"Подкрепа за развитието на човешките ресурси в областта на научните изследвания и иновации в Русенския университет"

финансиран по Оперативна програма „Наука и образование за интелигентен растеж 2014-2020"

Department „*Materials science and technology*"

Center for technology transfer *in Ruse University "A. Kanchev"*

Advanced Engineered Solutions

A Global Leader in

Specialty Chemicals

Surface Finishing Equipment

Engineered Powders

Analytical Controls

About Technic

- Technic is a privately held, global company with a belief in innovation and employee empowerment
- Approximately 1000 employees worldwide
- Strong financial resources and stability
- Various ISO 9000 approved facilities
- A strong commitment to new product research & development
- Annual Sales volume in excess of $400,000,000

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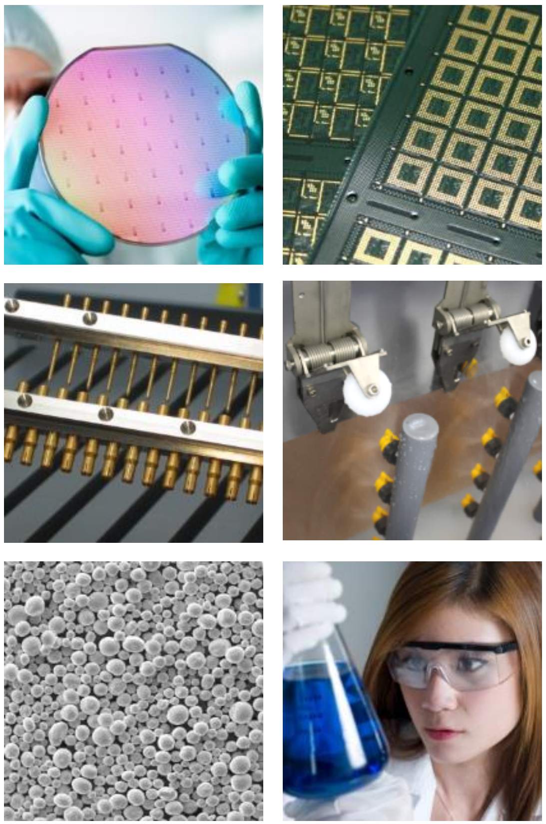
About Technic – *Company History*



Technic is a Rhode Island, USA based private company

- Family owned since inception
- Incorporated in 1944
- Original focus of the business was precious metal supply to the decorative / jewelry industry in the Providence, RI area

Expansion into the electronics industry in the 1950s

Technic has grown to be a leading global supplier of;

- Specialty Chemicals
- Surface Finishing Equipment
- Engineered Powders
- Analytical Control Systems

About Technic - *Technic Business Units*

- Corporate Headquarters / Specialty Chemicals / Precious Metals, Cranston, RI, USA
- Equipment Group: Pawtucket, RI; Clearwater, FL; and Singapore
- Engineered Powders: Woonsocket, RI, USA
- Plating Services: Suzhou, China
- Semiconductor Applications Lab: Anaheim, CA USA
- Ultra-Pure Chemicals: Paris and Chalon, France
- Metal Concentrates (SCS): Royersford, PA, USA
- In addition, regional sales & service offices provide representation in all major markets

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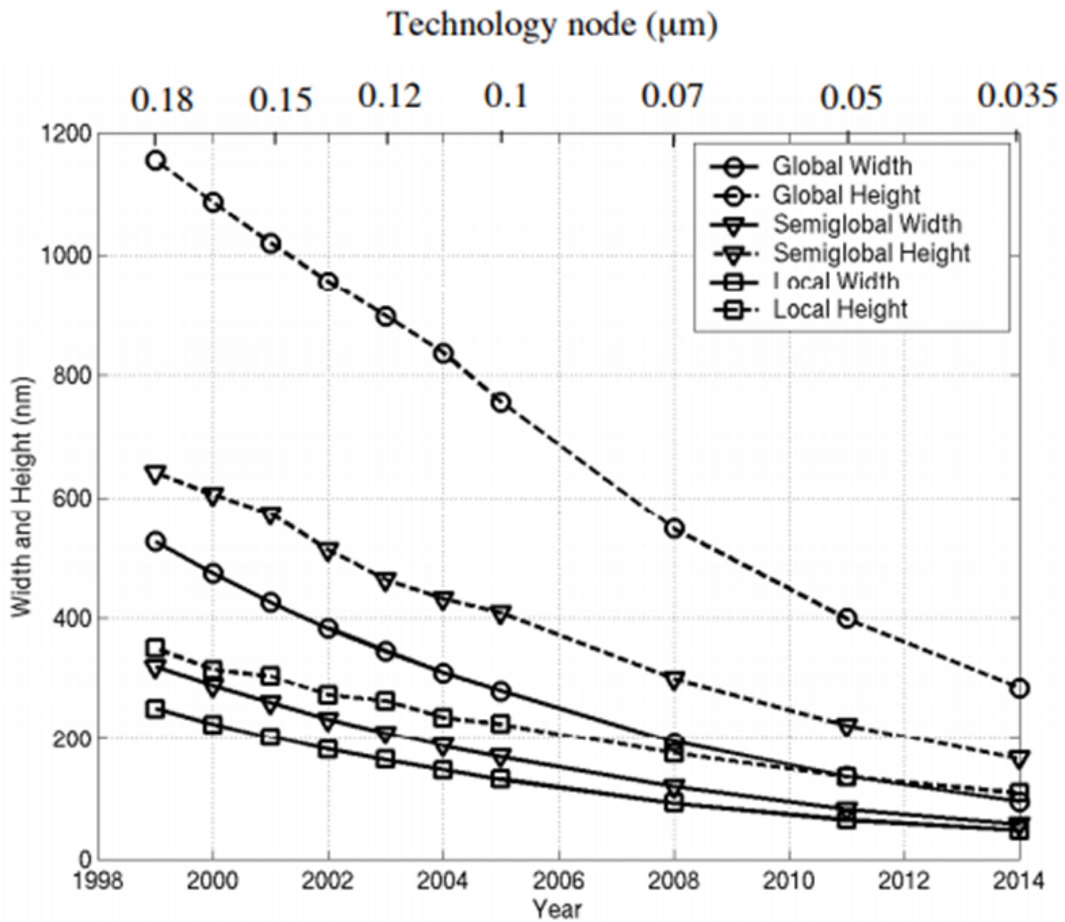
Beyond Ni/Au: Next Generation Finishes for Electronics Applications

Beyond Ni/Au: Functions of Electronic Finishes

- Provide electrical conductivity
- Improve corrosion resistance
- Impart good wear resistance
- Enable attachment to other surfaces (where applicable)
  - Soldering, insertion, etc.
- Traditional electroplated Ni/Au deposits have achieved the above objectives successfully for decades
  - Ni: 1-2 µm +
  - Au: 0.1-0.75 µm (depending on application)
- ***UNTIL NOW…***

Beyond Ni/Au:
Electronic Finishes : New Requirements

As IC semiconductor devices and PCB dimensions are scaled down, the demands on the electronic interconnects increase dramatically



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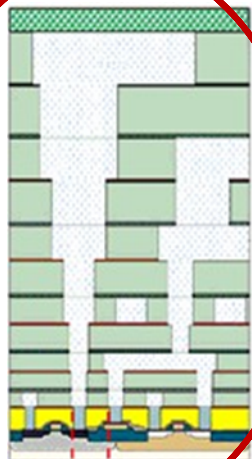
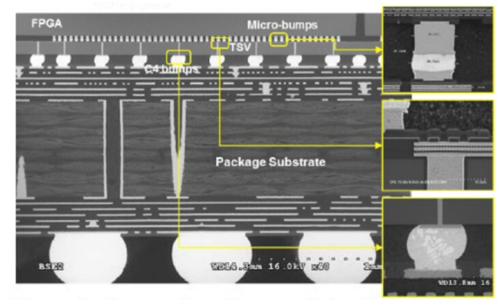
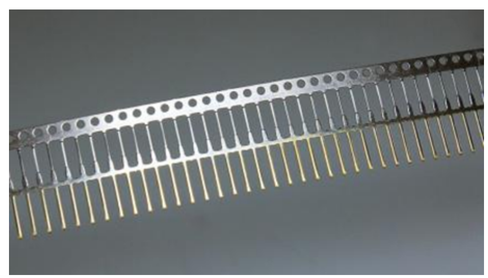
Beyond Ni/Au:
Electronic Finishes : New Requirements



