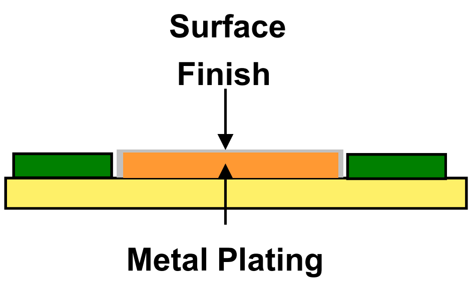
What is a Surface Finish?

A *surface finish* may be defined as a “coating” located at the outermost layer of a PCB
(which is dissolved into the solder paste upon reflow or wave soldering)

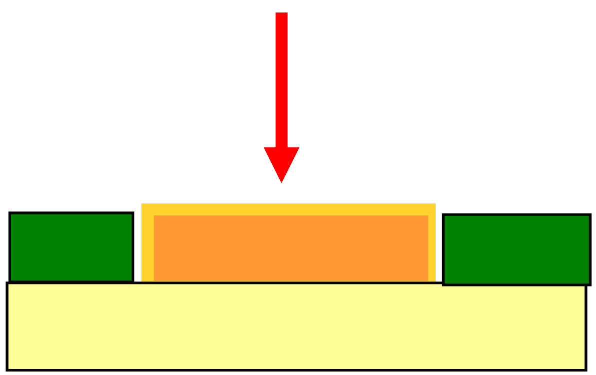
Two Main Types of Coatings
- Metallic
- Organic

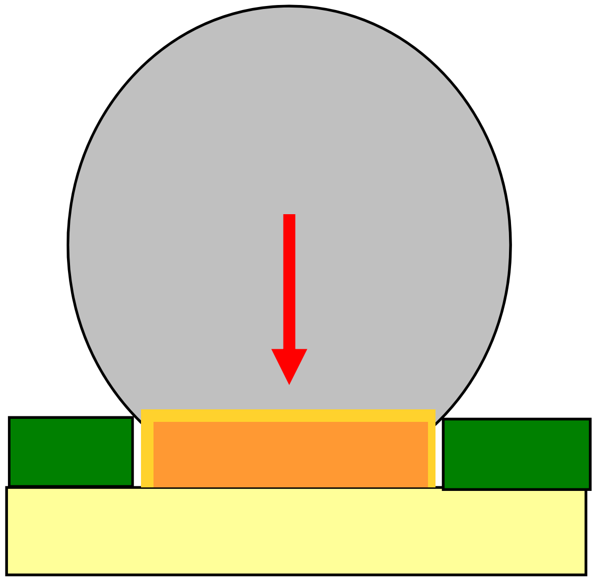


Note:
(Base) Metal Plating is typically copper (in most cases).
But, in a few (like ENIG) the Nickel-phosphorous
(5-12% P co-deposit) serves as the solderable surface.

Why use a Surface Finish?

The surface finish protects the PCB Surface Copper until it's Assembled

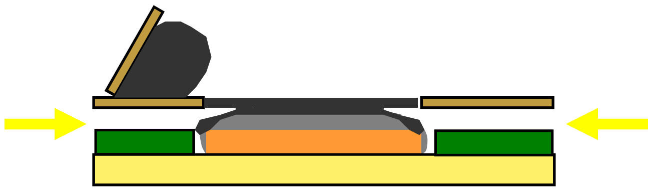


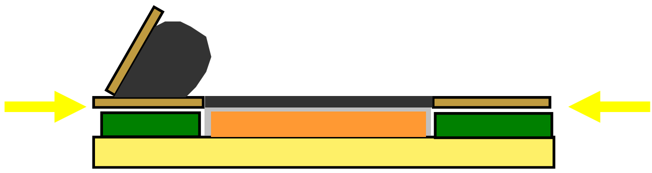


How to Select a Proper Surface Finish?

