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Next Generation Pb-free Immersion Finishes, Methodologies used to Determine Coating Thickness and the Impact of Thickness Variations and Rework on Soldering

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Abstract

The next generation of surface finish coatings to replace HASL are now being installed by various PWB manufacturers and have been implemented by many OEMs. Coating thickness requirements are part of the OEMs' specification given to the board manufacturer. Clearly from previous and existing final finish coating performances, thickness has shown to have a major impact on the performance of the surface finish during soldering. OEMs have traditionally specified wide thickness specifications, to meet production variations by PWB producers. This paper investigates the current methodologies / alternatives used to determine accurately and consistently the thickness of these new immersion silver & tin coatings, and how this variation may impact solderability performance under various pre-conditioned states.

Introduction

The technology of surface finishes for printed circuit boards is seeing a dramatic shift from Hot Air Solder Leveling (HASL) towards alternative finishes like Electroless Nickel - Immersion Gold (ENIG), Immersion Tin, Immersion Silver and Organic Solder Preservatives (OSPs).

This trend is mainly caused by the worldwide environmental pressure to ban the use of lead for electronic assemblies, as well as the demands of modern assembly technology, which require a higher coplanarity of the surface finish for surface mount assembly.

One of the main benefits of HASL is the extremely good resistance of the surface against aging under high temperature conditions. Alternative finishes, due to their thickness, offer excellent coplanarity, but can result in inferior surface protection.

As thickness of the surface finish is critical to the performance, a good understanding of the true thickness deposited onto the copper substrate is essential with the existing and new finishes. In addition to measuring the true thickness, what is the impact of thickness variations across a PWB and how does this variation affect the performance during assembly?

Electroless Nickel-Immersion Gold (ENIG) has clearly demonstrated the importance of deposit thickness. Accuracy and consistency is key. At the same time, the measurement tool and ease of use have to be acceptable for use in production, to be an effective means of thickness control.

OEMs have always used coating thickness, where applicable, as part of their engineering specifications to PWB producers and have used this criteria as part of their incoming quality control. They have traditionally specified wide thickness measurements to meet production variations by PWB producers. This paper investigates the current methodologies/alternatives, used to determine accurately and consistently the coating thickness of immersion silver and tin.

Next Generation Finishes

The HASL board finish has been working well for many years, but circuit complexity and component density is leading to decreasing pitch. This in turn is stressing the capability of both vertical and horizontal HASL processes. As lead pitch becomes finer than 0.64 mm, placement of soldermask dams between lands becomes more and more challenging. Solder leveling the boards without dams creates a need to trade off with increased solder shorts and reduced solderability due to intermetallic growth from insufficient solder thickness. Due to the dynamic nature of the hot air leveling process, this trade off makes it very difficult to control consistency.

Clearly HASL represents a process limitation as component pitches become finer. In addition to the technical limitation of co-planarity, it faces a worldwide environmental legislation ban due to the hazardous lead component. Lead and certain other hazardous materials are to be potentially phased out by 1st January 2004 in certain countries. However, market forces are clearly driving this to happen before that date and several Japanese OEMs have already taken the initiative to be lead free before year-end 2001. The replacement of lead containing solder with alternatives as an industry standard has yet to be decided, but several options have been proposed. However, in the case of surface finishes, the two market leaders are immersion silver and tin.

Immersion Tin

Electrolytic and immersion tin coatings have been around for several years. Both have suffered from several problems, including whiskers and dendritic growth associated with high coating thickness, poor process control and high levels of copper/tin intermetallic formation, which impact the solderability performance of the coating. To overcome these challenges and to meet the requirements of lead free soldering, a novel immersion tin process, Stannatech™, was developed by Atotech.

Basic Principles of Immersion Tin

Deposition of immersion tin onto copper cannot be driven by potential differences as a normal displacement reaction. Thus thiourea alters the reverse potential for this reaction allowing the reaction to take place. The reaction is still self-limiting once the tin has covered the majority of the copper surface.

$$Sn^{+2} + 2Cu^{0} + 6CH_2CSCH_2 + CH_3HSO_3 = Sn^{0} + 2Cu(CH_2CSH_2)_6SO_3 + H^{+}$$

The system, which is based on Methanesulfonic acid, provides improved solubility and stability and prevents unwanted crystallization as per the sulfate and chloride electrolytes.

Process Steps To Apply The Immersion Tin

Acid Cleaner

This is a powerful cleaner for removing oxides, soils and developer residues after solder mask application and curing. It is the first step in the pre-treatment of boards in electroless or immersion processes. Typically vertical application 5 min @ 60^{0} C.

Micro Etch

A highly concentrated sulfuric acid based microetch. It provides a defined micro roughness for seed adhesion in activation processes and a clean copper surface for immersion processes. Typically vertical application 2 min @ 30^{0} C.

Conditioner Stannadip™

The conditioner used after Microetch is for preparing the highly active copper surface. The conditioner creates uniform energy levels on the clean copper surface for the displacement reaction to take place in the following immersion tin process. Typically vertical application 2 min @ 25 °C

Immersion Tin Stannatech™

An immersion tin process producing a fine, dense, pure tin deposit. Extremely low ionic residues are a feature of the halogen free immersion solution. This, together with constant deposition speed, long lifetime and no interference with dissolved copper ensures deposit quality. Typically vertical application 15 min @ 60 °C [Thickness 0.85-1.0 microns of Stannatech™ immersion tin].

Immersion Tin Coating Thickness

As there are many chemical vendors providing immersion tin, there are also many specifications to the immersion tin coating thickness.

The thickness ranges are as follows:
0.3 –1.1 microns (12-44 microinches)

The typical tools employed to measure the immersion tin coating for PWB production are either X-Ray fluorescence and/or Sequential Electrochemical Reduction Analysis (SERA). Thickness of the immersion tin layer has a direct relationship with solderability performance. Even though a low thickness of immersion tin (.4 to .6 µm) will be solderable, at this low thickness shelf life and the number of thermal excursions (reflow cycles) will be limited. This is all related to the aging effect of immersion tin, which results in an intermetallic compound (IMC) formation at the Sn/Cu interface due to solid-state diffusion.