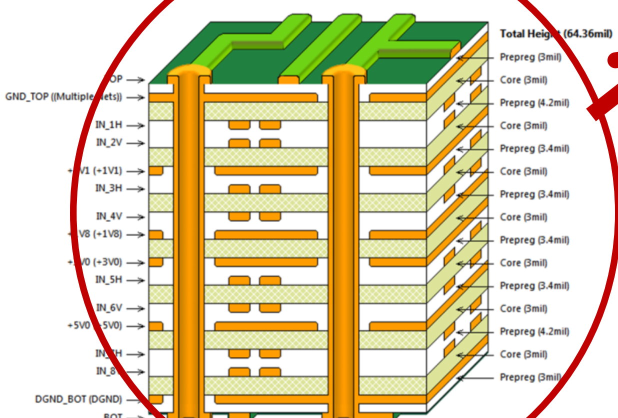
SEMICONDUCTOR



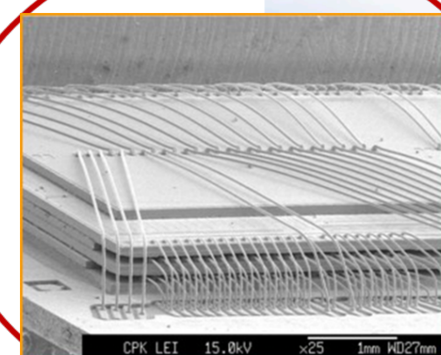
IC PACKAGING



CONNECTORS



PCB



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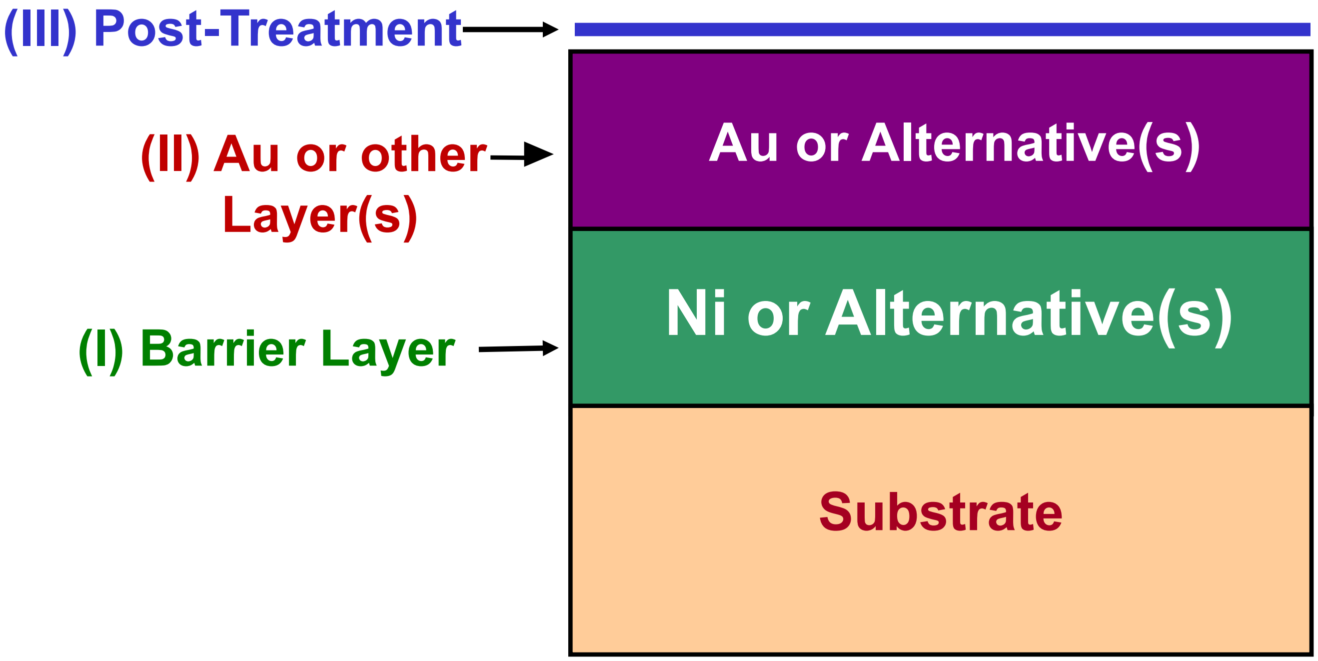
Beyond Ni/Au: Typical Electronic Finish



Improved Barrier Layers

Goldeneye Nickel

Goldeneye Nickel

- Traditional barrier layer for electronics finishes is matte nickel sulfamate
- **Goldeneye Nickel** is an advanced nickel electroplating process specifically engineered to significantly improve nickel thickness distribution and corrosion-resistance from a proprietary electrolyte in high speed/reel-to-reel plating applications
- **Goldeneye Nickel** produces a semi-bright, low stress, ductile deposit

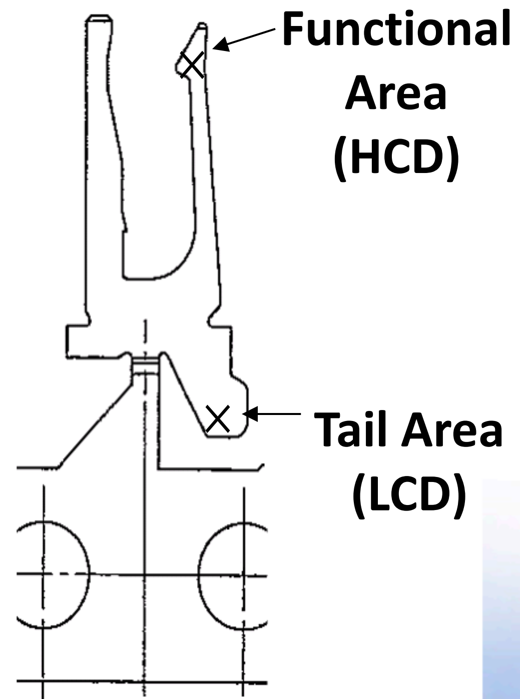
GE Nickel vs. Ni sulfamate

Deposit Characteristics		
	GE Ni	**Ni Sulfamate Matte**
Appearance	**Semibright**	**Matte**
Stress	**~2500 psi (17.2 MPA)**	**~5500 psi (37.0 MPA)**
Hardness	**~450 knoop**	**~250 knoop**
Structure	Nano-crystalline	Micro-crystalline
Solution Conductivity	155.6 mS/cm	68.0 mS/cm

Nano-crystalline Ni vs. Ni Sulfamate

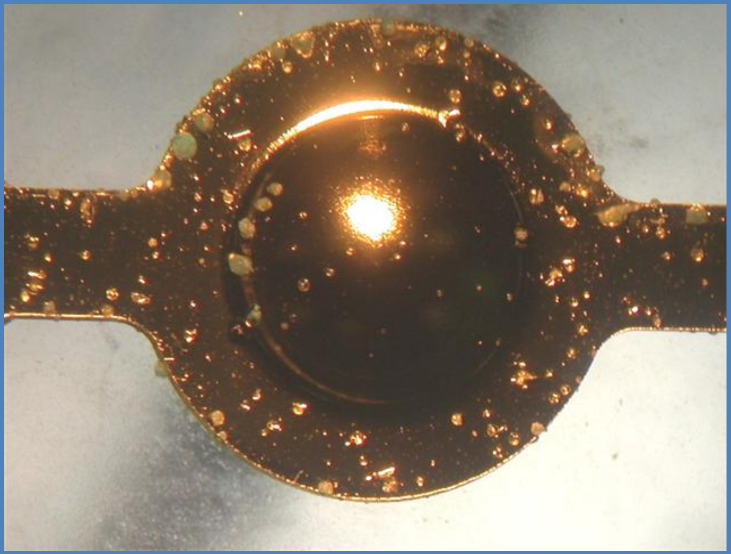
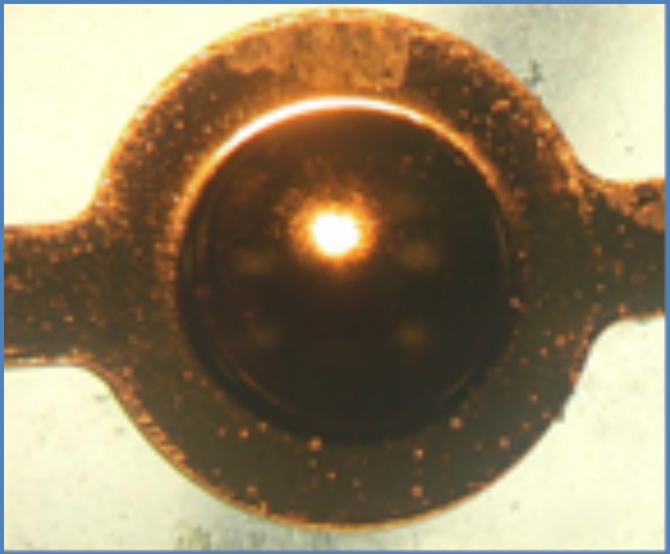
Thickness Distribution Comparison

Bath	HCD (μm)	LCD (μm)	HCD:LCD Ratio
Ni S.	1,04	0,36	2.9
GE Ni	**1,09**	**0,56**	**2.0**
Ni S.	2,13	0,81	2.6
GE Ni	**2,18**	**1,24**	**1.8**
Ni S.	3,12	1,19	2.6
GE Ni	**3,07**	**1,83**	**1.7**



The thickness distribution of the Low Current Density (LCD) area is significantly improved (30 to 40%) by Nano-Ni process.

Nano-Crystalline Nickel vs. Ni sulfamate Corrosion Comparison

	
Ni sulfamate - 3,05µm Au - 0,76µm	Nano-Ni - 2,54µm Au - 0,76µm

After 2 hour nitric acid vapor (NAV) exposure

Goldeneye Nickel Product Portfolio

- GE Ni has evolved from its original application as a Ni sulfamate replacement for gold-savings applications to become a more significant nanocrystalline barrier layer and/or final finish technology in multiple applications:
  - Goldeneye Nickel / GE Ni II / GE Ni III
  - Goldeneye Level Nickel HS
  - Goldeneye Satin Nickel
  - Goldeneye Black Nickel
  - Goldeneye Matte Nickel
  - Goldeneye Nickel-Iron
  - Goldeneye Nickel-Tungsten
  - Goldeneye Cobalt-Tungsten
  - Goldeneye Nickel EF

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Goldeneye Technology – New Logo

Goldeneye

Advanced Nano-Plating Technology

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Goldeneye Nickel Tungsten

Goldeneye NiW

- Alloy composition: 60/40 ± 10% Ni/W
- Hardness: 640 HV
- Deposit structure: Nano-crystalline
- Stress: 10-20K psi
- Highly corrosion resistant
- Improved wear resistance compared to nickel
- DC plating; no special rectification required
- Wide operating window

Cobalt-Tungsten (CoW)
A Nickel-Free Barrier Layer

- For certain applications, elimination of nickel entirely from the plated layer system is desirable (e.g., Ni dermatitis)

- **Cobalt-Tungsten alloy (CoW) barrier layer** electroplating technology has been developed for these applications

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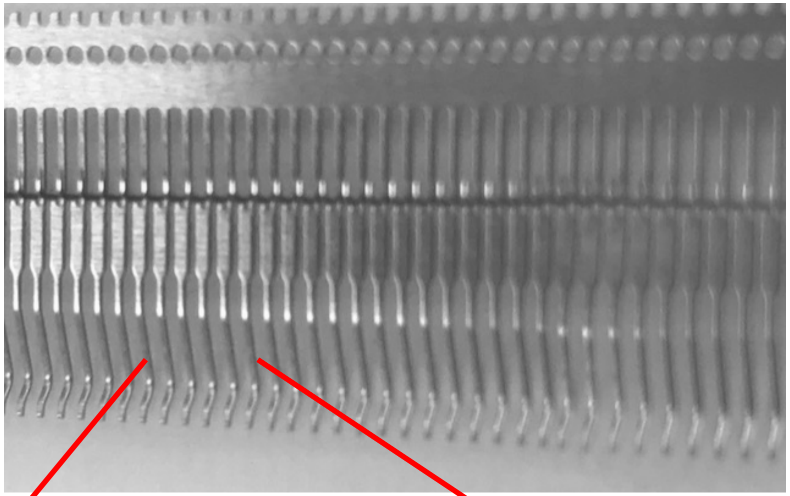
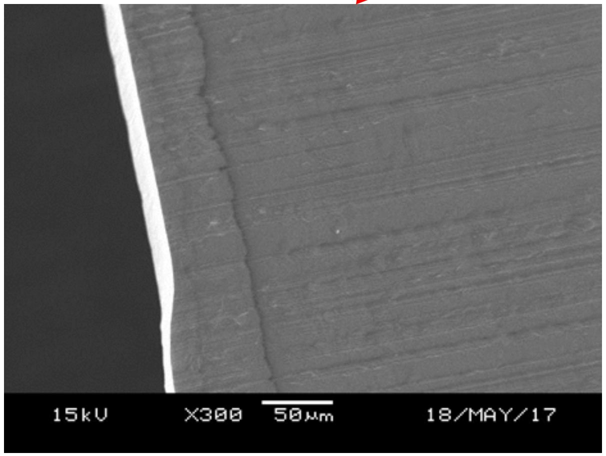
CoW Properties

