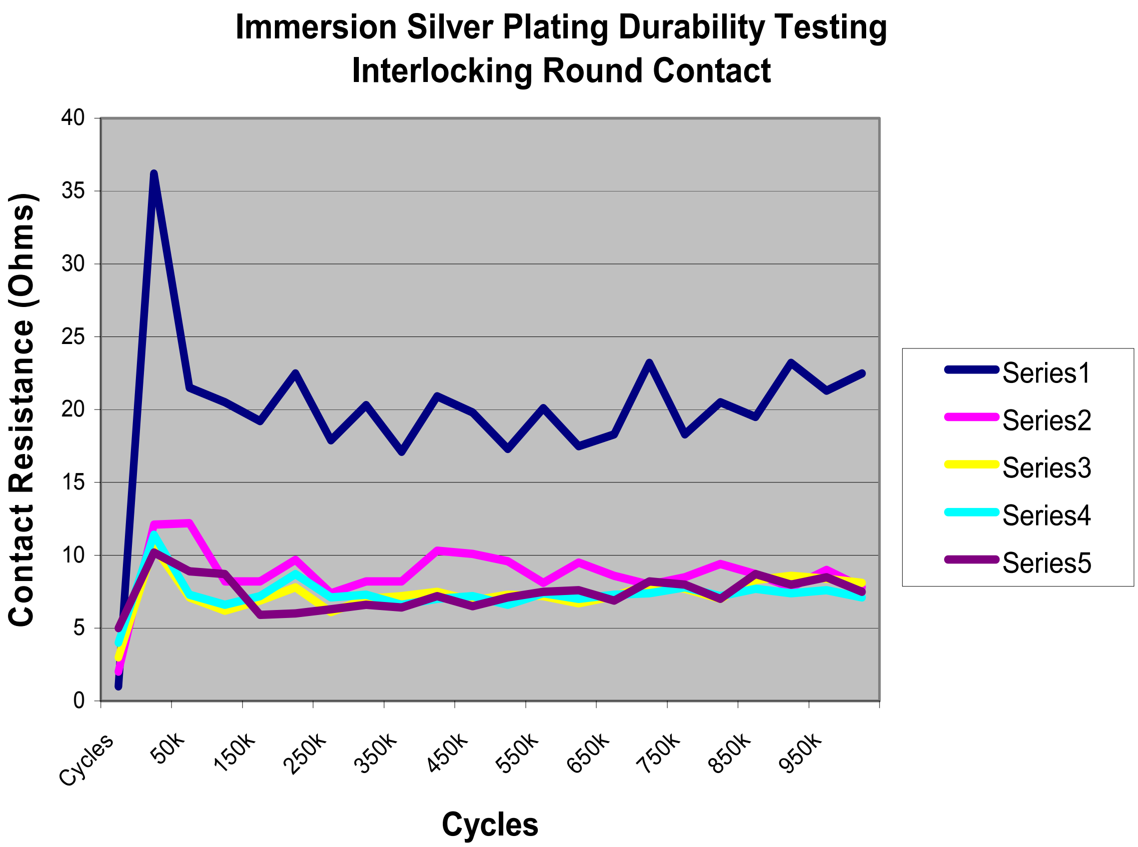


Figure 12 - Contact Resistance Readings for Soft Touch Membrane Switches Tested on Supplier "A" I Ag

Electrolytic Corrosion and Thickness Issues

One concern that continues to haunt the acceptance of I Ag is the potential for electrolytic corrosion and subsequent dendritic growth. It has always been the contention of the I Ag industry that the deposit is too thin to be susceptible to this defect. However based on the fact that the upper limit has not yet been defined for the thickness specification and combined with the fact that I Ag is one of the few alternate finishes that can be reworked (additional Ag is plated onto the existing deposit) a fear that a very thick deposit may cause a problem resulted in a series of additional tests being run.