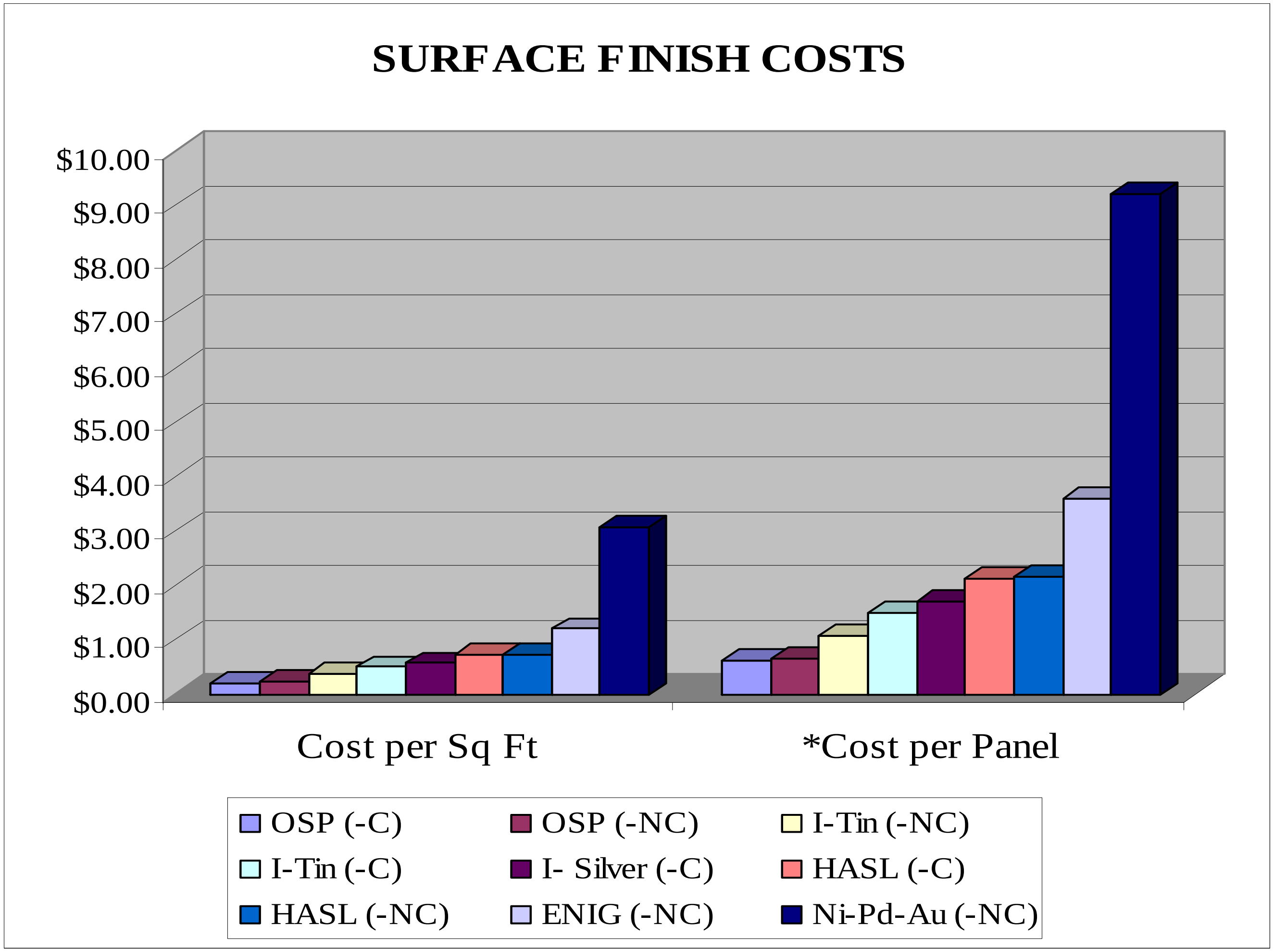
Reasons for Finishes

- Coplanarity (See Below)
- Lead-Free (RoHS and WEEE) (RoHS 5 or RoHS 6)
- Contact Resistance (Compression Connection)
- Tarnish Resistance
- Press-fit Requirements
- Wear Resistance
- Hardness
- Chemical Resistance
- Wire Bonding (Au or Al?)
- Cost
- Compatibility with other Surface Finishes





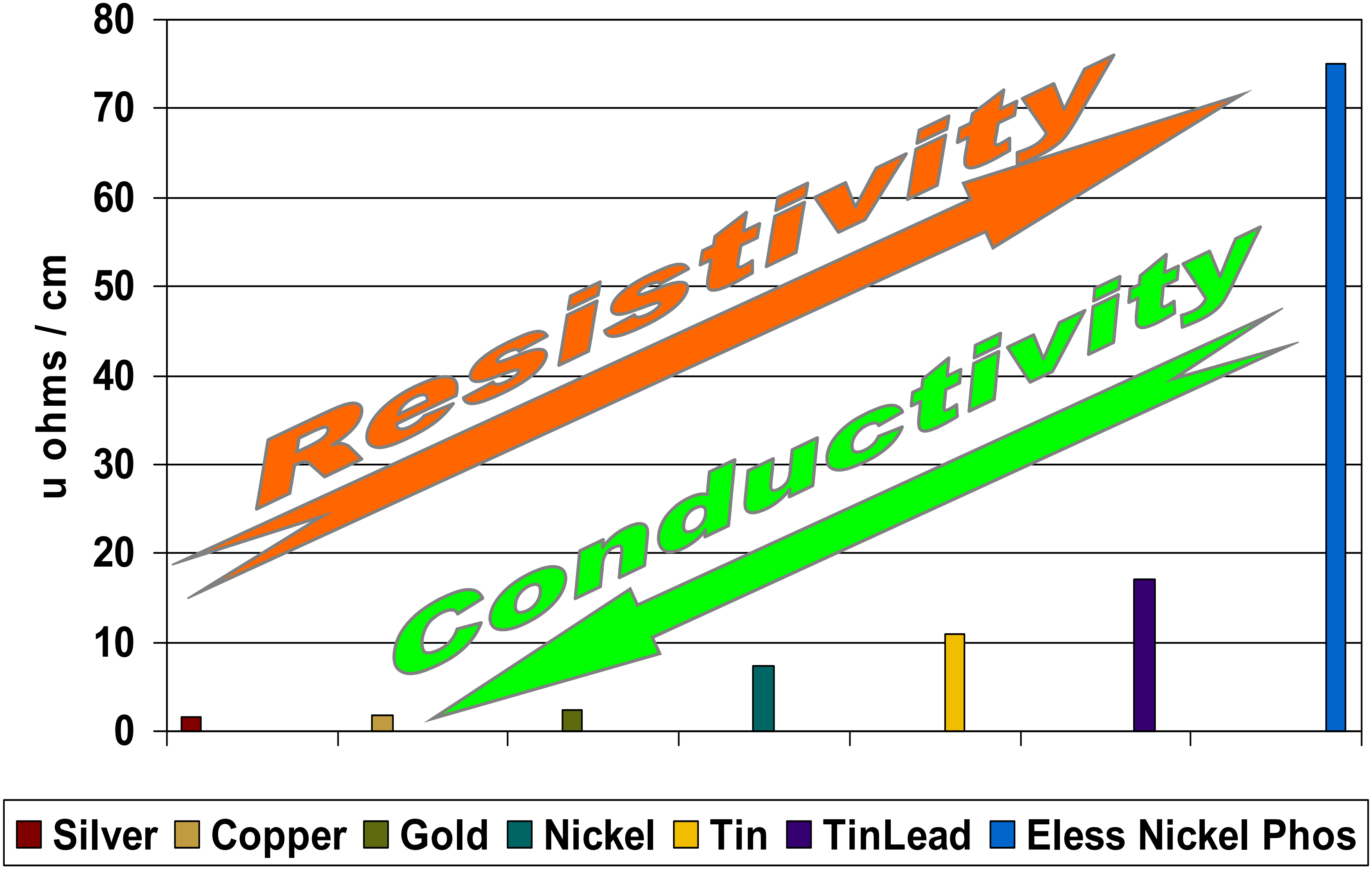
Surface Finish Cost Comparison



-C: Conveyorized Process
-NC: Non-Conveyorized Process

***Source: Cisco Systems**

Resistivity of PCB Metals



Source: *1

Galvanic Series - Electromotive Force

Gold + 1.4 Volts
Platinum
Iridium
Palladium
Silver + 0.80
Mercury
Ruthenium
Copper + 0.344
Bismuth
Antimony
Tungsten
Hydrogen **0.0 Volts**
Lead
Tin
Molydenum
Nickel - 0.25

Group I	Group II	Group III	Group IV	Group V
Magnesium	Aluminum 2S	Lead-tin Solder	Copper-Nickel	Graphite
Zinc	Cadmium	Lead	Monel	Gold
Galvanic Steel	Aluminum 17ST	Nickel	Silver Solder	Platinum
	Steel	Brass	Nickel (passive)	
	Iron	Copper	Stainless Steel	

Metals can cause noise voltage due to a galvanic reaction between two metals. (Positive ions from one metal can be transferred to the other)

The farther apart the metals are in the series, the faster the rate of corrosion (fretting). When dissimilar metals must be combined, try to use metals from the same series group.