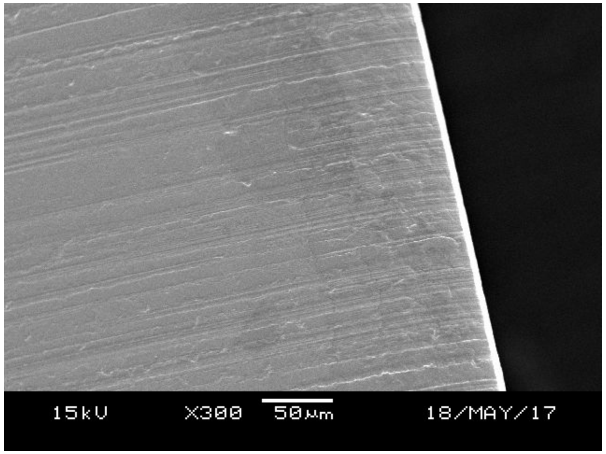
- Alloy composition: 65/35 ± 5% Co/W.
- Hardness: 600-700 HV
- Deposit structure: Nano-crystalline
- Wide operating window.
- Drop-in replacement for nickel or nickel-tungsten plating solutions in existing lines.
- Nickel-free deposit with no nickel dermatitis issues - suitable for consumer applications
- Low deposit stress
- Excellent corrosion-resistance

Cobalt-Tungsten Alloy
Deposit Appearance



15 ASD
65% Co-35% W





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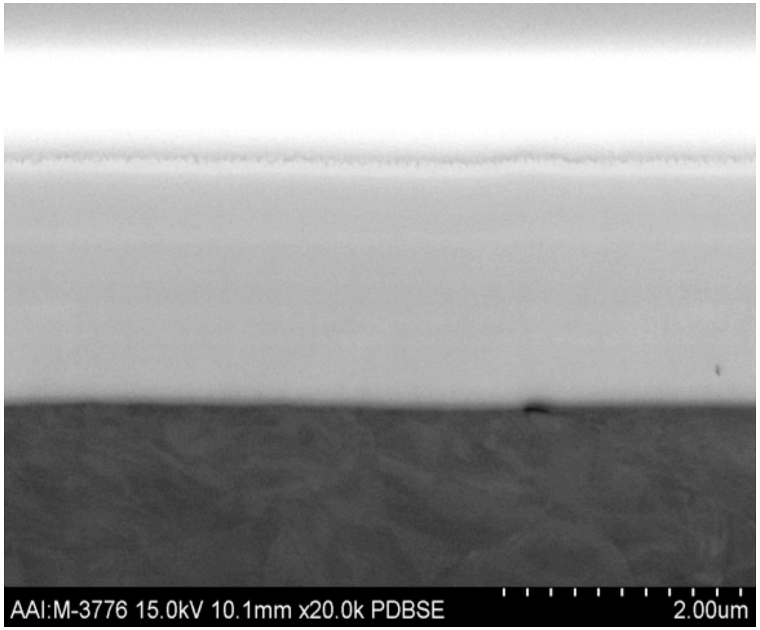
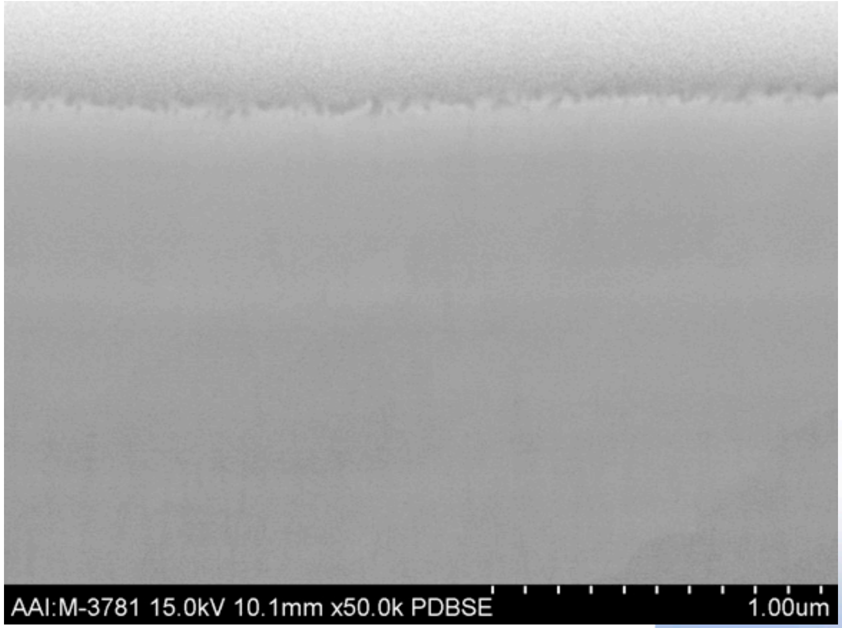
Cobalt-Tungsten Alloy
FIB / SEM Cross-section data

