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The Advanced NiAu-Process for Second Image Technology

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Overview

Designs of new electronic products show a significant drive for smaller and more complex PWBs. This continuing trend of miniaturization affects components in the same way as for the connecting pads on a printed circuit board. Driving force on the one hand is the telecommunication industry, in particular mobile phones and hand held devices and on the other hand by developments in networking and server applications.

The effect of this is a transition in assembly technologies from through hole technology in the past, to surface mount, up to latest technologies with BGAs, CSPs, MCM or Flip Chip. (See Figure 1.)

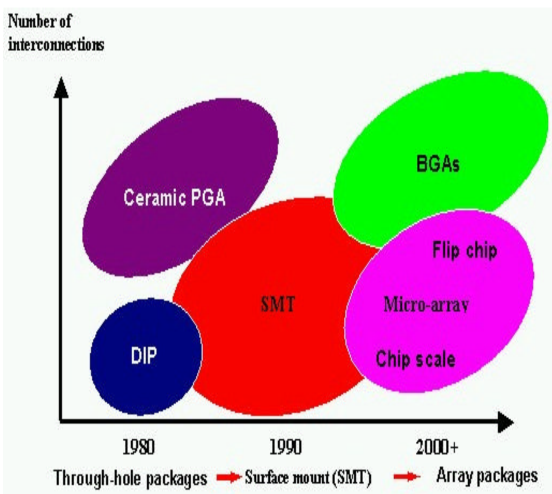

Figure 1 - The Change of Component Type During the Last Decades, Going Along with the Changes in Assembly Techniques

With continuing changes in assembly technologies, the demands of the final finish of a PWB increases, where HASL as final surface was first choice for through hole assembly and for the beginning of SMT.

With an increase of the interconnect density combined with an increase of fine pitch, HASL reached its technical limits.

Features of HASL are variations in tin/lead thickness distribution - from 1µm up to 50µm and high thermal stress to the PCB while processing / dipping into a molten solder alloy. This kind of processing is leading to warpage. Features like these implemented the move to alternative coatings; HASL could not fulfil all technical requirements for assembly anymore.

Due to technical demands, new surface finishes were required. First choice for multiple reflow was electroless nickel immersion gold - ENIG. This finish has world wide a high acceptance on the market, with benefits unique to ENIG.

These days other finishes are moving into the market with the same advantage of planar surfaces for multiple reflow cycling, as there are electroless palladium, immersion tin and immersion silver.

All these HASL alternatives combine low thermal operating temperatures during processing and planar surfaces for assembly.

Generations of Final Finishes

Taking the example of mobile phones, using first generation surface finishes, key contacts where covered by printing carbon paste and solderable pads were covered in either HASL or OSP.

Due to pressure from cost savings and technical demands, a new surface finish was required. ENIG fulfilled all demands, requested for these technologies. The great advantage over the existing final finishes; ENIG is applied on keypads for contact switching at the same time, as for component pads for soldering. This advantage saved additional manufacturing steps in assembly production as carbon paste printing. (See Figure 2.)

Currently, the latest generations of final finishes for high density interconnect PWBs focuses now on different aspects. Where the move from uneven HASL to the planar ENIG was also a move to a different technique to apply the final coating – dipping into a molten metal compared to electroless and immersion. Today's generation for surface finishes goes more in detail into the characteristic of the strength of the intermetallic compound (IMC), which is being formed between the substrate and the solder. With today's pad dimensions getting smaller, the joint reliability is more in focus.

Technology	2000	2002	2004
Substrate			
Material	Build-up	Build-up	Build-up
Area (cm^2)	34	30	27
Layer count (No.)	1+2+1/1+4+1/6-8	1+4+1	2+2+2
Min pad/via diameter (µm)	200/100	175/100	125/75
Min line/space (µm)	75/75	50/75	50/50
Integrated passives	No	No	Yes
Assembly			
Total component count	310	305	310
Ave component density (Component/cm^2)	9.4	9.9	10.1
Pad density (No./cm^2)	13.2	14.4	15
Smallest pitch peripheral (mm)	-	-	-
Array (mm)	0.5	0.5	0.4

Source: BPA 1999

Figure 2 - The Roadmap for High -End Mobile Phones with Dimensions of Pad Sizes for the Next Few Years (?)