Immersion Silver

Immersion silver is an alternative final finish that is a drop in to replace HASL. This finish creates a reliable copper-tin solder joint, created by the dissolution of silver into the selected solder. There are many different Immersion Silver technologies and chemistries available to the PCB industry, which use similar concepts and approaches.

Basic Principles of Immersion Silver

Deposition of immersion silver onto copper is driven by the electropotential differences between the two metals while in an acidic ionic solution, where Copper (metal) is displaced by silver ions. The reaction is self-limiting. However, this point is dependent on many factors; in addition to the silver an organic protection layer is co-deposited to help preserve the solderability and appearance of the surface finish.

$$Cu \rightarrow Cu\,(I) + e^{-} \quad E^{\circ} = 0{,}521\ V$$
$$Ag\,(I) + e^{-} \rightarrow Ag \quad E^{\circ} = 0{,}7996\ V$$

$$Cu + Ag\,(I) \rightarrow Cu\,(I) + Ag \quad E = 0{,}2786\ V$$

Process Steps to Apply Immersion Silver

Acid Cleaner

This is a powerful cleaner for removing oxides, soils and developer residues after solder mask application and curing. It is the first step in the pre-treatment of boards in electroless or immersion processes. Typically horizontal application 0.5 min @ 40- 60 °C.

Micro Etch

A highly concentrated sulfuric acid based microetch. It provides a defined micro roughness for seed adhesion in activation processes and a clean copper surface for immersion processes. Typically horizontal application 1- 2 min @ 30 °C.

Pre-Dip Silver Finish ST

Used after the microetch step the pre dip protects the silver bath from contamination. Typically horizontal application 0.5 min @ 25- 30 °C.

Silver Finish-ST

Advanced immersion silver for deposition of a fine, pore-free and pure silver layer. This together with constant deposition speed, long lifetime and no interference with dissolved copper ensures deposit quality. Typically horizontal application 2 min @ 50^0C [Thickness 0.20-0.40 microns of silverFinish ST™].

Immersion Silver Coating thickness

As there are many chemical vendors providing immersion silver there are also many specifications to the immersion silver coating thickness.

The thickness ranges are as follows:

0.1 – 0.5 microns (4-20 microinches)

The typical tool employed to measure the immersion silver coating for PWB production is X-Ray fluorescence.

Methodologies Used to Determine Final Finish Thickness in PWB Production

The PWB industry has traditionally relied on cross sectioning for thickness measurements at various stages of PWB manufacture. However, in the case of final finishes, a non-destructive method is best suited. So the XRF has become the industry standard for surface finishes. What has become apparent is that many XRF suppliers exist and each offers various models with different levels of software integration and hardware, not to mention different calibration standards.

As a general rule, the new generation of equipment has a higher level of software capability, which aids measurement accuracy and reproducibility. In the programming of the XRF software various critical constants are needed for accurate determination, such as density of metal being measured. This is normally taken to be the density of the pure metal, but in many cases this is not true for immersion tin and silver. Chemical vendor should advise.

In the case of immersion tin, different chemical vendors have used different density factors to account for tin thickness. This can lead to false thickness measurements, which in turn could lead to poor solderability.

Negatively charged electrons of an atom are bound to the atom by their attraction to the positively charged protons in its nucleus. An electron can be ejected from its atomic orbital if it is struck by a light wave (photon) of sufficient energy (i.e., greater than that binding the electron to its nucleus). When an inner orbital electron is ejected from an atom, an electron from a higher orbit "drops down" (cascades) to fill the lower orbital vacancy. As a result of this transition, the atom releases potential energy in the form of a photon in the X-ray frequency range. This phenomenon is called fluorescence.

The potential energy between two given orbital shells of a particular element will always be the same. Similarly, the photon emitted when an electron shifts between orbitals will always possess the same energy. For this reason, such a photon is termed a characteristic X-ray of the element. There are numerous shell transitions possible within an atom; when exposed to X-rays, each element emits a collection of X-rays within a characteristic range or spectrum of energies.

When X-rays of a specific and controlled intensity bombard a sample, its constituent elements will fluoresce characteristic X-rays at a rate proportional to the concentration of the elements present. Given this correlation, it is possible to measure the coating thickness as well as identify the elemental composition of a sample. This is the fundamental basis of XRF analysis.

XRF Measurement System Overview

Main components. The basic design of an X-ray fluorescence (XRF) thickness and composition measurement instrument incorporates: (Figure 1.)

- A source of high intensity X-rays
- A mechanism to define the X-ray beam size
- A sample positioning mechanism and focusing optics
- Pulse detection, shaping, and analyzing electronics
- Algorithmic tools for determination of thickness and/or composition of films, solids, and liquids

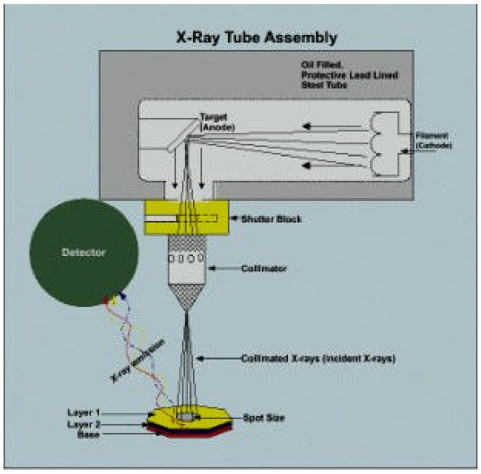

Figure 1 - Principles of XRF measurement

How it Works

We know that an element exposed to a source of high intensity X-rays will itself emit X-rays, or fluoresce, at energy levels unique to that element. System XR directs a beam of X-rays at a sample to induce fluorescence from the elements present. A detector apparatus senses these X-ray emissions and converts them into electronic pulses. A multi-channel analyzer sorts the incoming pulses by energy level, counts the number of pulses detected at each energy level, and stores this information in memory. The system computer generates a histogram based on these data, called a spectrum. Algorithmic tools are employed to derive a thickness and/or composition measurement from the spectral data.