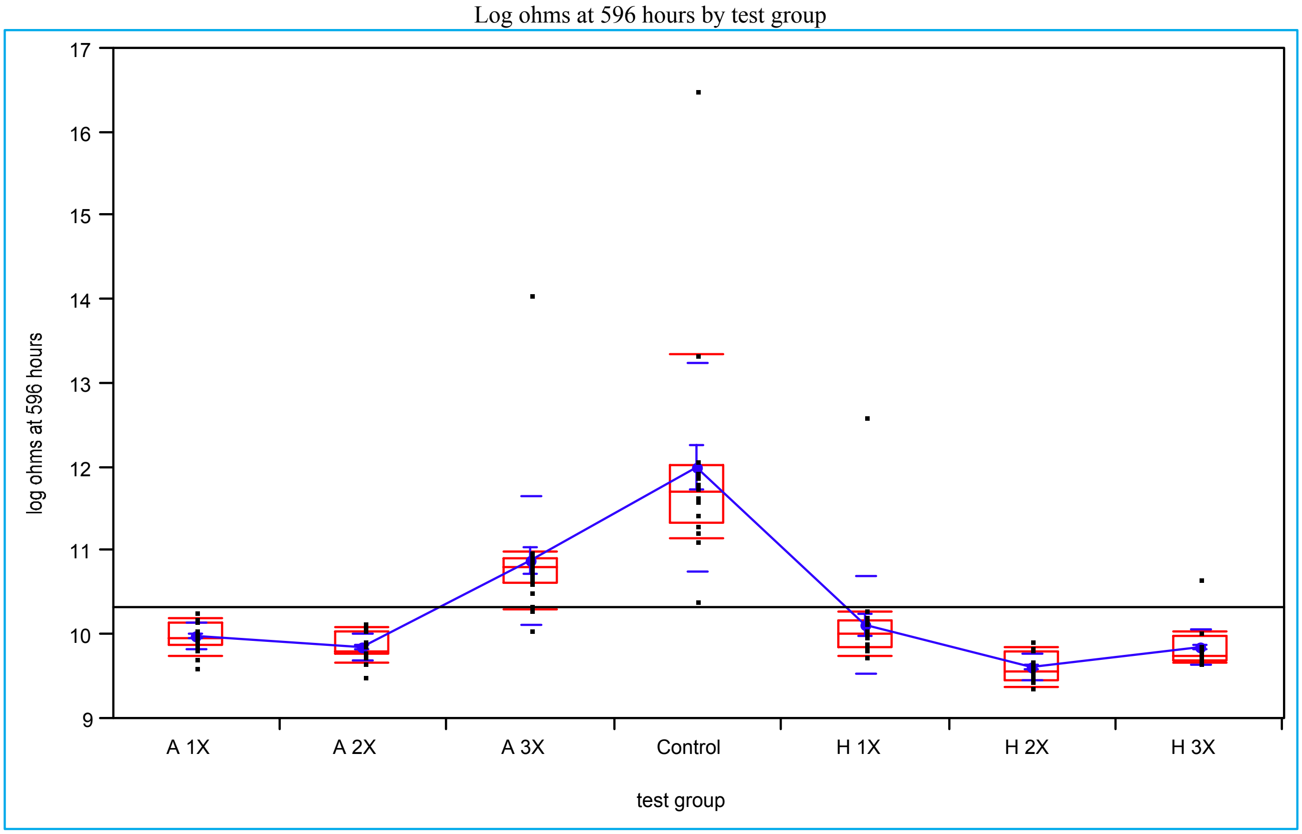
The committee chose the TM-650 test method 2.6.14.1- "Electrochemical Migration Resistance Test"- to determine if IAg was:

a) Susceptible to electrolytic corrosion and

b) Did thickness play a role?

As per the TM test, B-25 coupons were manufactured, and exposed to a normal process as well as 2X and 3X the normal process dwell times. The 12 mil line/12 mil space comb pattern was chosen for the test off the B25 pattern. Two different supplier of I Ag were run for this test. A constant 10 volt bias was applied after running a 96 hour SIR test. Test duration was 500 hours.

Some test anomalies were experienced for the first test – flux splash from wiring the test comb patterns, which predicated a second run. In both cases NO electrolytic corrosion was evident either visually or electrically. A bare copper control group was run during each 596-hour test.



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
A 1X	20	9.9906	0.16970	0.03795
A 2X	20	9.8736	0.16520	0.03694
A 3X	20	10.8958	0.78772	0.17614
Control	20	12.0077	1.25274	0.28012
H 1X	20	10.1342	0.60794	0.13594
H 2X	20	9.6182	0.17569	0.03928
H 3X	20	9.8557	0.23523	0.05260

Figure 13 - Log Ohm Resistance Values for Two Silver Suppliers – A & H with up to 3X Normal Process Dwell Times and the Bare Copper Control Board

It should be noted that the thickness values recorded for this test were very surprising to the group. The 3X supplier A produced values approaching 100 µinches as measured on the 12 mil line of the comb pattern. It is so thick that it will be micro sectioned and measured using SEM once it has had a hard metal over-plate.

Summary

The specifications are well under way.

Solderability from the testing is a given for both these deposits if applied correctly.

The IAg specification is definitely further along than the ISn even though the silver has demonstrated multifunctionality and therefore more testing has had to take place.

Electro-migration for Ag looks like a non-issue if the TM-650 test method is the pass/fail criteria for acceptance, however there are other specs – UL, Telcordia etc. The group continues to work on this and in conjunction with the 3-11 task group.

The use of IAg as a switch pad material needs further work. What does the surface look like after the 1 million cycles? If the time to complete 1 million cycles were increased to real life would it still survive?

For the ISn specification “tin whiskers” still remain an open issue. The group is hoping to either a) be able to mention the potential for whisker growth, b) one of our members has demonstrated a 6 month shelf life whisker free which means that there is a solution to the problem, c) be able to incorporate work from other industry groups.

The whole issue of board cleanliness with the ISn deposit has still to be worked on – it is a very “dirty” process and of the five suppliers only ONE submitted samples that would meet the current specification of 1.56µg/cm² NaCl equivalent.