Introduction of Secondary Image Technology
Secondary image technology combines the application of two final finishes, ENIG and OSP, on the same PCB. (See Figure 3.)

- ENIG = key pads, contact switching, soldering, Al-wire bonding and electrical testing
- OSP = soldering of BGAs / CSPs

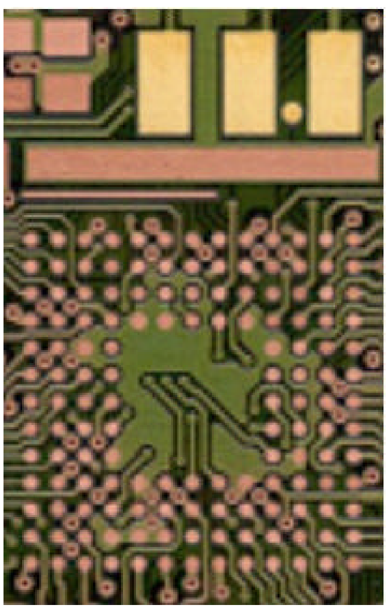

Figure 3 – NiAu Next to OSP on One Board

The secondary image technology shows the great advantage of achieving higher reliability of solder joint integrity especially for BGAs / CSPs, than the previous NiAu technique. The higher reliability is based on OSP coated copper pads with CuSn-intermetallic compared to ENIG plated pads with NiSn-intermetallic.

In the past assemblers of CSPs and BGAs have reported solder joint fractures at the Nickel / solder alloy interface for conventional NiAu finishes. This is commonly referred as "Interfacial or Brittle fracture".

This interfacial fracture is a clean cleavage between the solder and the Nickel metallization. This phenomenon is the driving force for the SIT technology.

The Secondary Image Process
ENIG, as key of the secondary image technology (SIT), combines the tasks coming from the dry film application prior to ENIG and the tasks from the OSP process followed as final step.

Figure 4 is showing the comparison of the "pure" ENIG process flow vs. the secondary image technology (SIT). The left side of the picture shows the typical process flow for ENIG, solder mask application, followed directly by ENIG. On the right hand side the SIT process is shown. After soldermask application, those pads / areas will be covered with dry film, which will not be plated with ENIG. After ENIG plating, followed by dry film stripping, the boards will finally be coated by OSP.

The process flow of SIT shows very clearly the tasks of this application.

- First task, the dry film type and application needs to be optimized to cope with the temperatures and chemistries of the SIT-ENIG process.
- Second task, the SIT-ENIG process needs to be set to lowest temperatures for an optimum resistance of the dry film at this environment.
- Third task, having the dry film application optimized, same as the SIT-ENIG process, the

dry film needs to be stripped without influencing the soldermask.

- And finally the OSP process needs to be compatible with ENIG plated pads connected to pure copper pads, without attacking the ENIG layer or having a too high etch rate at copper areas.

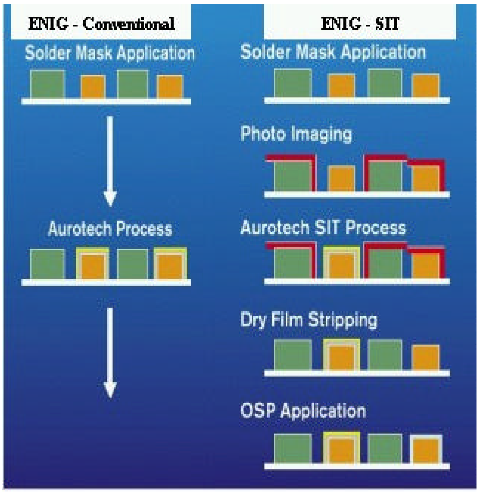

Figure 4 - The Comparison of the "Pure" ENIG Process Flow Vs. the Secondary Image Technology (SIT)

Process Control

Control Equipment ENIG - SIT Chemistry

Figure 5 shows a fully automatic control unit used to monitor the electroless Nickel bath in the SIT process. It supervises the nickel concentration and the pH value and keeps these parameters in a tight range. Both parameters have mayor influence to the depositioning quality of the Nickel layer; therefore they are controlled and monitored in the narrow range of a few digits.