The X-ray fluorescence intensity is proportional to the number of tin/silver atoms within the probed volume (fraction of a mm^2, several µm depth). From this intensity, with the density of the layer entering as proportionality constant, the tin/silver layer thickness is calculated.

When the instrument is properly calibrated, the measured layer thickness is correct for a freshly deposited tin/silver layer. The calibration is crucial for the X-ray fluorescence.

XRF-Standards
These are available from various sources, generally you would use certified standards, which are available from the equipment supplier or National Institute of Standards and Technology (NIST). The standards normally consist of pure metal at a given thickness on the base material. However, especially in the case of silver, this is not a pure metallic coating, but a combination of an organic protection layer. Therefore the chemical /XRF vendor should also be consulted for correct operation of the XRF unit.

Immersion Tin
An investigation was carried out to examine the accuracy of the XRF thickness measurement on immersion tin. This was confirmed using the Electrochemical Stripping Coulometric Method and Atomic Force Microscopy. At the same time, we also examined the impact of the pure tin density factor (Figure 2).

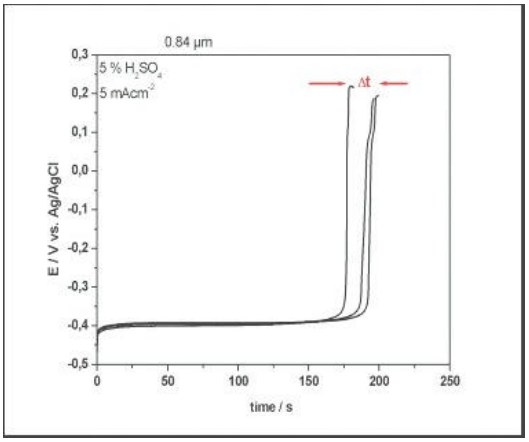

Figure 2 - Coating Thickness used Immersion Tin 0.84µm

Electrochemical Stripping Coulometric Method
Stripping coulometry was performed at 5 or 10 mA/cm^2 in 5% H_2SO_4 under galvanostatic conditions. The potential of the sample during stripping of Sn at the indicated current density is around –0.4 V vs. an Ag/AgCl reference electrode. When the pure, unalloyed Sn is consumed, the potential rises steeply to the potential of Cu dissolution, around +0.1 V vs. Ag/AgCl.

Assuming the current to be due to the reaction
$Sn \rightarrow Sn^{2+} + 2e^-$ (1)

the thickness of pure metallic tin, d_{Sn}, can be evaluated from the time until the potential rises, t_s, and the current density j, according to

$$d_{Sn} = \frac{M_{Sn} \cdot j}{2 \cdot F \cdot r_{Sn}} \cdot t_s \quad (2)$$

with M_{Sn} = 118,71 g/Mole the molar mass of Sn, F = 96485 C/Mole the Faraday constant, and r_{Sn} = 7.29 gcm^{-3} the density of Sn (Figure 3).

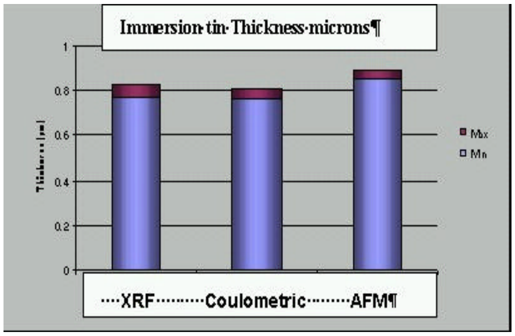

Figure 3 - Results Graphed Using XRF, Stripping Coulometric and AFM Method Assuming Tin Density 7.29 g/cm^2

Stripping coulometry gives the thickness of the pure, unalloyed Sn layer.

Atomic Force Microscopy
For thickness determination with AFM, the samples were masked with adhesive tape and the pure, unalloyed Sn was stripped galvanostatically in 5% H_2SO_4. After stripping, the tape was removed and the step edge between the etched and un-etched area was measured with AFM.

The step height measurement gives, in principle, the same information as stripping coulometry, namely the thickness of the pure, unalloyed Sn layer. In contrast to coulometry, however, the thickness determination with AFM is independent of the density of the Sn layer (Figure 4).

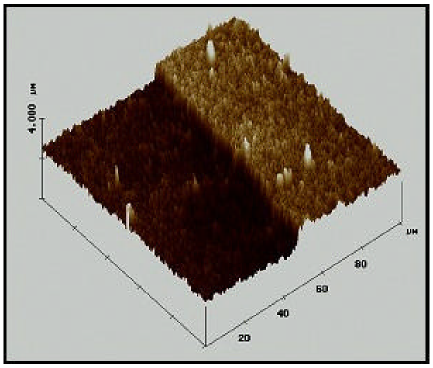

Figure 4 - AFM Profile Exhibiting the Step between Total Tin vs. Copper Base Material

This exercise demonstrated that using all three methods, the variation was approx +/-10%, but if we were to use the new density factor for tin (6.5 g/cm^2) then this variation was further reduced. This showed that correct calibration of the XRF is imperative and the XRF can be an effective tool for non-destructive measurement of immersion tin. Once accuracy was confirmed a series of tests were carried out to check at what immersion tin thickness impacted solderability (Figure 5).