20,000X

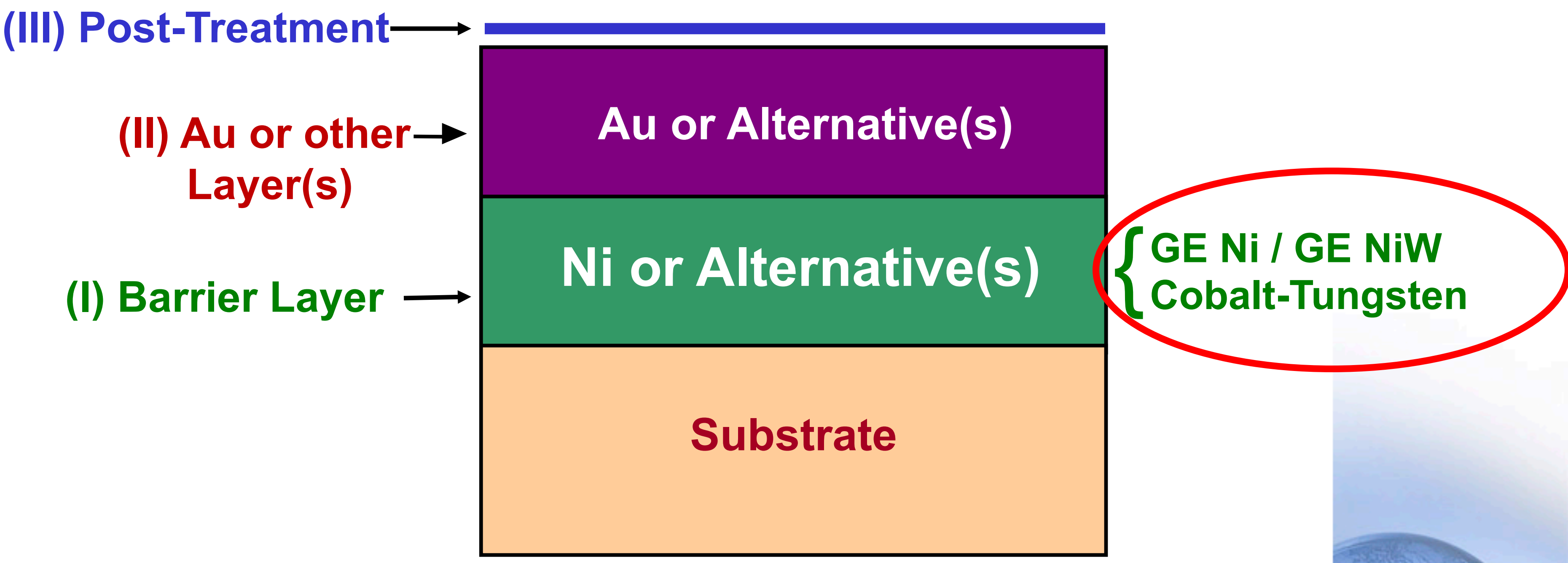


50,000X



CoW has nano-crystalline structure

Beyond Ni/Au: Typical Electronic Finish

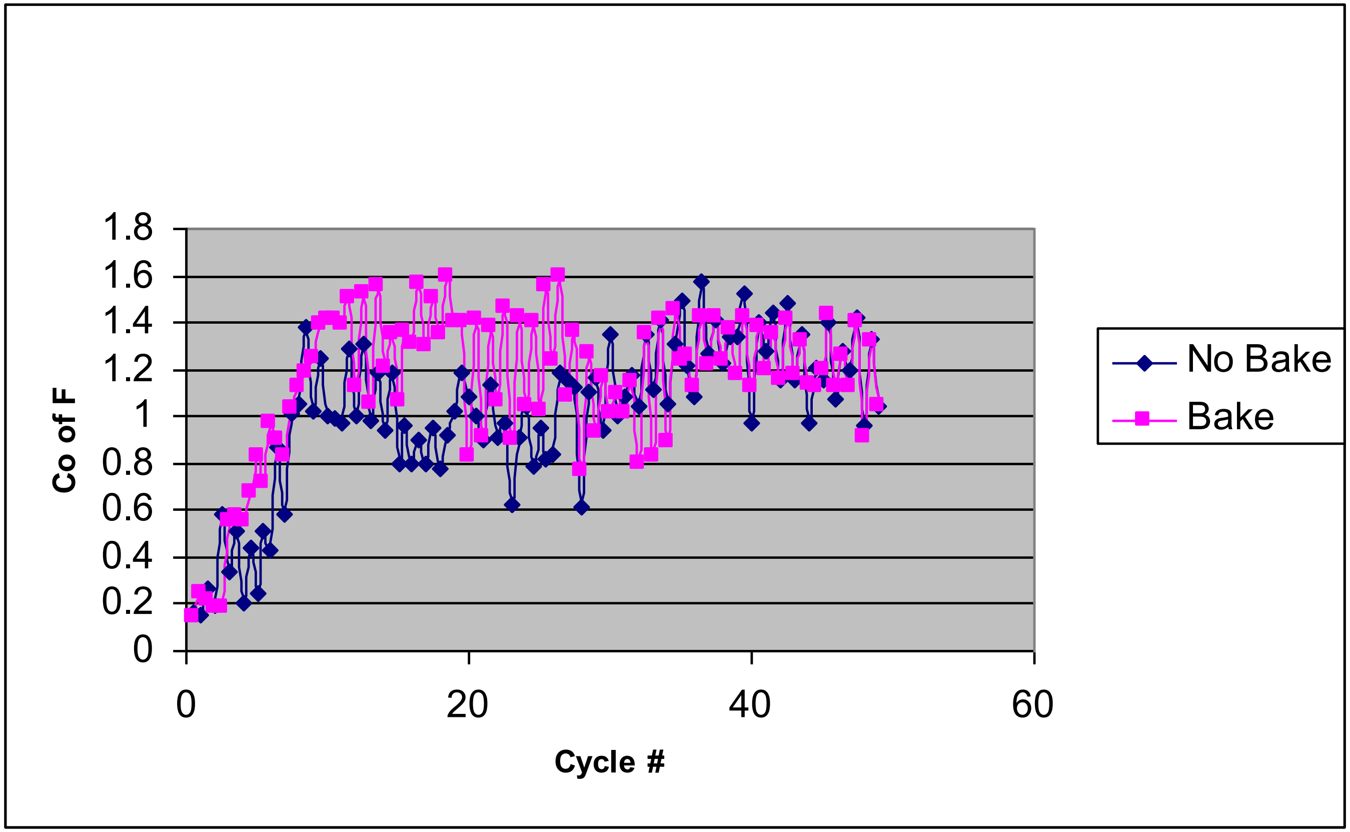


Alternatives to Gold / Post-Treatment Processes

Silver on Connectors-Introduction

- Until today, 2 technical issues have limited silver's implementation in non-automotive applications
  - Wear resistance esp. after multiple insertion cycles
  - Corrosion resistance – overcoming the silver tarnish issue
    - Automotive use of silver is currently restricted to sealed applications with minimal insertions
- Solution: Wear-resistant /corrosion-resistant silver plating process

Conventional Silver Wear Resistance Results

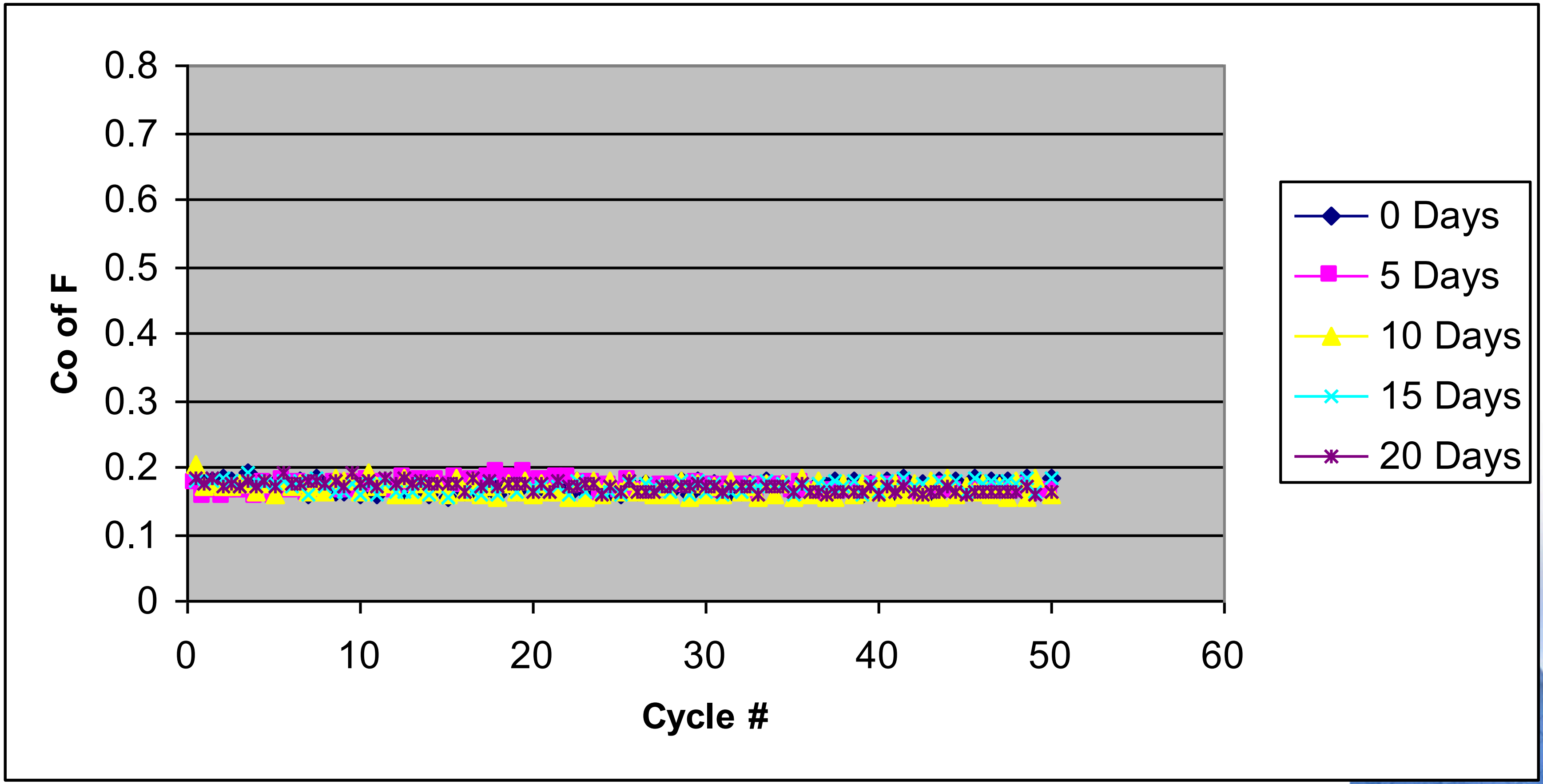


CoF of conventional silver is high ~1.2 before & after bake

Silver Alloy Plating

- Silver alloy plating from a two-part system consisting of a silver alloy electroplated deposit and a unique post-treatment process chemistry.
- This combination provides excellent deposit conductivity combined with superior corrosion properties and significantly improved wear resistance compared to conventional silver.

Durasil™ Wear Resistance Results With bake / 0-20 days MFG Exposure



Durasil™ Corrosion Resistance Results 0-20 days MFG Exposure

Above: no bake
Below: with bake

Conclusion: Minimal to no corrosion observed after 20 days MFG exposure

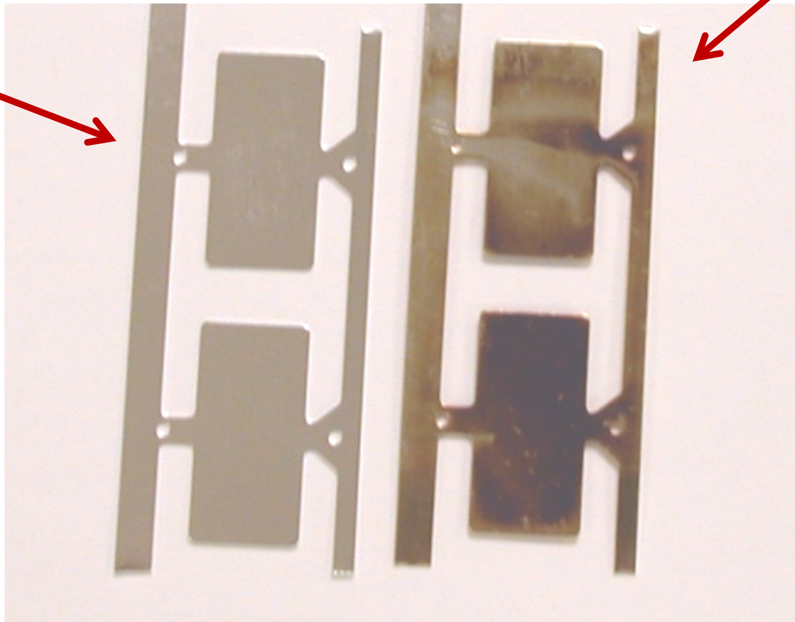
Techniseal nano-coating on Silver

Sulfur Corrosion Testing

5% K2S Solution
Parts fully immersed for 5 minutes

With Techniseal

No Treatment



Goldeneye

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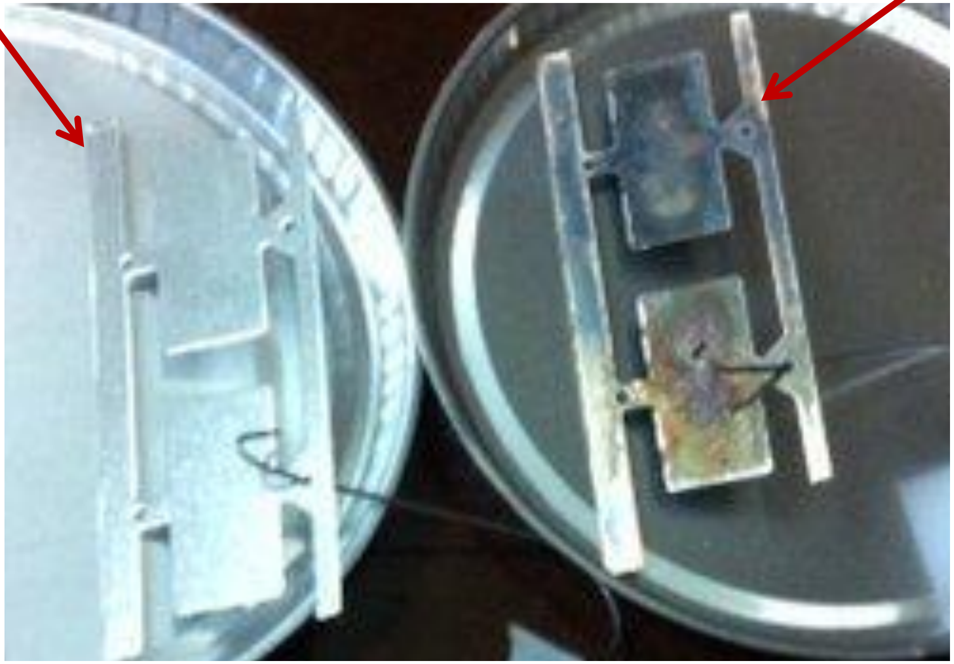
Techniseal nano-coating on Silver