Surface Finish Types

Metallic Coatings:

- ***HASL (Hot Air Solder Level)***
- ***ENIG (Electroless Nickel/Immersion Gold)***
- ***Electrolytic Ni /Au (Electrolytic Nickel / Gold)***
- ***Imm Ag (Immersion Silver)***
- ***Imm Sn (Immersion Tin)***
- ***Reflow Tin/Lead***
- ***Electroless Nickel/Palladium-Immersion Gold***
- ***Selective Solder Strip (SSS)***
- ***Sn Ni (Tin-Nickel)***
- ***Unfused Tin/Lead***
- ***Electroless Nickel-Immersion Palladium***

Not common

Organic Coatings:

- ***OSP (Organic Solderability Preservative)***
- ***Carbon Ink (Screened on)***

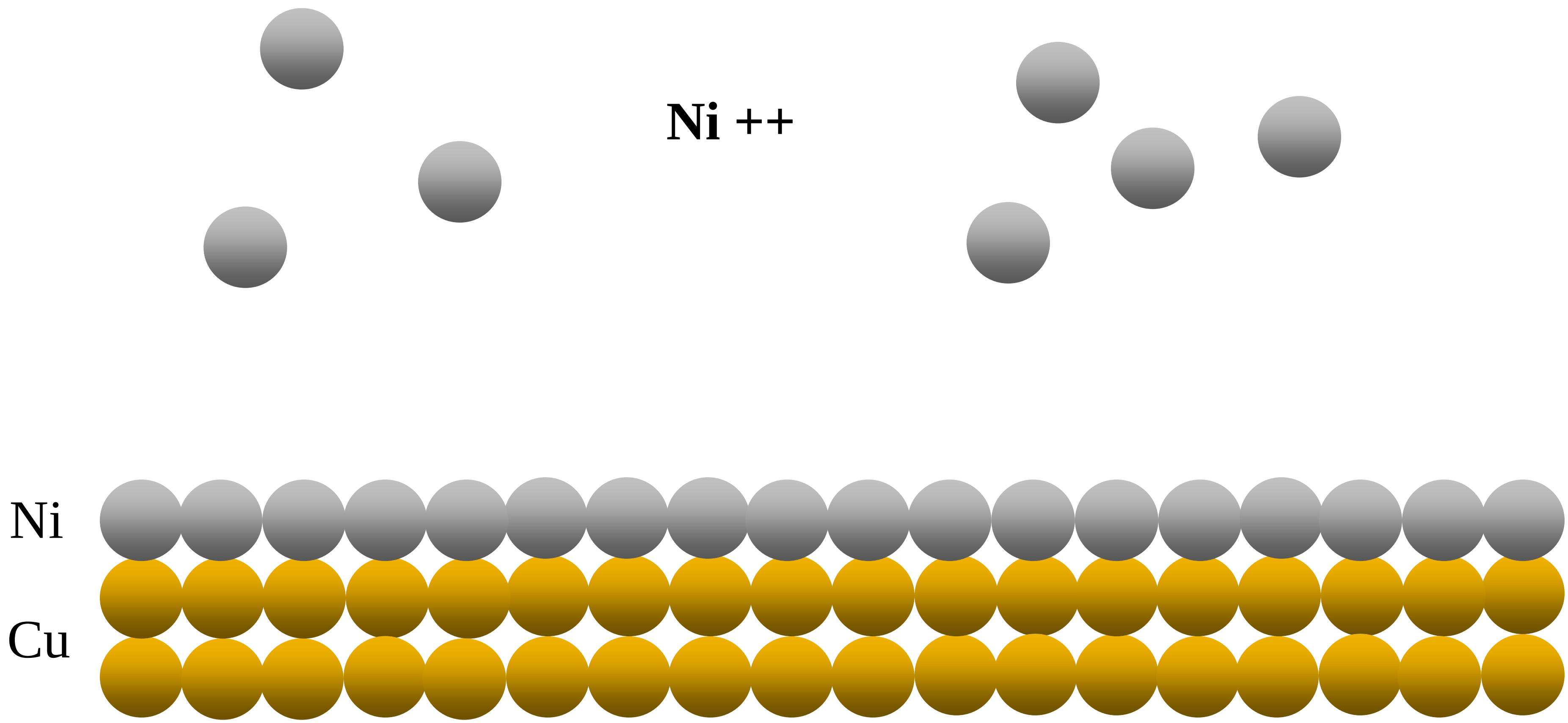
(Or combinations of the two - OSP and Selective ENIG or Hard Gold)

Electroless Plating (Only)

- ***Process is nonelectrolytic***. *(No electrical current applied)*
- ***Metal ions are reduced** by chemicals in the plating solutions.*
- ***Deposits** are from a process that continues once it is started (autocatalytic).*
- ***A uniform coating** that can be applied on irregularly shaped features.*
- ***Applied by rack** (in a "batch" process).*
- ***Deposits are generally harder**, more brittle and more uniform than electroplated deposits.*

Electroless Plating

- ***Electroless Nickel (Depicted Below)***



Electroless Ni / Electroless Gold

Typical Thickness: 0.25 – 1.3 µm (10 - 50 µ in) Electroless Gold over 3 – 6 µm (120 - 240 µ in) Electroless Nickel

More Common in the Packaging Industry

ADVANTAGES

+ **Gold Wire-Bondable**
+ **Planar Surface**
+ **Consistent Thicknesses**
+ **Multiple Thermal Cycles**
+ **Long Shelf Life**

DISADVANTAGES

- **Solder Joint Embrittlement Potential When Incorrectly Specified**
- **Ni/Sn Solderjoint**
- **Difficult to Control**
- **Cannot be Reworked by Fab**
- **Expensive**
- **Lab Support Extensive**