Figure 5 - The Control Unit[1]

The Nickel measurement is based on a photometric method, at a wavelength, which is not influenced by dry film leach out.

The pH value is measure directly by a pH electrode. (See Figure 6.)

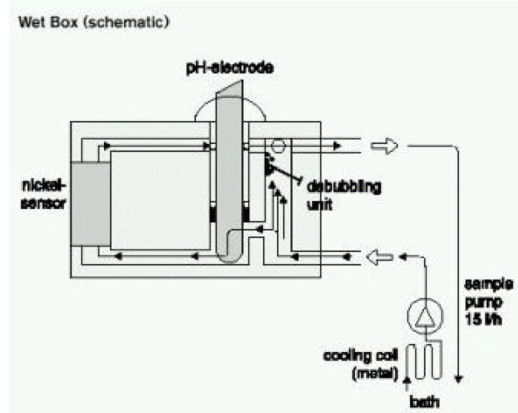

Figure 6 - The Schematic Principle of the Wet Box[1]

Stabilizer Controller - OnlineController

This fully automatic stabilizer controller analyses and adjusts the inorganic stabilizer. For its importance to avoid tooling hole plating or extraneous plating in areas where dry film under cut occurs or in tight gaps between solder mask and dry film, each measurement and each add is documented. These files can be downloaded from the computer control device of the online controller as quality report. (See Figure 7.)

Figure 7 - The Fully Automatic Online Controller

As clearly seen on Figure 8, taking the online controller only for measuring, the concentration dropped a few times below the critical value for extraneous plating. This phenomenon is known to production, where tooling hole plating or extraneous plating only occurs random. After setting the online controller to auto dosing the concentration stayed stable at a higher range.

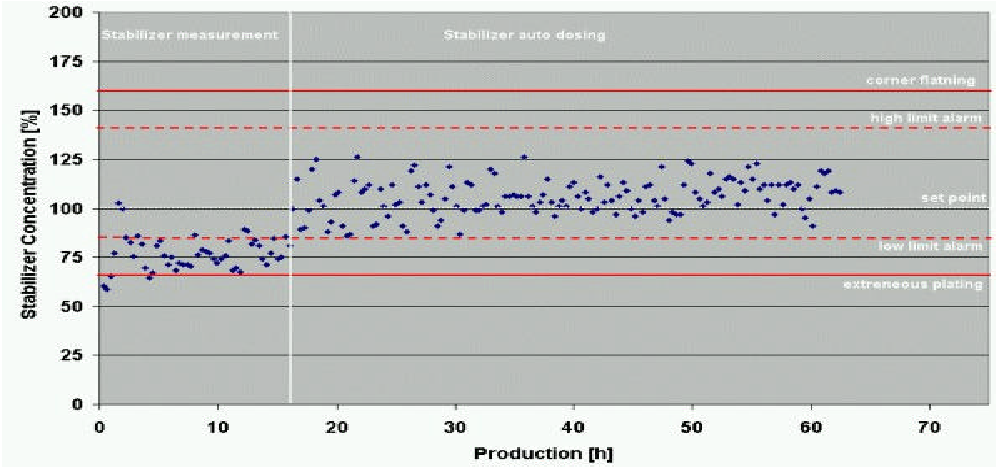

Figure 8 - The Data Points of the Stabilizer Measurements/Concentration for 60h Production

Anodic Protection System for Stainless Steel Parts

The stainless steel protection system produces a permanent anodic protection potential. It is designed for use with stainless steel tanks, heaters and piping systems for electroless Nickel solutions. (See Figure 9.)

All stainless steel parts, which get in contact with the electroless Nickel solution, will be passivated by using e.g. diluted nitric acid.

This passivation of stainless steel parts is maintained by the potential, provided from the protection system. An electronically controlled potential, by an internal reference standard (IRS) maintains the same protective potential across the whole connected equipment. This reference standard (IRS) is not influenced by high temperature or high humidity compared to the use of an external reference standard. The IRS ensures high stability over break down of the anodic protection and therefore a maximum on safety against plate out on stainless steel parts. It also protects from damages on stainless steel parts, by avoiding an incorrect high anodic potential, which damages the plating tank and dissolves stainless steel parts into the electroless Nickel solution.