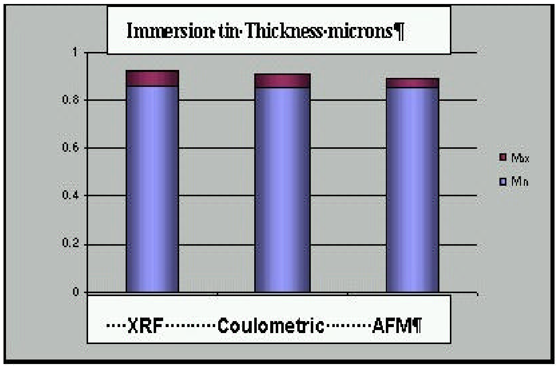

Figure 5 - Results Graphed using XRF, Stripping Coulometric and AFM Method Assuming Tin Density 6.5 g/cm^2 Calculated s.g. by Taking the Step Height of Stripping into the Equation

Impact of Tin Thickness on Solderability using Solder Spread Testing

Solder Spread Test Method

Function

- Test to evaluate the wettability of surface finishes on PCBs.

Advantages

- Practical test with industrially used solder paste
- No use of highly activated fluxes
- Independent of layout design
- Quantitative

Practical Test

- Solderpaste is printed with a stencil (thickness 120µm) onto the top of the surface of the PCB (See Figure 6)

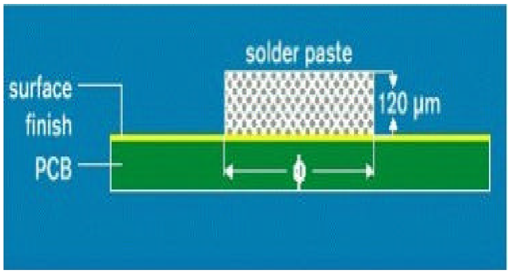

Figure 6 – Printed Solder Paste

- The solder paste printed sample will be heated in a reflow oven up to melting point or higher (Figure 7)

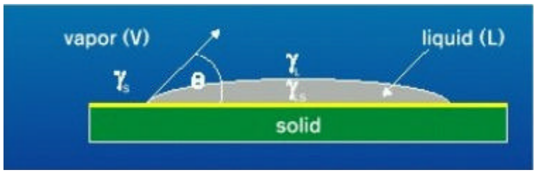

Figure 7 – Solder Paste Printed Sample

- As the solder becomes liquid, the molten solder spreads out on the surface. This is dependent on the surface wettability. After melting, the solder spread is measured and the wetting angle is calculated by a mathematical formula.

- The molten solder represents the liquid phase (L). The solid phase (S) corresponds to the surface finish of the PWB. The vapor phase (V) corresponds to the flux evaporation.

The approach uses Young's relation, which is described by the following equation: (Figure 8)

$$\gamma_{SV} = \gamma_{SL} + \gamma_{LV} \cdot \cos \Theta$$

LV = Solder / flux surface tension
SV = Finish / flux
γ_{SL} = Finish / solder

$$\text{where } \Theta = \arccos \frac{\gamma_{SV} - \gamma_{SL}}{\gamma_{LV}}$$

Figure 8 – Young's Relation Shows Results

Solder Spread vs. Tin Thickness after Various Conditioning

Solderability has been tested using the solder spread test. The measured wetting angle is directly correlated to the wetting force. The smaller the wetting angle, the better the solderability. Wetting Angle greater than 15°degrees would represent poor solderability under production conditions.

Influence of As Received on Solderability

Fresh samples show an excellent solderability. Even a deposition thickness of 0.3 µm gives excellent solderability with values of 5-10° (Figure 9).

Figure 9 – Wetting Angles for As Received Solder Paste

Influence of Four Hours 155°C on Solderability

After high temperature ageing (4 hrs 155°C) a clear influence of surface thickness can be observed: From 0.3µm up to a thickness of 0.8µm a drastic decrease of the wetting angle can be observed compared to non aged surfaces, which indicates a decreased solderability (Figure 10).

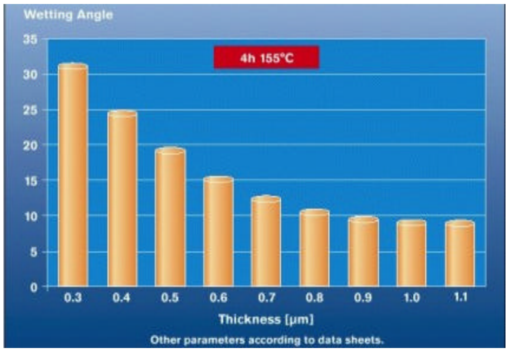

Figure 10 – Wetting Angles After Four Hours Ageing

Influence of Eight Hours 155°C on Solderability

Eight hours storage at 155°C shows an even stronger effect on degrading solderability; here good solderability can only be observed with Tin thickness around 1.0 µm (Figure 11).

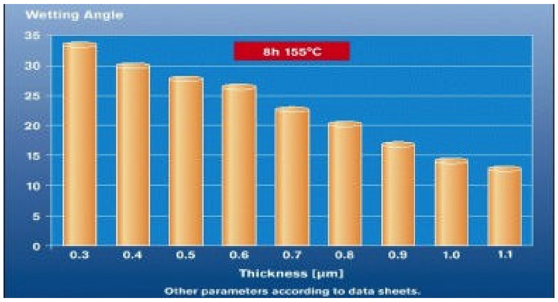

Figure 11 – Increase in Wetting Angle See with Increased Aging Time

Influence of Seventy-Two Hours 100°C on Solderability

Three days storage at 106°C show a clear increase in the wetting angle for thin tin layers up to 0.6µ, thicker tin surfaces are not effected under this storage condition (Figure 12).