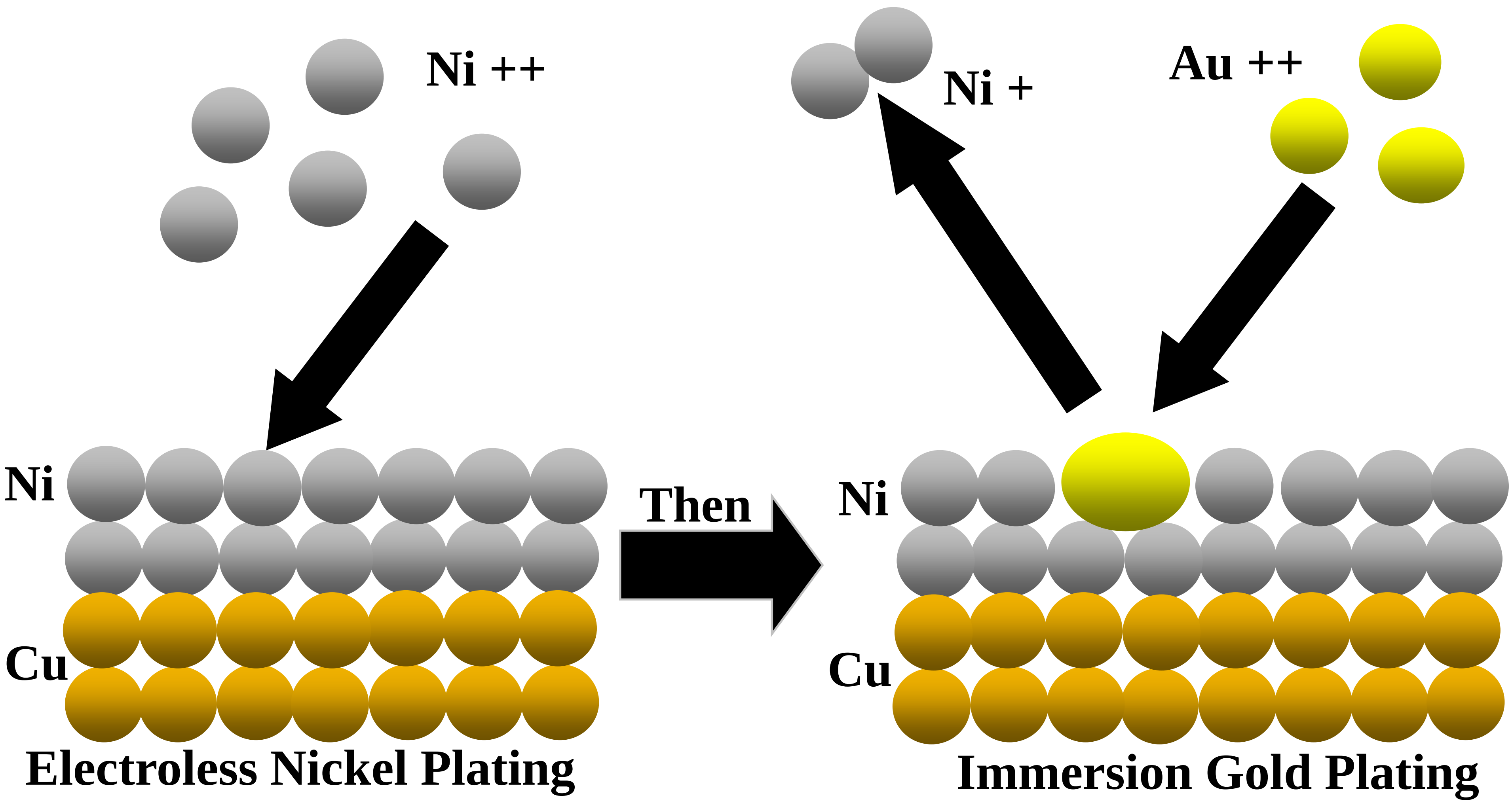
ENIG (Electroless and Immersion Plating)

Typical Equipment used for the Plating of ENIG

Automated ENIG Plating Line (PAL)

Electroless and Immersion Plating

- ***ENIG (Depicted Below)***
- ***Electroless Ni/Electroless Palladium-Immersion Gold***



ENIG (Electroless Nickel/Immersion Gold)

Typical Thickness: 0.05 - 0.23 µm (2 - 9 µ in) Gold over 2.5 - 5.0 µm (100 – 200 µ in) Electroless Nickel

ADVANTAGES

+ **Planar Surface**
+ **Consistent Thicknesses**
+ **Multiple Thermal Cycles**
+ **Long Shelf Life**
+ **Solders Easily**
+ **Good for Fine Pitch Product**

DISADVANTAGES

- **Not Gold Wire-Bondable**
- **Expensive**
- **Suspect Issues with Grid Array Packages (Ni/Sn Solderjoint)**
- **Waste Treatment of Nickel**
- **Cannot be Reworked at PCB Fabricator**
- **Waste Soldermask Compatibility**
- **Not Optimal for Higher Speed Signals**
- **Lab Support Extensive**

Electroless Ni/Palladium-Immersion Gold

ENIPIG

Typical Thickness: 0.02 – 0.05 µm (1 - 2 µ in) Gold over 0.2 – 0.6 µm (8 - 24 µ in) Pd over 2.5 – 5 µm (100 - 200 µ in) Nickel

ADVANTAGES

+ Palladium Prevents Nickel from Passivating in the Presence of the “Porous”Gold Deposit
+ Aluminum Wire Bondable
+ Flat / Planar Surface
+ Good for Fine Pitch Product
+ High Reliability / Military

DISADVANTAGES

- Additional Process Step for PCB Fabricator; Added Cost Results
- Possibly Issues with Solder Pot on Wave
- Waste Treatment
- Ni/Sn Solderjoint
- Lab Support Extensive
- Very Expensive

Immersion Plating

- ***Chemical reaction*** *is used to apply the coating.*

- ***Metal ions*** *are reduced by chemicals into the plating solutions.*

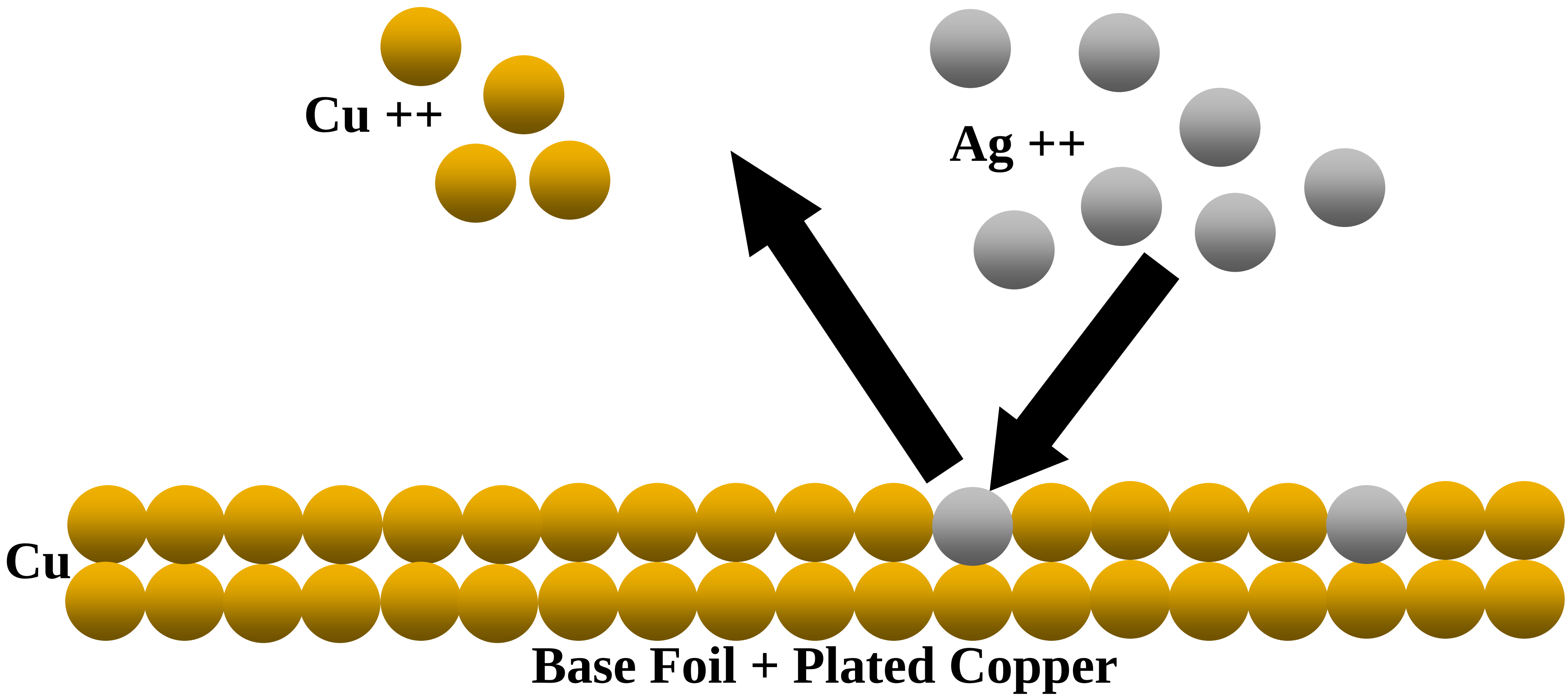
- *Then a* ***uniform coating*** *can then applied to irregularly shaped features.*