Sulfur Corrosion Testing

**Mixed Flowing Gas Exposure
per EIA-364-65B, Class IIa
5 days exposure**

With nano-coating

No Post-Treatment



Goldeneye

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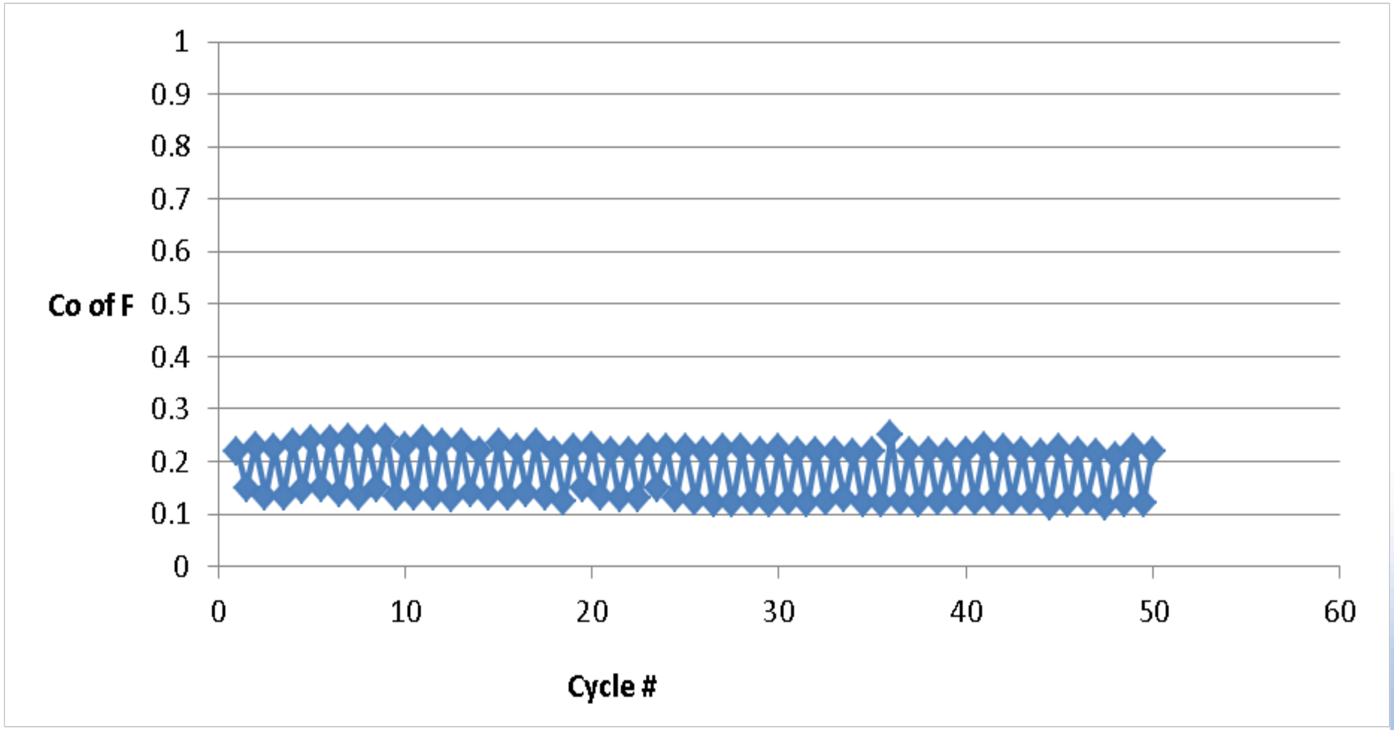
Nano-coating + lube

Wear Resistance Results



Excellent WR results equivalent to hard gold

Silver Alloy Plating Summary

- Deposit Hardness √
  - 175 Knoop as-plated; 145 Knoop after bake
- Contact Resistance √
  - Low and stable CR (~2.5m-ohm), after bake and/or after 20 days exposure to MFG
- Wear Resistance √
  - Low and stable CoF (~0.2) , after bake and/or after 20 days exposure to MFG
- Corrosion Resistance √
  - Minimal to no corrosion after 20 days exposure to MFG
- Solderability √
  - Passes J-STD-002C after 500 hrs bake

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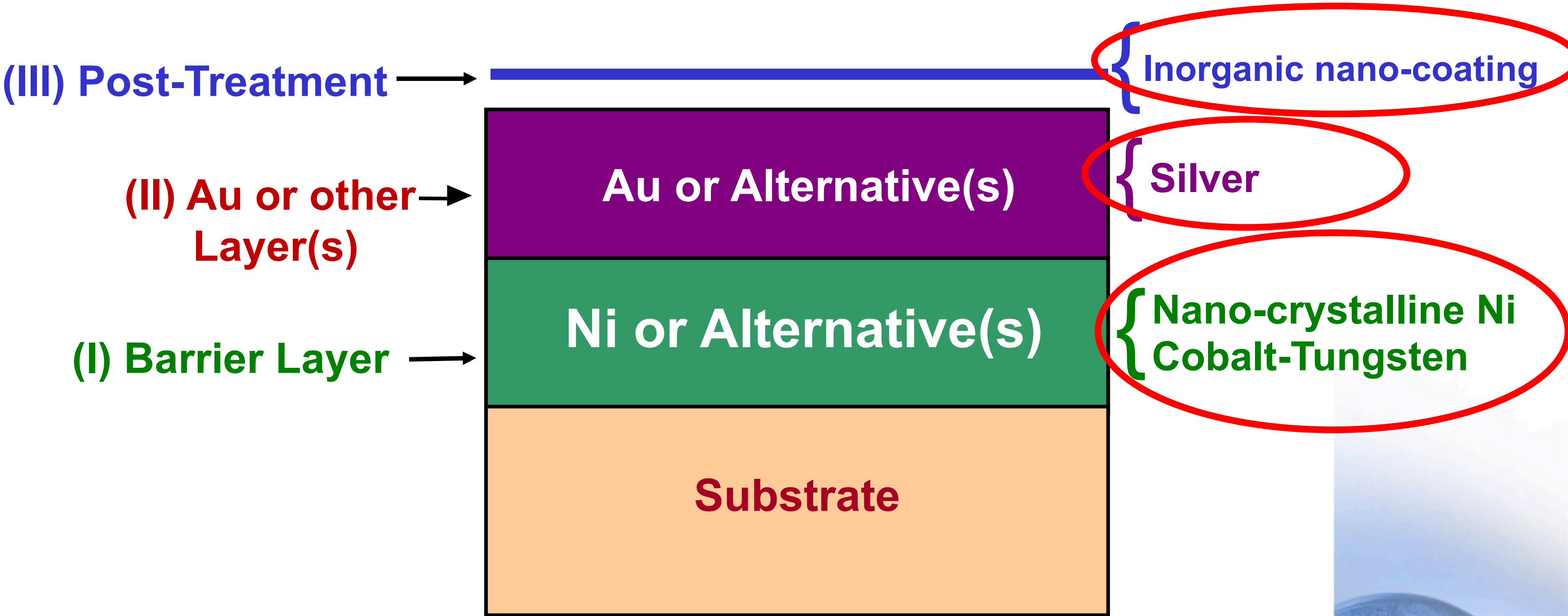
Silver on Connectors Summary

- Several options exist :
  - Silver alloy plating + post-treatment
  - Silver plating with nano-coating for corrosion protection only
  - Silver plating with 2-step post-treatment process sequence consisting of nano-coating + Post-Dip (lube), improvements in both silver protection AND wear resistance can be achieved
- These combinations provide similar technical performance comparable to hard gold in connector and related applications

Beyond Ni/Au: Typical Electronic Finish



Emerging Applications Requiring Completely New Electronic Finishes:

- Electrolytic Sweat Resistant (ESR) Connector Finishes
- Press-Fit Connector Pins
- High Frequency Applications (5G)