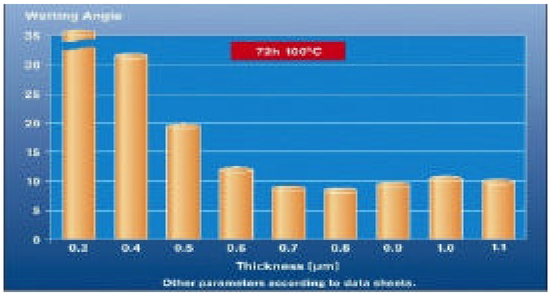

Figure 12 – Wetting Angles Continues to Increase with 72 Hours Ageing

Influence of Ninety-Six Hours 40°C 93% R.H. on solderability

Four days storage at 40°C, 93% relative humidity results in slightly higher wetting angles, however, the solderability is good even for low tin thickness (Figure 13).

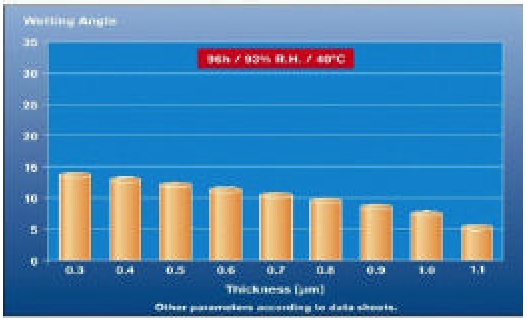

Figure 13 – Lower Temperatures Age the Solder Less

Influence of Dry Storage for Twelve Months on Solderability

Comparing panels as produced, shows excellent solderability even after twelve months storage in laboratory atmosphere. Having a 0.8 µm thickness, the wettability after one year storage is comparable to 1.0 µm after 4 hrs 155°C (Figure 14).

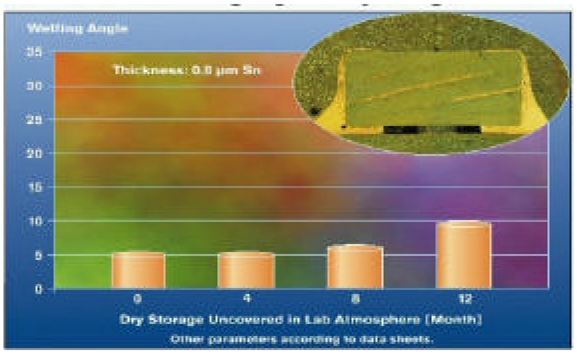

Figure 14 – Dry Storage Yields Good Solderability Retention

The solderability testing showed that any thermal excursions/conditioning could impact performance of the tin. Dry heat in particular is very detrimental. So tin thickness is key to preventing all the pure tin being converted to IMC products, thus 0.8-1.2 microns of immersion tin is recommended. The max tin thickness is not the critical factor, but the minimum thickness is essential.

Immersion Silver

The graph below illustrates the importance of correct standards to calibrate the XRF. In this case, there was good correlation with the wet analysis, SEM and XRF (Figure 15). However, using the incorrect standards generally results in a shift of thickness measurements (Figure 16). In this case with XRF vendor A using their standards vs. inernally generated standards, there was the shift to lower immersion silver thickness. A good practice would be to confirm your thickness data with known standards from the chemistry vendor. This would ensure that you are working within the current specifications limits of the vendor.

Immersion silver from different chemical vendors was measured using XRF. All boards processed horizontally, clearly show variation due to chemical bath and equipment impact on solution exchange rate. The immersion silver thickness was plotted against pad size (mm^2).

Clearly each chemical vendor has a slightly different thickness. The key factor is the deposition rate (microns/min). If the deposition rate is high, you will see higher variations across various pads as shown by these graphs. This influence can be reduced by minimizing the impact of solution exchange to the surface of the PWB. This is controlled by equipment design.

Another key factor to both finishes, but to a much lower impact to immersion tin, is the thickness variation across a large pad. This is demonstrated by the following graphs for immersion silver and tin.

This variation across a pad will occur on all metallic displacement reactions. This phenomenon can be reduced by controlling the rate of reaction, i.e. the faster the plating rate the more variation you will see, not only across a pad but also across the PWB. The immersion silver (Figure 17) has a greater variation in thickness than immersion tin (Figure 18)due to the very short process time in the immersion silver bath.

The XRF has shown that it can be a very effective tool to measure the thickness of immersion tin and silver. As with all applications, XRF needs good calibration standards and correct algorithms and constants to be inputted. The software and hardware also need to be taken into consideration. The other main advantage of the XRF is that this measurement technique is non destructive and allows large PWBs to be measured directly.