- ***Applied by a rack*** *(in a "batch" process).*

Immersion Plating

- ***Silver (Depicted Below)***
- ***Tin***

Galvanic Displacement - Simply an Exchange of Copper and Silver Atoms; No Reducing Agent Required



Immersion Silver Plating

Typical Equipment used for Horizontal Immersion Silver Plating

Conveyorized Horizontal Immersion Silver Plating Line

Smaller Proto Shops may use a Vertical Batch Process

Immersion Ag (Immersion Silver)

Typical Thickness: 0.15 – 0.45 µm (6 – 18 µ in)

ADVANTAGES

- + **Good for Fine Pitch Product**
- + **Planar Surface**
- + **Inexpensive**
- + **Short, Easy Process Cycle**
- + **Cu/Sn Solderjoint**
- + **Doesn’t Affect Hole Size**
- + **Can be reworked/Re-applied by the PCB Fabricator**

DISADVANTAGES

- - **High Friction Coefficient; Not Suited for Press-Pin Insertion (Ni-Au Pins)**
- - **Some Difficulty Plating Into uVias with Aspect Ratios > .75:1**
- - **Micro-voids Concerns**
- - **Corrosion Must be Controlled (Sensitive to Cl- and S-)**
- - **Handling Concerns**

Immersion Tin Plating

Typical Equipment used for the Immersion Tin Plating

Automated Immersion Tin Plating Line

Immersion Sn (Immersion Tin)

Typical Thickness: 0.6 – 1.6µm (25 - 60 µ in)

ADVANTAGES

- + **Reliability Testing Results Comparable to ENIG**
- + **Good for Fine Pitch Product**
- + **Planar Surface**
- + **Cu/Sn Solderjoint**
- + **Inexpensive**

DISADVANTAGES

- \- **Panels Must be Routed and Tested Prior to Coating**
- \- **Contains Thiourea, a Known Carcinogen**
- \- **Limited Rework Cycles at CM**
- \- **Horizontal Process Needs Nitrogen Blanket**
- \- **Too Viscous for Small Holes; Backpanels Only**
- \- **Handling Concerns**

Immersion Palladium (Pd)

Typical Thickness: 0.1 µm – 10 µm (4 - 400 µ in)

ADVANTAGES	**DISADVANTAGES**
+ **Good Solderability**	- **Availability**
+ **Cu/Sn Solderjoint**	- **Possibly Issues with Solder Pot on Wave**
+ **Used in Automotive Sector**	- **Handling Concerns**

Electrolytic Plating

- ***Electrolytic plating*** *is achieved by passing an electric current through a solution containing dissolved metal ions.*

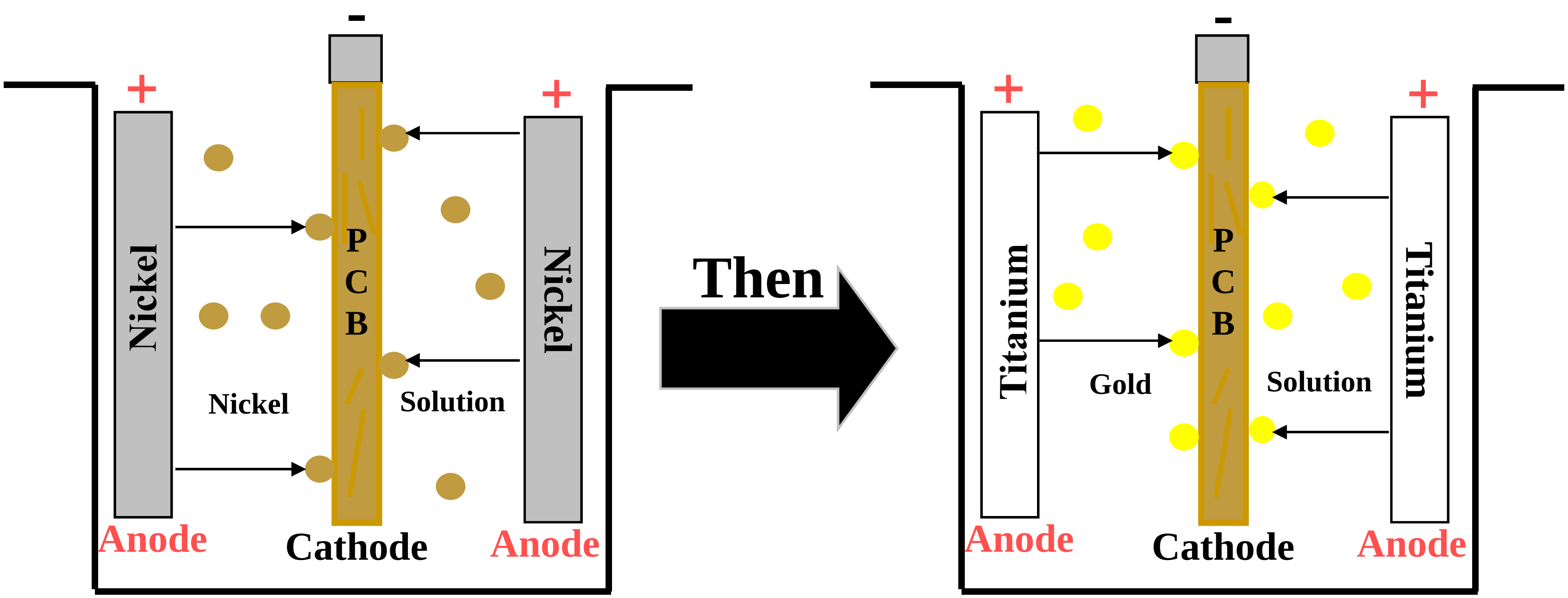
- *The PCB* ***panel then serves as the cathode*** *in an electrochemical cell, attracting the dissolved metal ions from the solution.*

- *The* **process** *includes* **controlling** *of plating parameters including* ***voltage and amperage, temperature, time, and purity of bath solutions****.*