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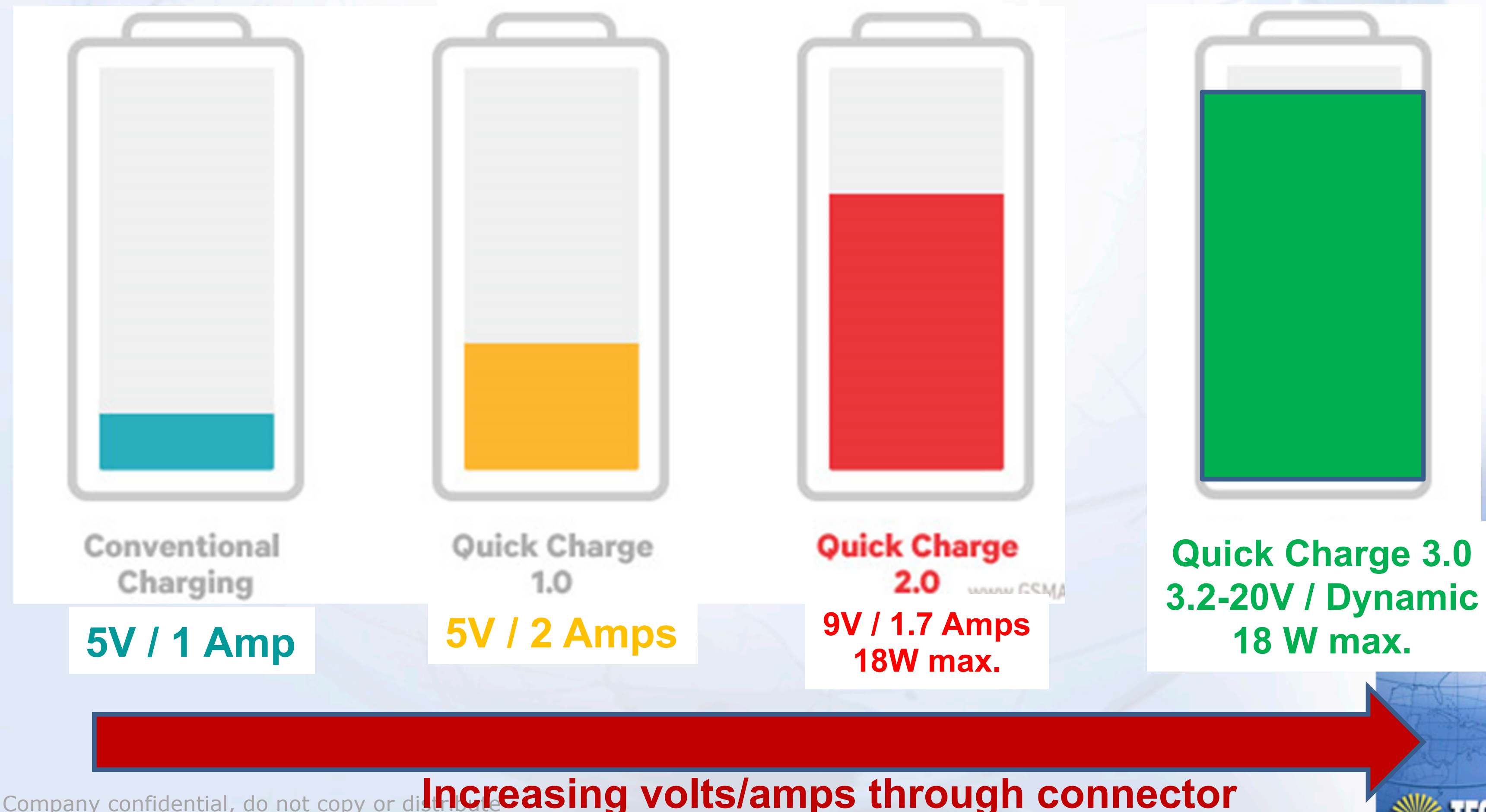
Mobile Phone Connector Plating Technology Shift

- Two recent changes in cell phone technology are having a major impact on the plated finishes used for mobile phone connectors:
  I. **Replacement of traditional headphone jack with a single connector that performs both the electrical charging function and the headphone connection**

Mobile Phone Connector Plating Technology Shift

II. Implementation of ‘quick-charge’ connector technology



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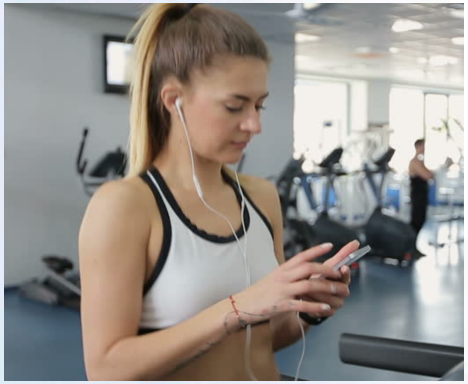
How does this affect Mobile Phone Connector Plating Technology?

I. Consumers exercising while using head phones &/or charging their cell phones (i.e., handling the connector) results in human sweat being present on the plated connector in the presence of electrical current

Sweat + Electrolysis = CORROSION



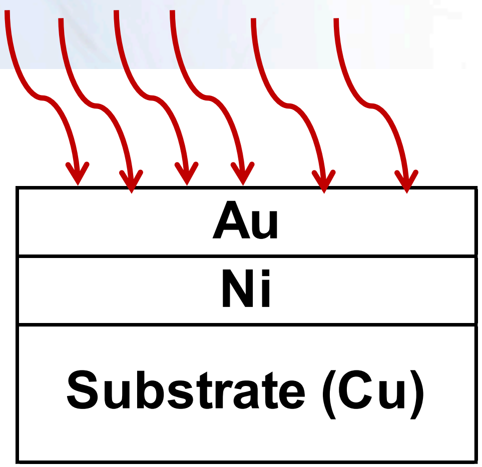
II. This electrolytic sweat-induced corrosion issue is made more severe when combined with the higher charging current/volts of quick charge technology

USB-C Connector Pins

Mechanism of Corrosion Using Various Test Methods

NAV Test

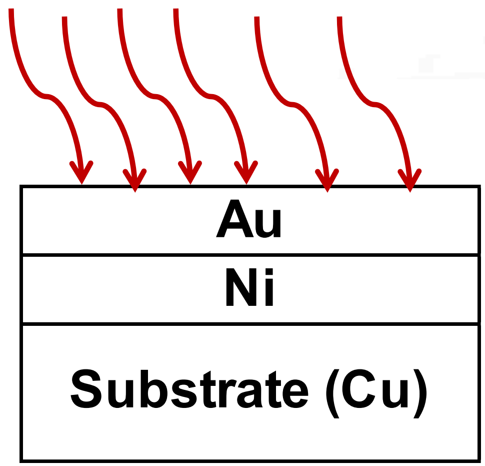
Nitric Acid Fumes



Mechanism = Corrosion occurs from outside to inside

NSS Test

NaCl Mist

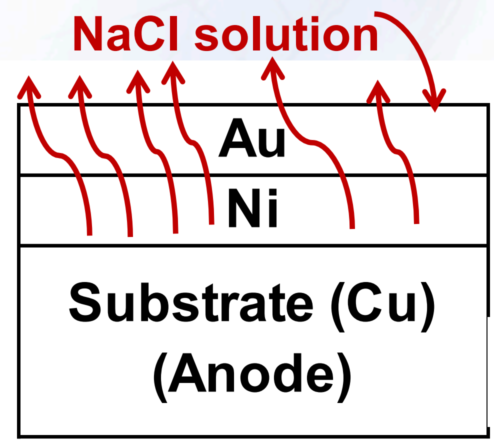


Mechanism = Corrosion occurs from outside to inside

Electrolytic Sweat Test

Cathode (-)Charge Applied

NaCl solution



Current Flow

(+) Charge Applied

Mechanism = Corrosion occurs from INSIDE to OUTSIDE

Requirements for Passing ESR Testing

- Base material preparation is critical
- Extremely corrosion-resistant barrier layer(s) is (are) required
  - Ni cannot be used for high-end applications
- Top layer must be a <u>Rh-containing deposit</u> (resistant to electrolytic sweat solution)
  - No gold (gold is easily attacked/corroded during ESR testing)
- Optimal layer system to be selected depends on trade-off of performance vs. cost

Electrolytic Sweat-Resistant Finishes

- *Every major cell phone company in the world is now investigating the implementation of multi-layer stacks with Rh-based final finishes for their sweat-resistant / quick-charge connector applications*

Rh-alloy	Top Layer
Pd 990	Intermediate Layer
Ni, NiW	Barrier Layer
Cu (optional)	Initial Layer
	E-Polish
	Substrate

Optimal layer system to be selected depends on trade-off of performance vs. cost

ESR Performance vs. Cost Summary

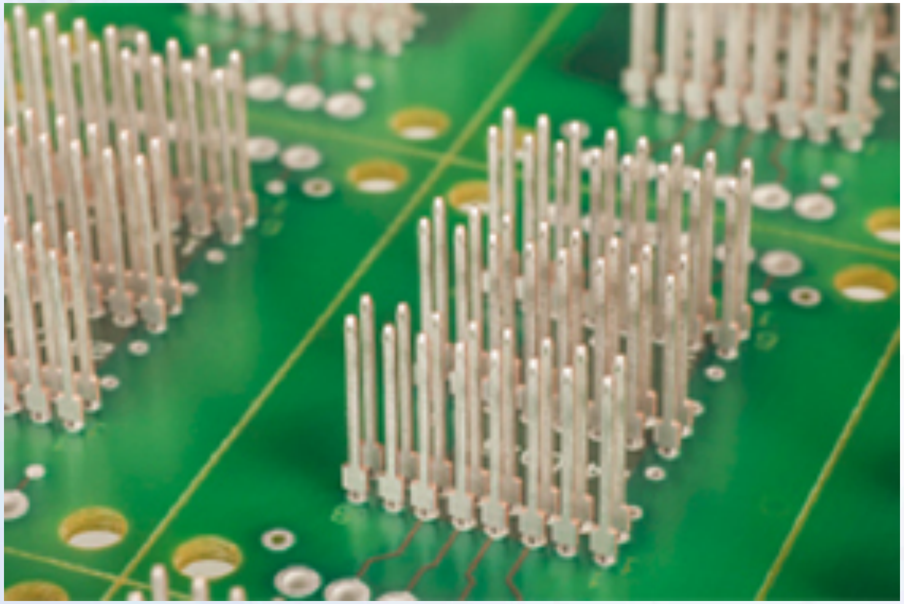
Classification	ESR Performance	Cost
Low-End	3-4 minutes	1.5 X
Mid-End	4-20 minutes	2.4 - 7X
High End	20-40 minutes	7 - 10 X
Utra High End	40-70 minutes	10 - 12X

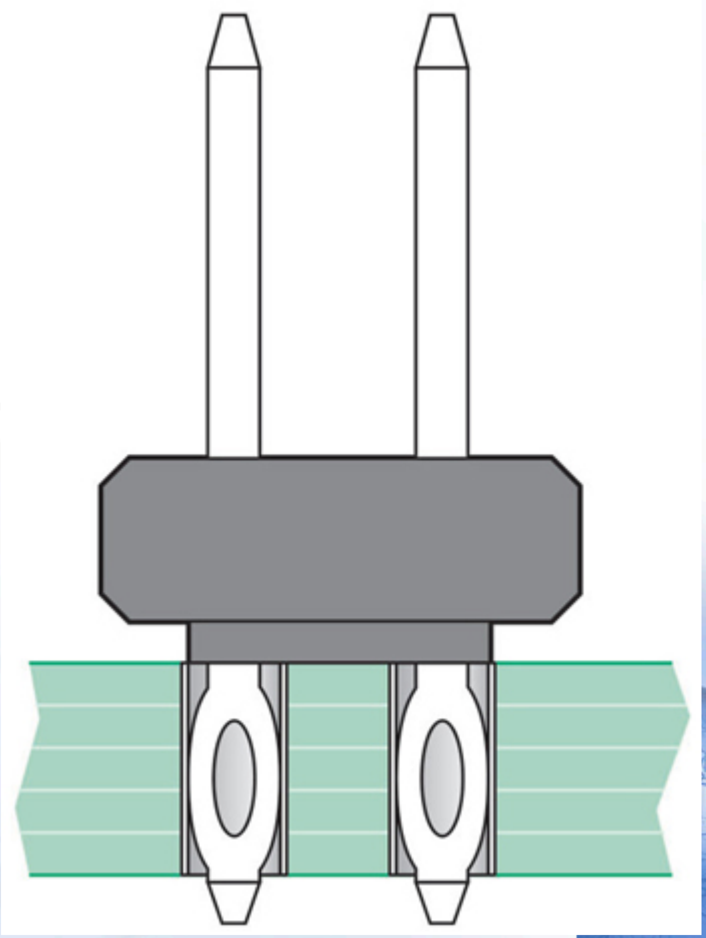
Top Global Cell Phone Companies – Sept. 2018