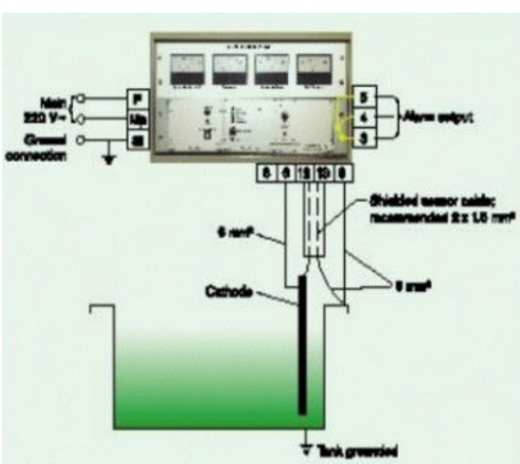

Figure 9 - The Electrical Connection of the Protektosat

The protection unit ensures a maximum of both stability and production performance.

Physical Properties of the Nickel Deposit

Electroless nickel layers with a Phosphorous content between 7-10% are known to industry as deposits with perfect compatibility to the immersion process of the Gold electrolyte. These deposits are robust and proven in millions of assemblies during the last decades. (See Figures 10 and 11.)

Density	8 g/cm³
P-Content	7 - 10 %
Hardness	550 HV
Ductility	< 1 %
Internal Stress	tensile stress
Electrical Resistance	75 - 85 Ohm/cm ferromagnetic to nonmagnetic
Structure	amorphous to finest polycrystalline, depends on P-content

Figure 10 - Physical Properties of the Electroless SIT Nickel Deposit

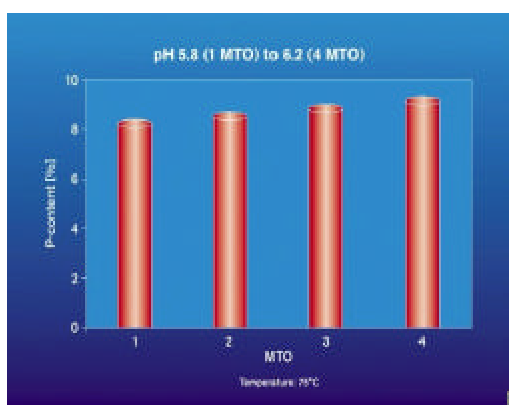

Figure 11 - The Constant Phosphorous Contend in the Nickel Deposit coming from a SIT Nickel Bath

This constant composition of the Nickel layer is the base for a constant immersion Gold reaction, with constant Gold thicknesses.

Solderability of the Nickel/Gold Layer

Solder Spread Test

A specified amount of solder paste is printed with a stencil (thickness 120 µm) onto the surface of the PCB and heated in a reflow oven to melting point or higher (see Figure 12). The solder becomes liquid and spreads out depending on the wettability of the surface. After solidifying the spread out of the solder is measured.

With a mathematical formula the wetting angle is calculated by use of the amount of printed solder (F 1 mm, height 120 µm) and the spread diameter.

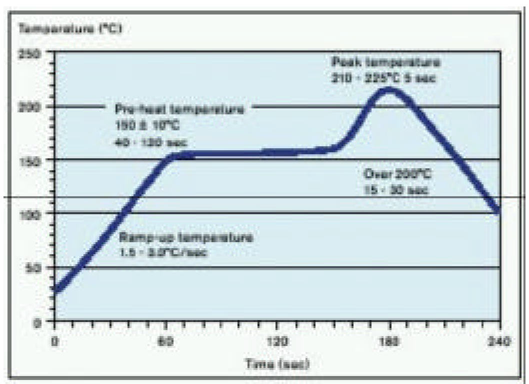

Figure 12 - Reflow Temperature Profile for Soldering – Solder Spread Test

Function of the Solder Spread Test

Test to evaluate the wettability of surface finishes on PCBs.