- *Operators* ***rack panels*** *that carry the part from bath to bath (in a* ***"batch"*** *process).*

Electrolytic Plating

- ***Electrolytic Nickel-Gold (Depicted Below)***



Electrolytic Nickel Plating

Electrolytic Gold Plating (Over Nickel)

Electrolytic Plating of Nickel an Gold

Typical Equipment used for the Electrolytic Plating of Nickel and Gold

Automated Nickel and Gold Plating Line
PAL and TAB Lines Shown

Electrolytic (Hard) Nickel / Gold

Typical SMT Thickness: 0.25 – 0.8 µm (10 - 30 µ in) Gold over 2.5 – 8 µm (100 - 300 µ in) Nickel

ADVANTAGES

+ **Plated Ni/Au Can be Used as an Etch Resist**
+ **Available for "Mixed Technology" Products**
+ **Au Wire-Bondable**
+ **Long Shelf Life**

DISADVANTAGES

- **Exposed Cu Sidewalls**
- **Nickel Slivers Likely After S.E.S.**
- **Costly Process**
- **Poor throwing Power**

Typical GF Thickness: 0.8 – 1.5 µm (30 - 60 µ in) Hard Gold over 2.5 – 8 µm (100 - 300 µ in) Nickel

Selective Solder Plating

Typical Equipment used for the Solder Plating

Manual Tin-Lead Plating Line

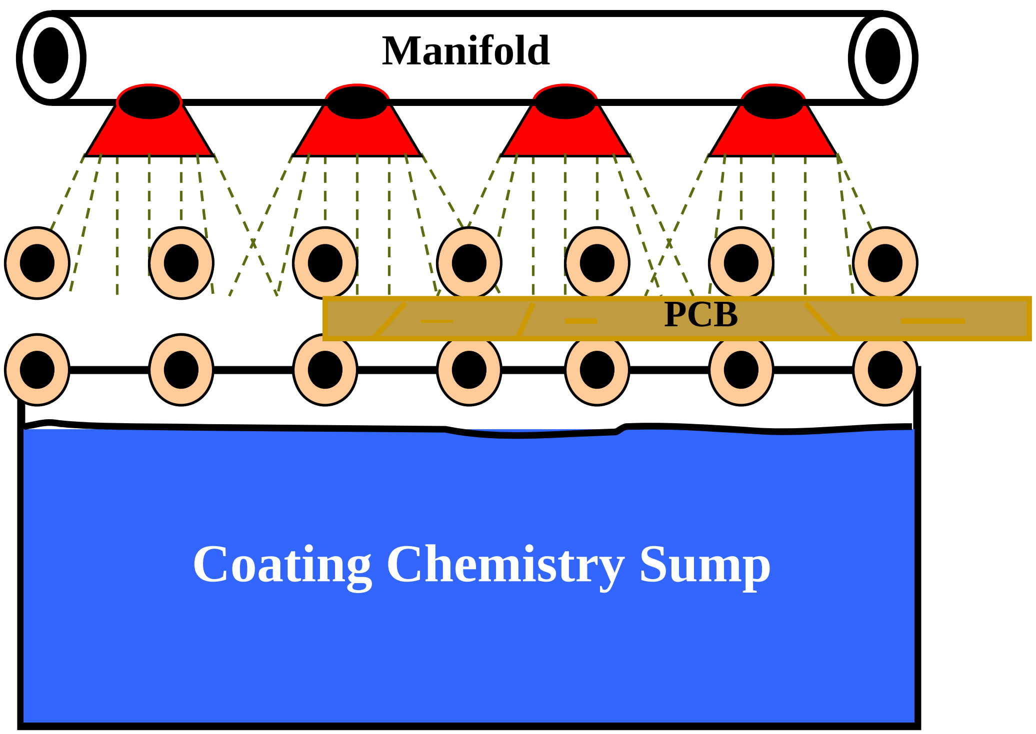
Selective Solder Strip (SSS)

Typical Thickness: 7 – 20 µm (300 - 800 µ in)

ADVANTAGES	**DISADVANTAGES**
+ **Hot Bar Reflow for TAB Devices** + **Alternative to HASL on Thick Product**	- **Multiple Resist and Photo Cycles** - **Difficulty in Controlling Plated Sn/Pb Thickness** - **Overlap (Butt) Line Difficult to Control** - **Expensive** - **Contains Lead**

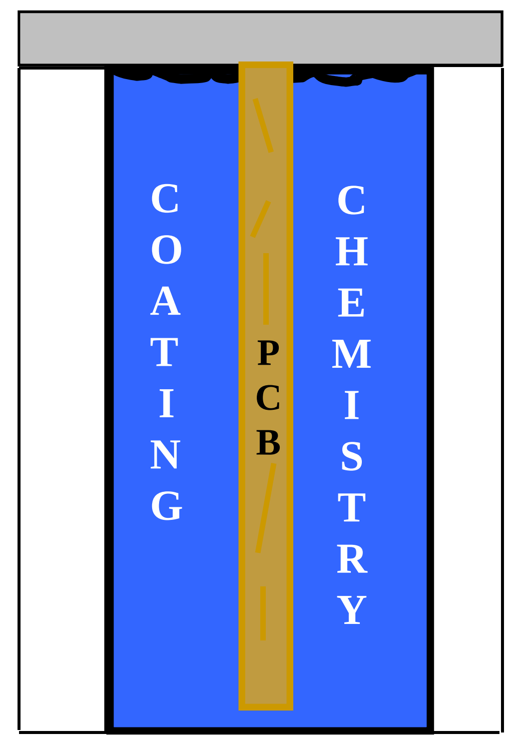
Dip Coatings

- ***HASL (Hot Air Solder Level)***
- ***OSP (Organic Solderability Preservative)***



Conveyorized Dip Module

OR



Vertical Dip Tank

OSP (Organic Solderability Preservative)

Typical Equipment used for the Coating of OSP

Conveyorized Horizontal OSP and Pre-Flux Line

OSP (Organic Solderability Preservative)

(Entek 106A(X), Shikoku Glicote SMD-E2L, Tamura Solderite)

Typical Thickness: 0.2 - 0.6 µm (8 - 24 µ in)

ADVANTAGES

+ Flat, Coplanar pads
+ Reworkable (at PCB Fabricator)
+ Doesn't Affect Finished Hole Size
+ Short, Easy Process
+ Low Cost
+ Benign to Soldermask
+ Cu/Sn Solderjoint

DISADVANTAGES

- Not a "Drop-In" Process (assy adjustments are required)
- Difficult to Inspect
- Questions Over Reliability of Exposed Copper After Assembly
- Limited Thermal Cycles
- Reworked at CM?; Sensitive to Some Solvents Used for Misprint Cleaning
- Limited Shelf life
- Panels Need to be Routed and Tested Prior to Coating (ET Probe Issue)
- Handling Concerns