Manufacturer	Smartphone shipments year-to-June 2018	Year-on-year change	Market share in Q2
Samsung	307.5 million	-1.9%	21.0%
Huawei	174.7 million	+14.9%	15.9%
Apple	217.5 million	+0.9%	12.1%
Xiaomi	116.7 million	+81.9%	9.5%
Oppo	111.9 million	+0.6%	8.6%
Vivo	93.4 million	+8.6%	7.9%
Lenovo	47.0 million	-9.1%	3.0%
Others	377.4 million	-23.1%	22.0%
Industry total	1.45 billion	-2.6%	100%

Source: IDC

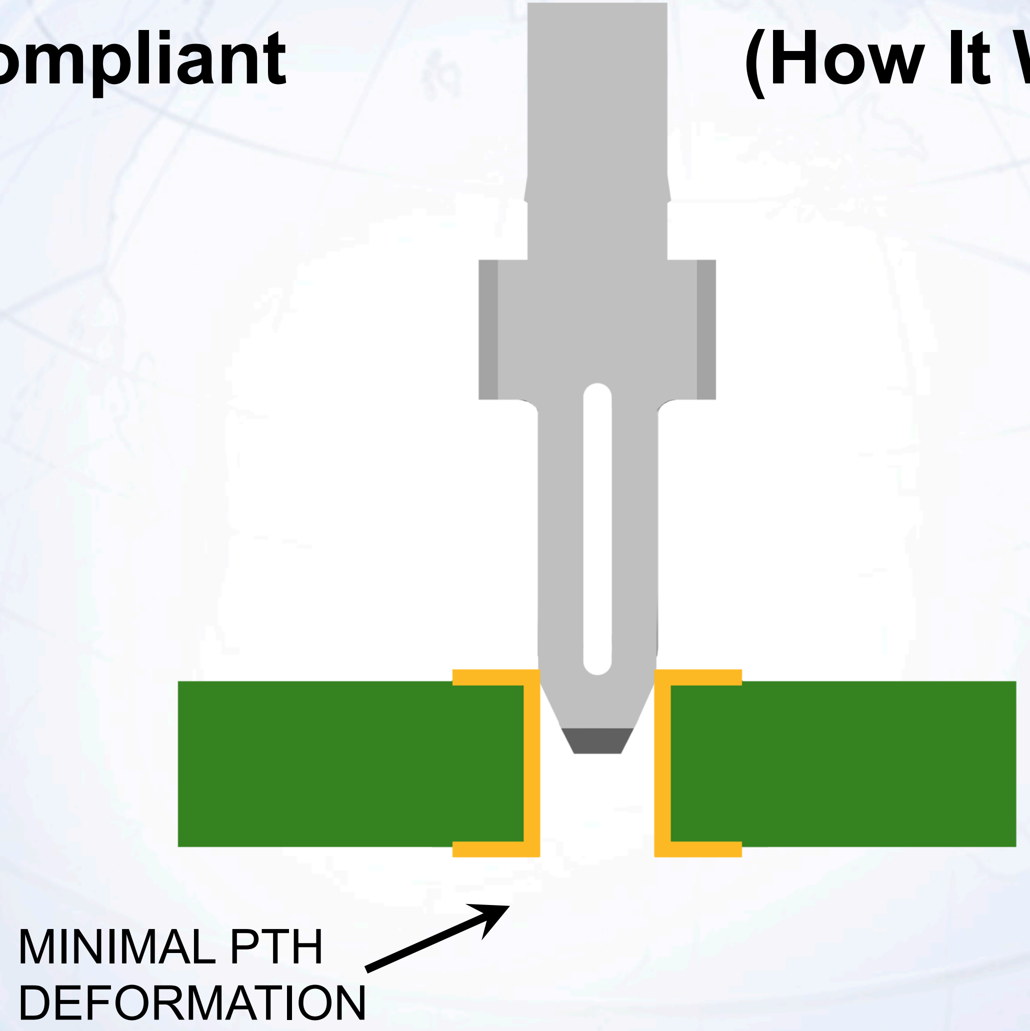
New Plating Technology for Connector Press-Fit Pin Applications



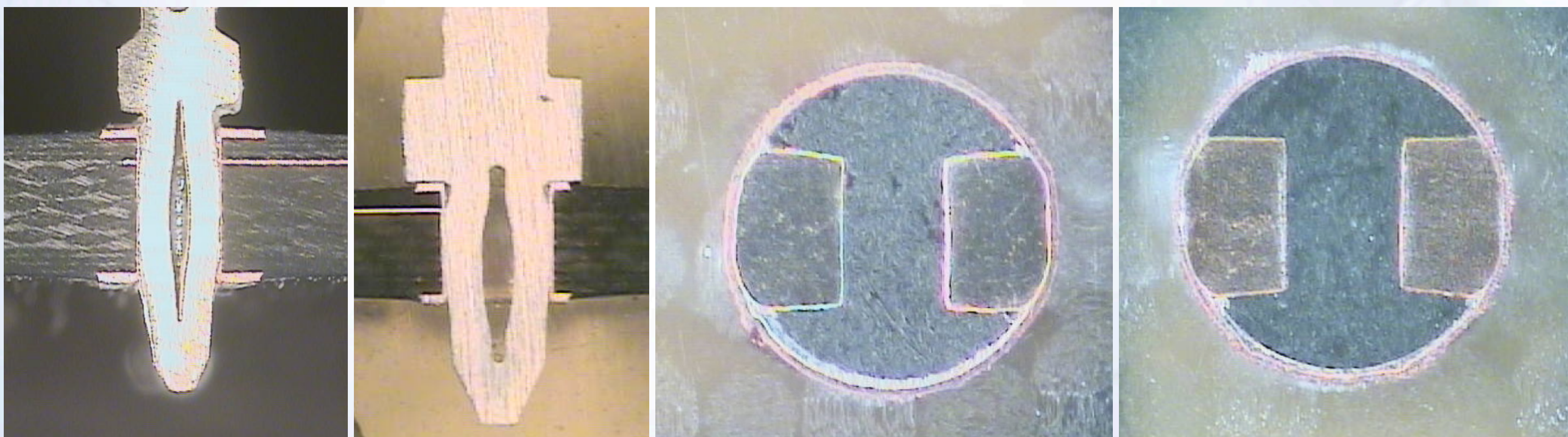


Press-fit technology is the insertion of flexible or rigid connector pins into plated through holes (PTHs) of printed circuit boards without soldering. The technology is industry accepted, widely used, reliable, and easy to operate.

Compliant (How It Works)



Terminal Cross Sections in PCB



0.81mm THICK TERMINAL

Advantages of press-fit technology vs. soldering

1. Prevention of thermal stress on the PCB and no soldering
2. Eliminating pins damage or breakage, solder bump or flux residue, etc.
3. Avoidance of short, cold solder connection, corrosion, etc.
4. Enable Plugins to connect with plugs directly, and no need for screws
5. Connectors with long pins can be connected from the backside of the PCB, for no soldering
6. Reparability that the connector or a single pin can be replaced easily
7. Stable and low contact resistance, good high frequency characteristics
8. No need to wash PCBs and prevention of polluted substances like fluxes for no soldering
9. High efficiency and low cost
10. Green technology , no solder or flus to store or recycle

Connector Press-Fit Pin Plating Technology - Introduction

- Matte tin has resulted in extremely long whiskers under certain press-fit conditions
- Connector companies and/or end users have been experimenting with various non-tin solutions for years
- Recently three alternative finishes have emerged as potential solutions for press-fit pin whiskers formed under compression
  - Ag/Sn
  - Indium
  - Bismuth

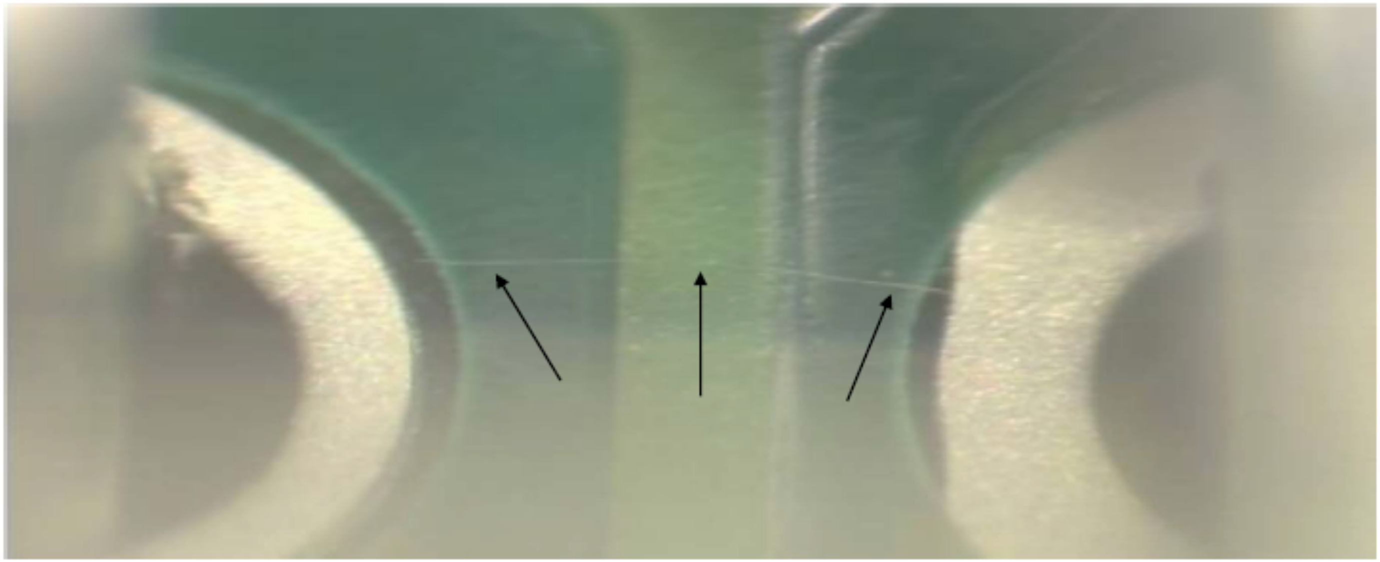
Silver-Tin Introduction

- Bosch has qualified Ag/Sn alloy (80% Ag; 20% Sn) as a press-fit connector finish
- Chemistry is difficult to work with; narrow operating window
  - Only one supplier has a commercial process (Dow)
- ATD is working on alternative approach of 2-layers Ag + Sn followed by ‘reflow’
- New project; not much data available yet