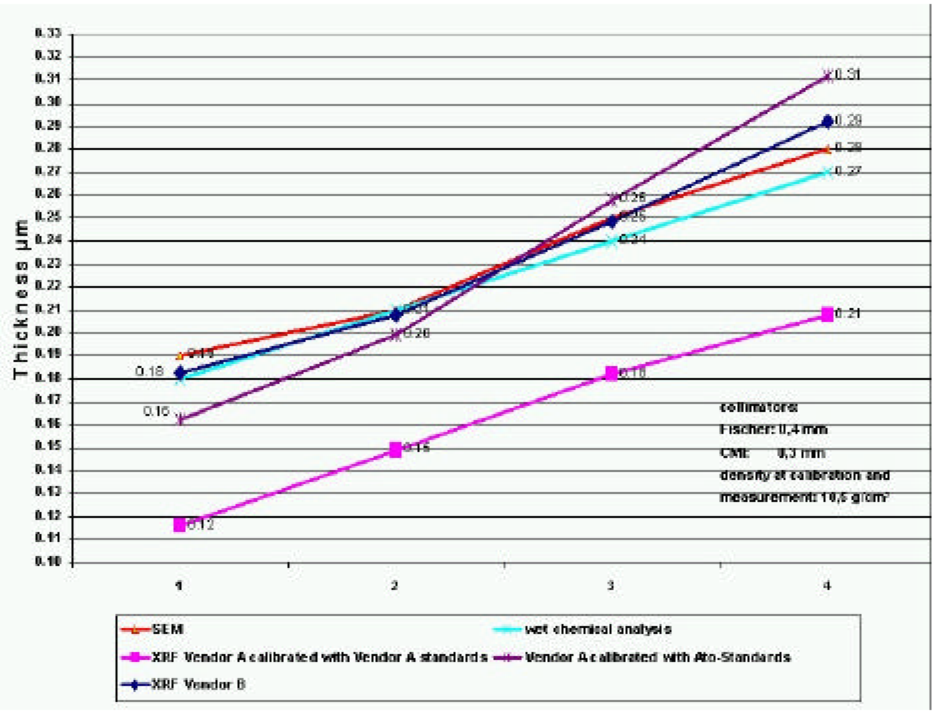

Figure 15 - Immersion Silver Thickness Using XRF

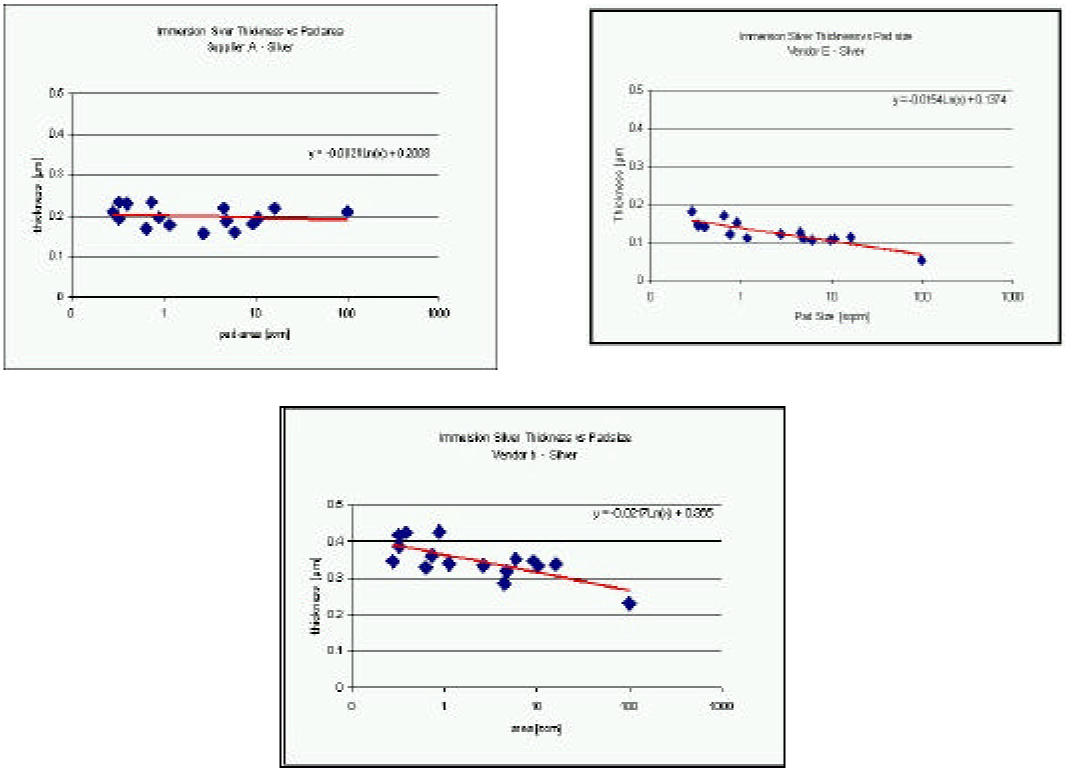

Figure 16 - Immersion Silver Thickness using Two Vendors of XRF Units and Two Different Sets of Standards

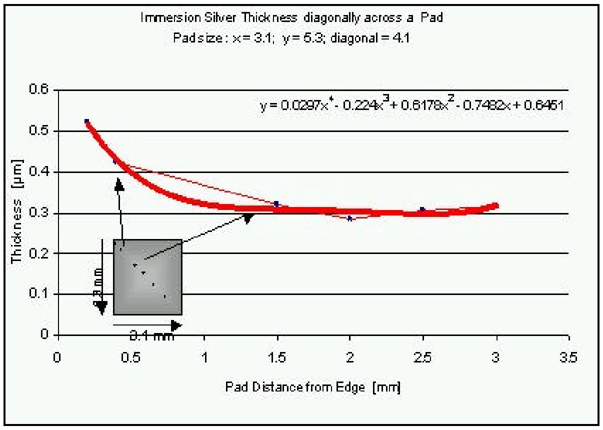

Figure 17 – Thickness of Immersion Silver Does Vary Across a Typical Pad

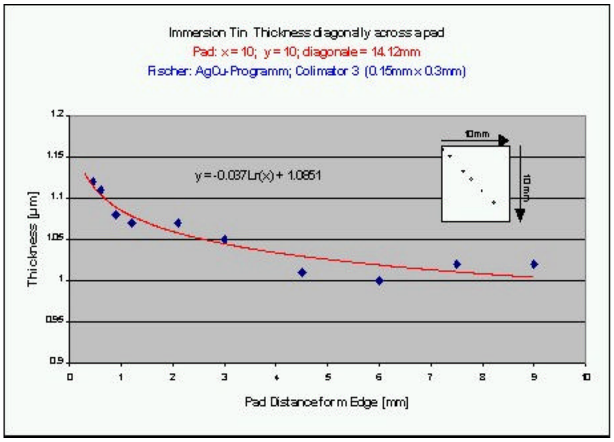

Figure 18 – Immersion Tin Also Varies in Thickness Across a Pad

Limitations of XRF

XRF measures the total amount of metallic tin/silver in the final finish coating. Therefore, in the case of immersion silver, the amount of organic co-deposited cannot be measured, which is of some concern (but this will be a subject for another paper). In the case of tin, the amount of IMC products also cannot be measured. Thus an investigation into coulometric analysis, for surface thickness and/or analysis was carried out. In this case a SERA unit was used.