High Temp OSP (Organic Solderability Preservative)

(Entek 106A HT, Shikoku Glicote SMD-F1, Tamura WPF-21)

Typical Thickness: 0.2 - 0.6 µm (8 - 24 µ in)

ADVANTAGES

- + **Flat, Coplanar pads**
- + **Reworkable (by Fabricator)**
- + **Short, Easy Process**
- + **Benign to Soldermask**
- + **Cu/Sn Solderjoint**

DISADVANTAGES

- \- **Availability**
- \- **Not a "Drop-In" Process (assy adjustments are required)**
- \- **Difficult to Inspect**
- \- **Questions Over Reliability of Exposed Copper After Assembly**
- \- **Limited Thermal Cycles**
- \- **Reworked at CM?; Sensitive to Some Solvents Used for Misprint Cleaning**
- \- **Limited Shelf life**
- \- **Panels Need to be Routed and Tested Prior to Coating (ET Probe Issue)**
- \- **Copper Dissolution into Solder Volume**
- \- **Handling Concerns**

OSP and Selective ENIG

ADVANTAGES

- \+ **Advantages of OSP for SMT**
- \+ **Advantages of ENIG in through-holes**
- \+ **Cu/Sn Solderjoint**
- \+ **Can be used in Lead-Free**

DISADVANTAGES

- \- **Complex process for PCB suppliers**
- \- **Larger**

Currently being used in today's handheld portable products

(aka, Combi-Finish or SIT)

HASL (Hot Air Solder Level)

Typical Equipment used for the Coating of HASL

Vertical and Horizontal HASL Equipment

HASL (Hot Air Solder Level)

LEADED Version

Typical Thickness: .65 - 50 µm (25 - 2000 µ in)

ADVANTAGES	**DISADVANTAGES**
+ "Nothing Solders Like Solder"	- Co-Planarity Difference Potential Off-Contact Paste Printing
+ Easily Applied	- Inconsistent Coating Thicknesses (on Varying Pad Sizes)
+ Lengthy Industry Experience	- Contains Lead
+ Easily Reworked	- Not Suited for High Aspect Ratios
+ Multiple Thermal Excursions	- Not Suited for fine-pitch SMT and Grid Array Packages
+ Good Bond Strength	- PWB Dimensional Stability Issues
+ Long Shelf Life	- Bridging Problems on Fine Pitch
+ Easy Visual Inspection	- Subjects the PCB to High Temp
+ Cu/Sn Solderjoint	

HAL (Hot Air Level)

UNLEADED Version

Equipment being used for the Coating of Lead-Free HAL
Same as for Leaded Versions but with a few Modifications

- **Higher Temp Steel Solder Pots and Stronger - Higher Temp Pumps**
  (Effective heat transfer by improved alloy circulation)
- Pre-heat panel (pre-dip)
- Longer contact time with PCB
- High temperature resistant chemistries (oils and fluxes)
- Copper control (Drossing – Dilution and Skimming)

***Source: CEMCO / FSL**

HASL (Hot Air Level)

UNLEADED Version

iNEMI Test Panels:	Sn-0.3%Ag-0.7%Cu	2.61 - 14.2 μm
	Sn-3%Ag-0.5%Cu	1.0 - 12.3 μm
	Sn-0.7Cu + Ni	2.7 - 14.7 μm

ADVANTAGES

+ **Easily Applied and Reworked**
+ **Familiar HAL Dynamics**
+ **Good Bond Strength**
+ **Long Shelf Life**
+ **Easy Visual Inspection** **(Wettability)**
+ **Cu/Sn Solderjoint**

DISADVANTAGES

- **Co-Planarity Difference Potential Off-Contact Paste Printing**
- **Inconsistent Coating Thicknesses (on Varying Pad Sizes)**
- **Not Suited for High Aspect Ratios**
- **May not be suited for fine-pitch SMT and Grid Array Packages**
- **PWB Dimensional Stability Issues**
- **Bridging Problems on Fine Pitch**
- **Subjects the PCB to VERY High Temp**
- **Copper Feature Dissolution**
- **"Dull" and "Grainy" Appearance**
- **More Process Controls Req'd**

Lead-Free Solder Options

ALLOY SYSTEM	COMPOSITION	MELTING RANGE (°C)
Sn-Ag	Sn-3.5Ag	221
	Sn-2Ag	221-226
Sn-Cu	Sn-0.7Cu	227
Sn-Ag-Bi	Sn-3.5Ag-3Bi	206-213
	Sn-7.5Bi-2Ag	207-212
Sn-Ag-Cu Eutectic	Sn-3.8Ag-0.7Cu	~217
	Sn-4Ag-0.5Cu	~217
	Sn-4.7Ag-1.7Cu	~217
SAC305	Sn-3.0Ag-0.5Cu	218-219?
SACX0307	Sn~0.9Cu~0.17Ag~0.14Bi	217-228
Sn-Ag-Cu-Sb	Sn-2Ag-0.8Cu-0.5Sb	216-222
Sn-Zn-Bi	Sn-7Zn-5Bi	170-190

EUTECTIC ALLOYS

***Source: Nihon Superior Co., LTD**

Process Parameters for Lead-Free HAL with Ni-Stabilized Sn-0.7Cu

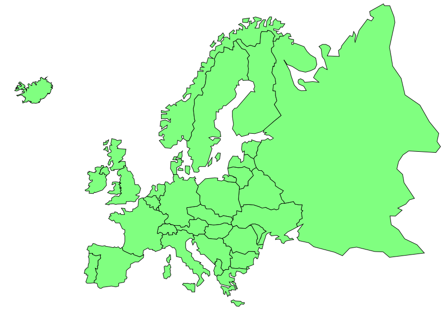
The main considerations in changing a HAL process from 63/37 Sn/Pb to SN100C (Ni-stabilized Sn-0.7Cu) is:

- The higher melting point

ALLOY	MELTING POINT	PROCESS TEMPERATURE	PROCESS WINDOW
63/37 Sn/Pb	183° C	250° C(482)	67° C
Sn-0.7Cu+Ni	227° C	265° C(509)	38° C

*Source: Nihon Superior Co., LTD

Lead-free HAL running SN100C



There are now about 80+ shops operating lead-free HAL machines in Europe.

Running Lead free HAL machines in USA (Currently around 18 units)

(~400 in the World

High Volume Production is determined by demand.
So proportionately, the need for lead-free boards
is still relatively small.

Source: Florida CirTech, Inc.
and Nihon Superior Co., LTD

Lead-free HASL in Europe

Company	Machine Supplier
AT&S	Pentagal
Dünkel & Schürholz	Quicksilver
Ramaer	Lantronic
Vogt-Fuba / Dresden	Quicksilver
Brautmeier (Leiterplatten)	Quicksilver
Greule	Quicksilver
Piu-Printex	Quicksilver
Schwerdtfeger	Pentagal
Photochemie	Quicksilver

These companies have machines installed for lead-free HAL

There are now 80+ operating HAL machines in Europe. (~400 in the World)

Production volume is determined by demand for lead-free boards which is still small

Source: Florida CirTech, Inc.