Advantages

- Practical test with solder paste used in assembly
- Low activated fluxes
- Independent of layout design
- Quantitative

Practical Test

1. Solder paste is printed with a stencil (thickness 120 µm) onto the top of the surface of the PCB. (See Figure 13.)

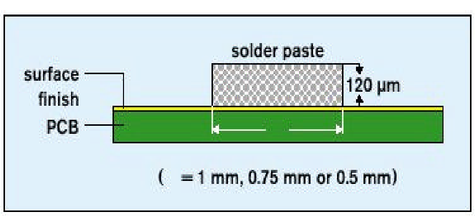

Figure 13 – Solder Paste on Top of the Surface

2. The solder paste printed sample will be heated in a reflow oven up to melting point or higher.
3. The solder becomes liquid and spreads out, depending on the surface wettability. The molten solder represents the liquid phase (L). The solid phase (S) corresponds to the surface finish of the PCB. The vapor phase (V) corresponds to flux evaporation. (See Figure 14.)

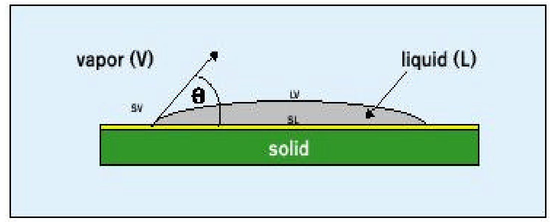

Figure 14 – Solder Becomes Liquid and Spreads Out

4. After melting the solder spread is measured and the wetting angle is calculated by a mathematical formula.

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

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

where Θ = arcos

γ_{LV} = Solder / flux surface tension

γ_{SV} = Finish / flux

γ_{SL} = Finish / solder

Surface Tension

The wetting angle Θ is directly linked to the surface tension. Therefore it reflects the wetting quality. When wetting quality increases, the contact angle decreases.

Therefore, the wettability and solderability of a surface finish can easily be determined by the value of the wetting angle. (See Figures 15 and 16.)

In difference to dip and wetting balance test, the solder spread test is a real practical test and can be applied to examine production boards. Tests are being done with the actual solder paste, which is used for assembly. This test is independent of the design of the PCB.

By calculation of the wetting angle, there is a quantitative criteria for the wettability of the surface.

Figure 15 – Showing a Good Wetted Surface with a Large Spread of Molten Solder after Reflow

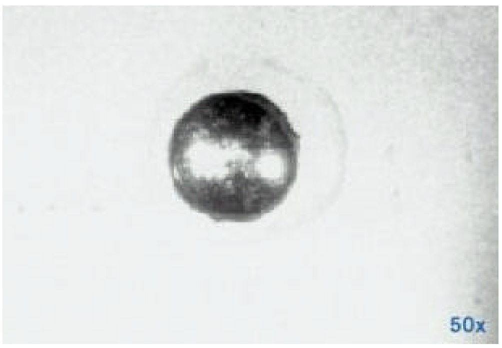

Figure 16 – Showing a Poor Wetting Surface with a Smaller Spread of Molten after Reflow

Solder Spread Results

Dry film layout related or due to electrical testing, not all pads for soldering will be done with OSP. There still might be some pads, covered by ENIG that need to be soldered. In Figure 17 it is clearly seen, that the final OSP process has no influence to the wettability of the tested SIT Nickel/Gold layer.

An artificial ageing for 4h at 155°C has no influence to the good wettability of the tested SIT – ENIG layer. The final OSP process does not interfere with the good performance, the wettability of the ENIG layer did not change. (See Figure 18.)

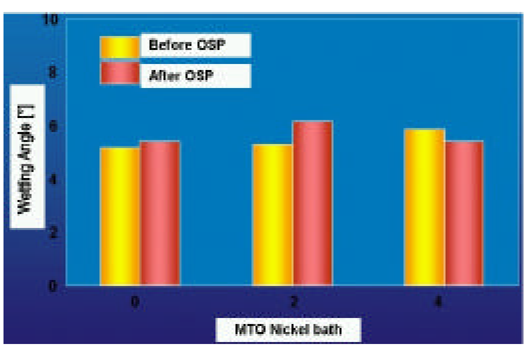

Figure 17 - The Solder Spread Results on SIT after the OSP Process

Figure 18 - Influence for Dry Heat to Wettability

Al-wire bonding on Two Different Gold Finishes, both Dry Film Contaminated

As seen on Figure 19, for a finalized PCB after OSP application, the al-wire bond strength is not influenced by dry heat. This is clearly shown for two different kinds of GOLD bath. None of the two Gold baths were influenced for Al-wire bonding by leach out of the dry film. Both gold layers perform excellent, even after dry heat conditioning of 4hrs at 155°C.