SERA Technique Introduction

The SERA (Sequential Electrochemical Reduction Analysis) technique (Figure 19) involves isolating a surface pad or plated through hole using a gasket with an accurately defined area. The hole or covered surface pad is then filled with electrolyte and defined current is applied between the tested surface and the auxiliary electrode placed within the cell above the board.

Figure 19 - Picture of the SERA Equipment

The electrode potential of the tested surface is then measured as a function of time against a reference electrode, which is placed in the electrolyte's storage vessel (Figure 20). The recorded potential-time curve consists of a series of plateaus with characteristic shapes depending on the type and quality of the metal surface (Figures 21 and 22).

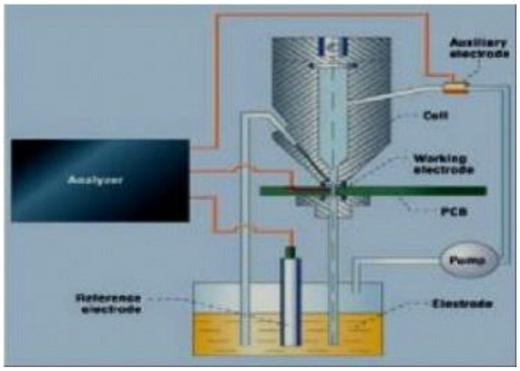

Figure 20 - SERA - Flow Diagram

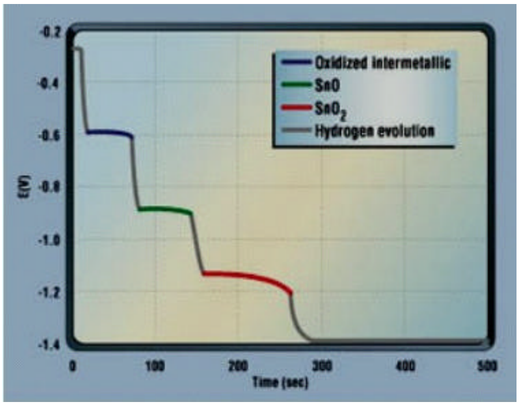

Figure 21 - The Recorded Potential-time Curve Consists of a Series of Plateaus with Characteristic Shapes Depending on the Type and Quality of the Surface

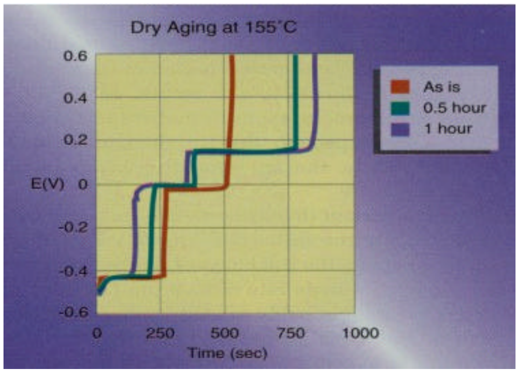

Figure 22 – Similar Potential-Time Information

Surface Analysis

This method is a chronopotentiometric measurement of the dissolution of Tin/silver oxides and intermetallic oxides for immersion tin.

A constant anodic current is applied between the part and an inert counter electrode and the anode potential is monitored as a function of time relative to a reference electrode (Figure 23).

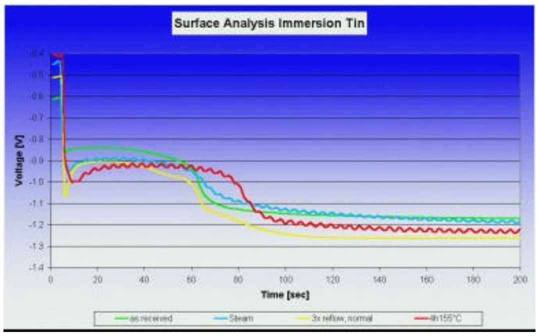

Figure 23 - Surface Analysis of Immersion Tin before and after Various Conditioning

The above analysis was repeated several times on various conditioned, immersion tin boards. We observed a large variation between the same samples, but the main factor was we could not draw any conclusion to the "aging" vs. the oxide growth. This can be seen if you observe the As Received vs. 3x reflow samples.

In this SERA application, an anodic current is applied to the tested surface, causing electrochemical dissolution of metallic layers (see Figure 4). Time required to dissolve the coating is proportional to the thickness of the coating, which is calculated using a modified Faraday's equation:

$$T = \frac{M \cdot I \cdot t}{n \cdot F \cdot S \cdot D}$$

Where,
M molecular weight
I current
t time
n number of electrons
F Faraday's constant
D density of coating
S surface area
T thickness

An immersion tin coating consists of the copper substrate, two intermetallic phases, the tin coating and the tin oxide (Figure 24). The two intermetallic phases are the η-phase - Cu_6Sn_5 and the ε-phase - Cu_3Sn. Therefore, the thickness is directly proportional to the time required to dissolute the layer.

The metallic densities are given as:

Tin	7.29 g/cm³
Cu_6Sn_5	8.28 g/cm³
Cu_3Sn	8.90 g/cm³

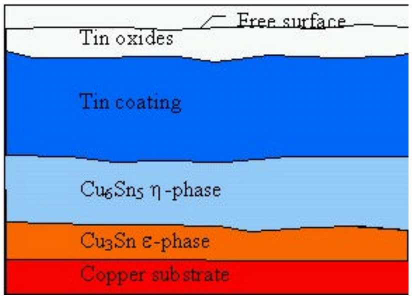

Figure 24 - Schematic Cross Section of an Immersion Tin Coating (Thicknesses are not True in Scale)

Experimentation

SERA - Immersion Tin

Samples plated in Stannatech™ immersion tin at approx 1 micron thickness were subjected to various thermal conditioning, 4 hours steam, 4 hours dry heat @ 155 °C, 3 X reflows at normal eutectic solder and finally 3 X reflows at a simulated Pb free solder temperature and then SERA internal analysis curves were examined (Figure 25). In addition to the curves, solderability was measured using a wetting balance in this case a Menisco ST 50 was used.