Running Lead free HAL machines in USA

(Currently around 18 units)

Pentaplex	Elgin, IL	Quicksilver
American PCB	Dallas, TX	Lantronic
Texas Circuitry	Dallas, TX	Lantronic
Multilayer	Dallas, TX	Lantronic
ElectroCircuits	Toronto, Canada	Lantronic
Excell Electrocircuits	Detroit, MI	Lantronic
Monitrol	Elk Grove, IL	Argus
Calumet Electronics	Calumet, MI	Quicksilver
Bartlett Mfg	Cary, IL	Argus
Galaxy Circuits	New Jersey	Avalon
Saturn	Michigan	Lantronic
SMG Circuits	New Jersey	Argus
Advance Electronics	Colorado	Penta

Source: Florida CirTech, Inc.

HAL (Hot Air Level)

UNLEADED Version

Equipment Trials / Findings using Lead-Free HAL

Alloy	Melting point	Process temperature
Sn/Pb	183º C	250º C
HAL Lead-free	217 to 227º C	265 to 280º C

Stainless Steel Erosion

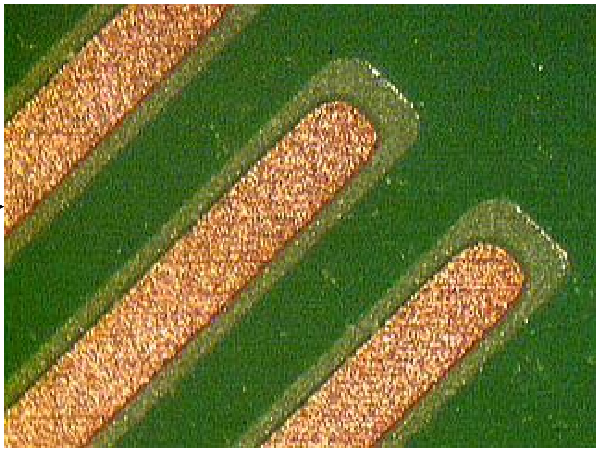
Source: Florida CirTech, Inc.

LEAD-FREE HAL (Hot Air Level)

EROSION OF COPPER PAD

Original Pad

18µm Copper

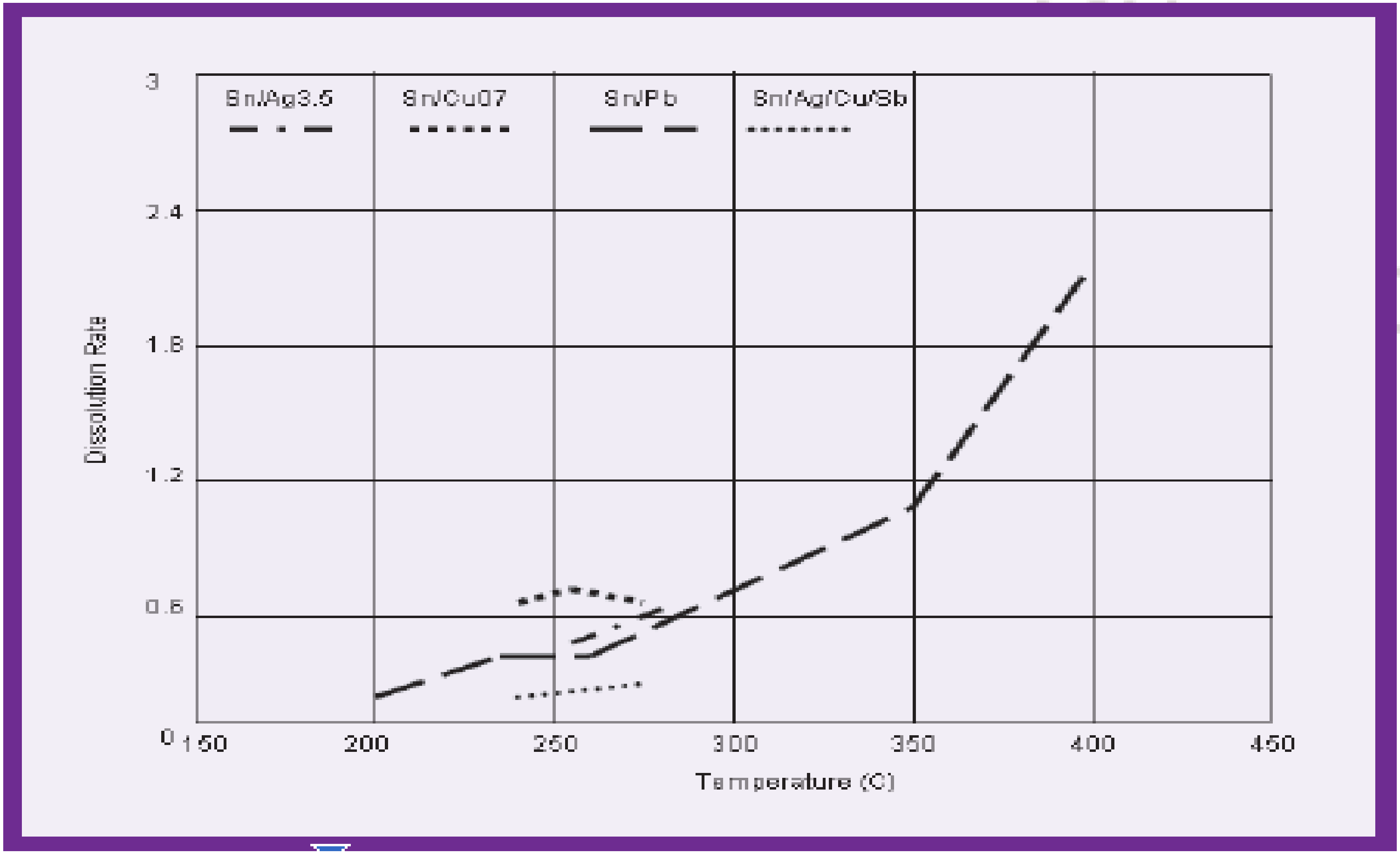


After 6 Passes over Wave Soldering Machine
105°C Preheat, 256°C Solder Temperature, 4 seconds contact time

Source: Florida CirTech, Inc.

LEAD-FREE HAL (Hot Air Level)

Dissolution rate of Copper



Copper Dissolution Rates of various Lead-Free Alloys.

Source: Circuits Assembly OCTOBER 2004

Lead free Assembly Equipment in the World

SN100C - >1800 Wave Soldering units
>200 in Europe
100 in the USA

The key point in running lead-free processes is acknowledging that the process window is smaller than for tin-lead solder

Source: Florida CirTech, Inc.