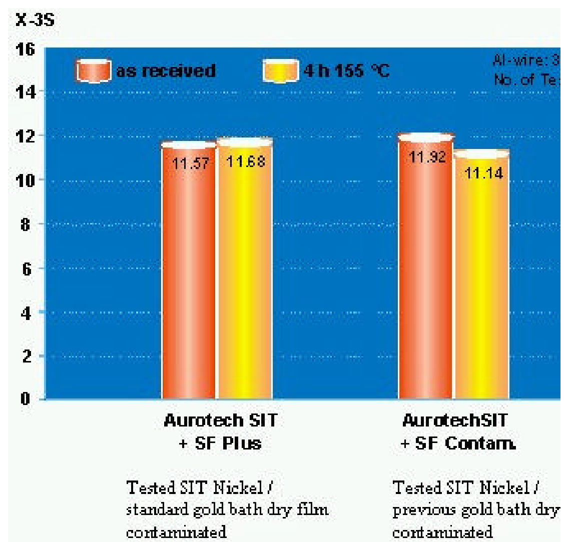

Figure 19 - Al-wire Bonding Pull Forces, for Tested SIT Comparing two Different Gold Baths –Dry Film Contaminated

Cross Section and Top View of the Tested SIT Layer, Before and After OSP Application

Figure 20 shows the tested SIT layer before and after OSP. The fine grain structure of the Nickel layer withstands the OSP process without being influenced. This is clearly seen at the cross section and at top view of the layer. No "spikes" are penetrated by the micro etch of the OSP process into the tested SIT layer. Perfect compatibility of the mid range Phosphorous Nickel layer with the immersion Gold reaction, combined with perfect resistance to the micro etches of the OSP process.

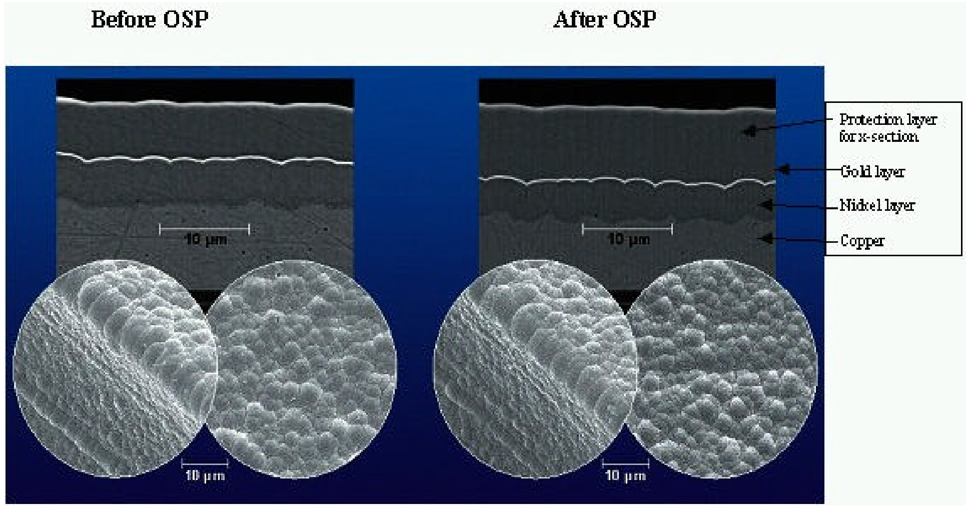

Figure 20 - Tested SIT Layer Before and After OSP

Summary

Final finishing processes are influenced by changes in technology, and ENIG as final process step is strongly influenced by these changes in technology.

The design of the SIT -ENIG process focuses on the smaller plating area created by the dry film, which is not designed for the ENIG process. These challenges required a new activator system, to cope with the reduced plating area and a lower Nickel bath temperature to cope with dry film application.

As process control is essential for quality and yield, PCBs produced in secondary image technology will add a dry film application and an OSP process to the complexity of a PCB. How well these three processes get on with each other, defines quality and especially yield.

Acknowledgements

1. Aurotech Nickel Controller III