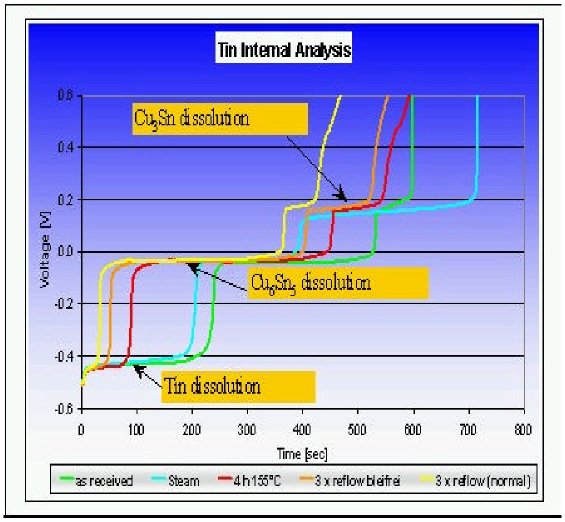

Figure25 - Curves Obtained by SERA Internal Analysis; Each Curve is Selected Example at Various Conditioning

Table 1 - SERA Internal Test Results and Comparison to the XRF Measurements (Mean Values from 10 Measurements)

	Pure Tin [µm]	IMC Sn_5Cu_6 [µm]	IMC $SnCu_3$ [µm]	XRF Tin [µm]
As Received	**1.08**	**0.71**	**0.15**	**1.18**
4 h 155°C	**0.33**	**0.81**	**0.18**	**1.08**
Steam	**0.93**	**0.48**	**0.61**	**1.08**
3 x reflow Pb free	**0.20**	**0.83**	**0.22**	**1.04**
3xreflow (normal)	**0.18**	**0.73**	**0.14**	**1.17**

The data obtained using the SERA, clearly show that the total tin thickness, which comprises of pure tin plus IMCs, is much greater than the data obtained from other measurement methods.

If you only use the pure tin data from SERA, this shows a strong correlation to the conditioning of the immersion tin coating (Figure 26). As you thermally condition the immersion tin, the amount of pure tin decreases. However, the balance of the IMC products does not change.

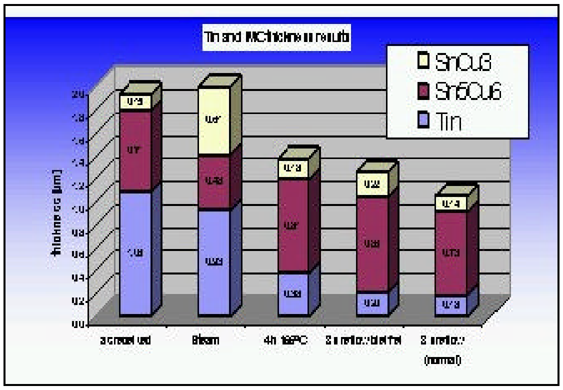

Figure26 - SERA Internal Analysis Results (mean values from 5 measurements)

There are two possibilities either the mathematics for the calculation is incorrect or the methodology is flawed. Hence, it was decided to carry out a test on just pure copper using the same procedure as stated by the SERA supplier. (HCl electrolyte is being used) These curves were plotted against the samples of the As Received immersion tin (Figure 27).

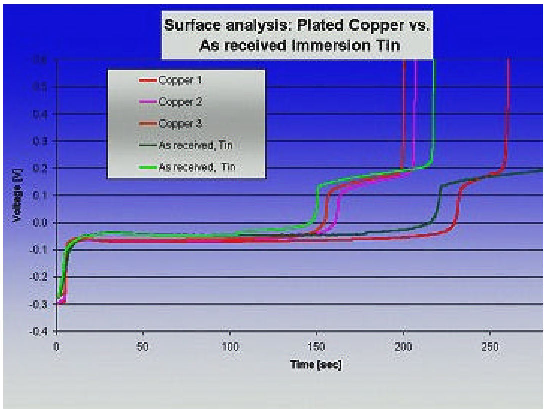

Figure 27 - Potentiometric Curves on Pure Copper vs. as Received Immersion Tin

The analysis revealed that the copper samples also show very similar traces to the As Received immersion tin. The results indicate that the hydrochloric acid, when used to measure the IMC products, is dissolving through the tin layer resulting in an electropotential measurement of the Cu+ and Cu++ species. The interpretation of the data has been confirmed with the SERA vendor.

Conclusion

Controlling the thickness of the next generation surface finishes is going to be essential, as thickness can be directly linked to performance in the field. Each vendor will provide PWB producers their own min-max thickness specification for the final finish. However, in this study we have found, especially with immersion tin, that thickness is critical when it comes to storage or thermal conditioning. Our recommendation is to keep the immersion tin in the range of 0.8-1.2 microns. The key factor is the minimum thickness.

In the case for silver controlling the thickness of a much thinner coating may require special standards from the chemical vendor, as this is not a pure silver coating. The thickness recommendation that we have found with our chemistry is 0.15-0.3 microns.

XRF will continue to be the tool that the majority of PWB producers will use as a quality control check for their next generation finishes. As this provides a non destructive and can directly measure the outgoing parts to assembly. Careful selection of standards and calibration will be needed. This will determine accuracy and reproducibility of the XRF machine. As with other surface finishes, the software and age of the XRF equipment has shown to also have a considerable impact on thickness measurements.

Using SERA for thickness measurements has shown conflicting results, when this was used to measure the total tin including the IMC products. However, if you only use the pure tin figures, this does show reasonable correlation to the XRF and to thermal conditioning, as indicated by the decrease in pure tin.

Further work needs to be carried out to clarify with the SERA vendor on the interpretation of the data, this will be presented at IPC EXPO 2002.

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