Continental - Indium

Occurrence of short circuits

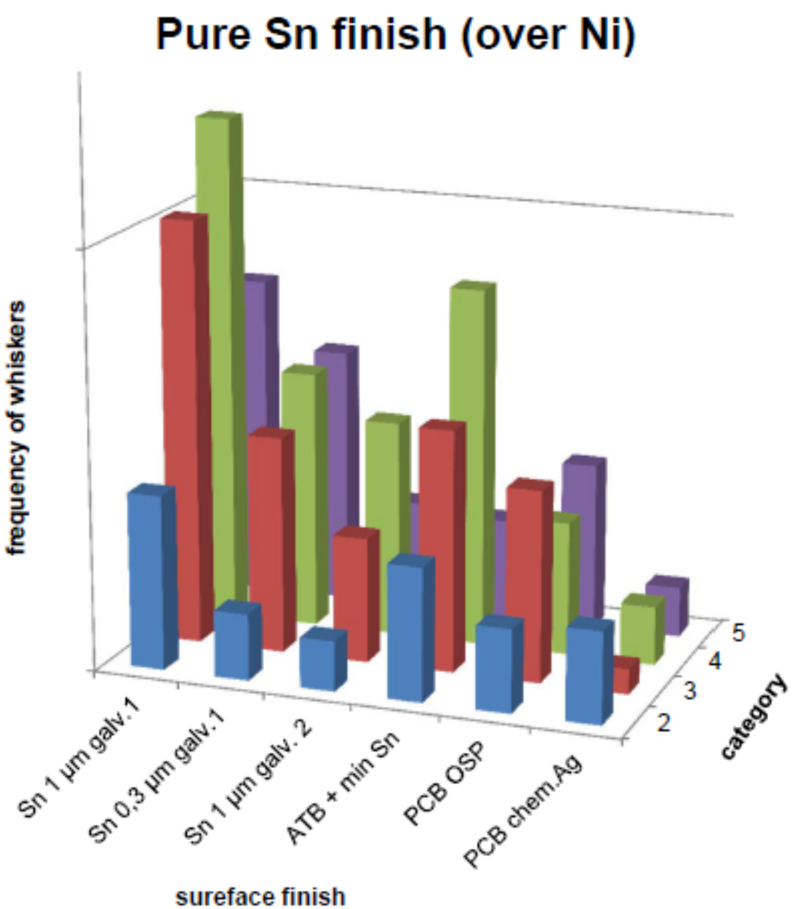
Whiskers potentially create short circuits or parasitary current paths. Fast growth of whiskers can be observed in press-fit connections due to high mechanical stress at pure tin surfaces.

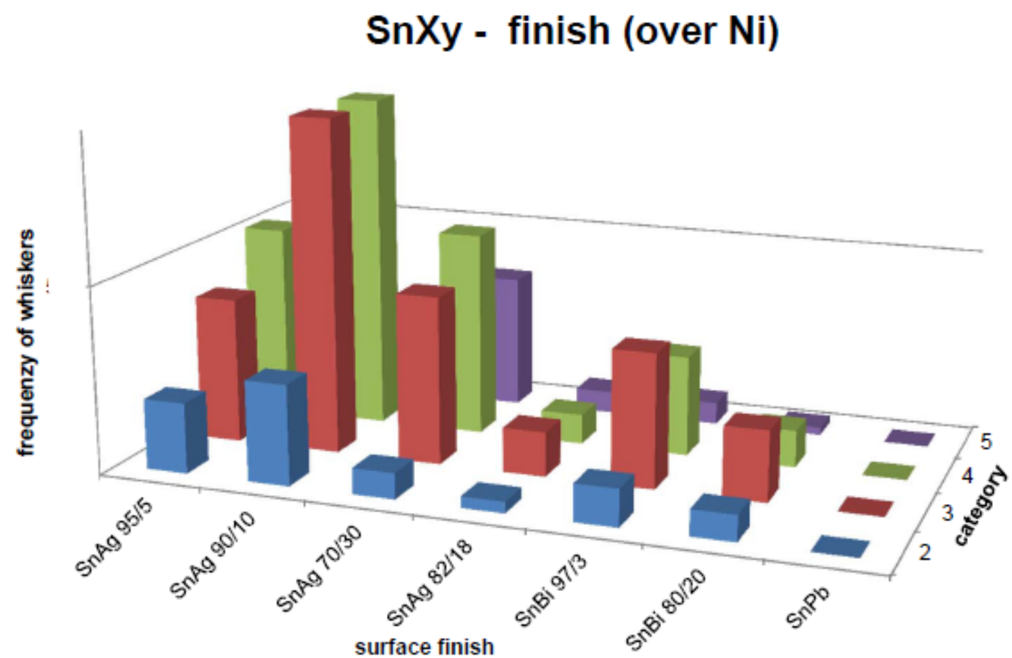


- Some 0-km and field returns identified at a body controller 2007
- Whiskers create direct parasitary signal path at sensor exits (very low current flow)
- Whisker length > 2 mm within 2-6 weeks after insertion in this case

Direct bridging of low signal electrical contacts

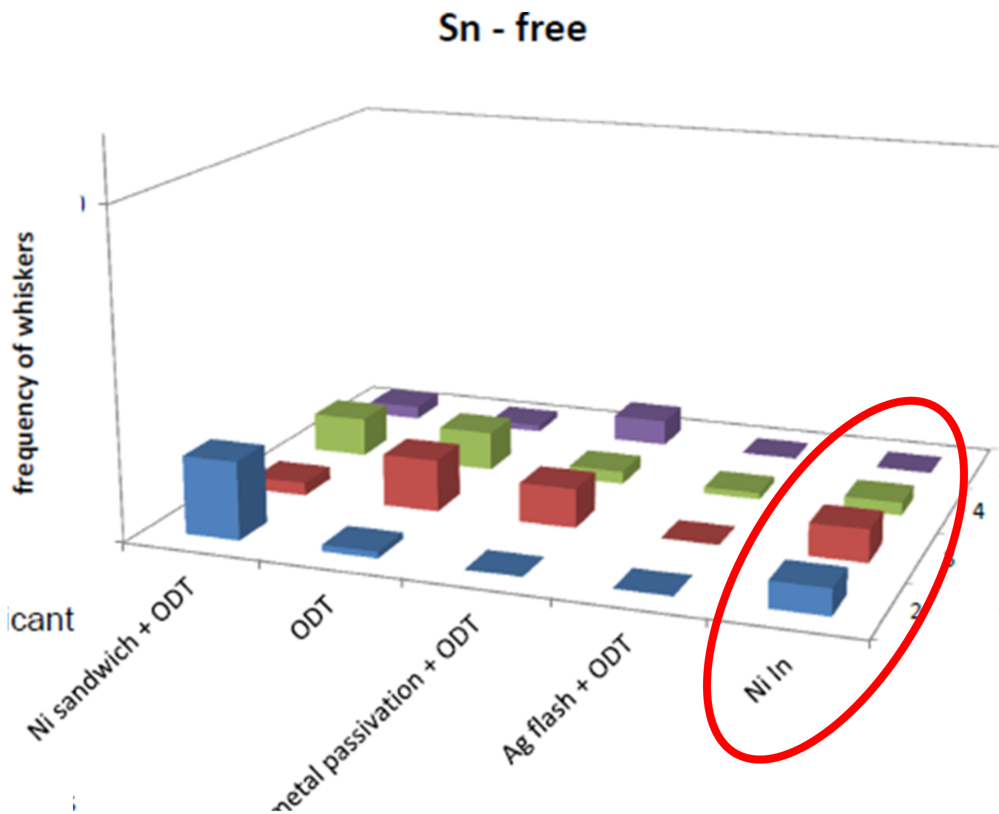
Tin Whisker Growth Comparison





Source : "Whiskers and Alternative Surface Finishes at Press-in Technology"
Dr. Hans-Peter Tranitz, Continental AG

Tin Whisker Growth Comparison



Indium is now a qualified/specified finish for Continental's press-fit applications

Source : "Whiskers and Alternative Surface Finishes at Press-in Technology"
Dr. Hans-Peter Tranitz, Continental AG

Continental – Indium Spec.

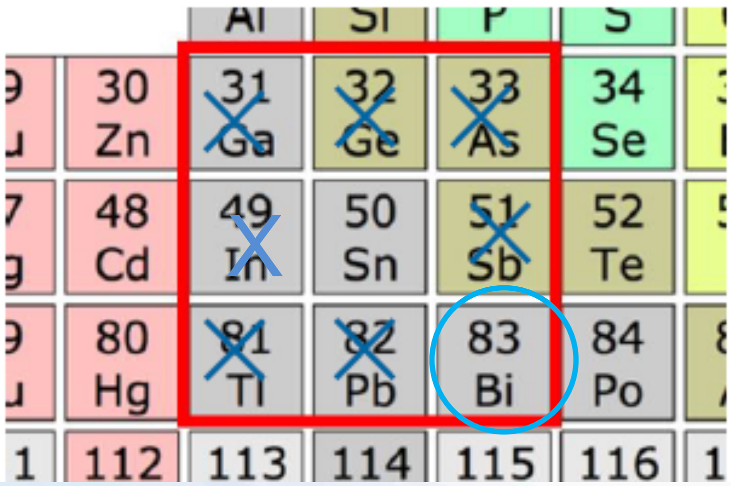
These requirements apply to new components with press-fit pins which will be introduced after this specification release date. Excluded are new components with press-fit pins arising from family concepts (e.g. variant of an existing product as pin coding, assignment).
Meeting these requirements for previously qualified components is preffered but not required.

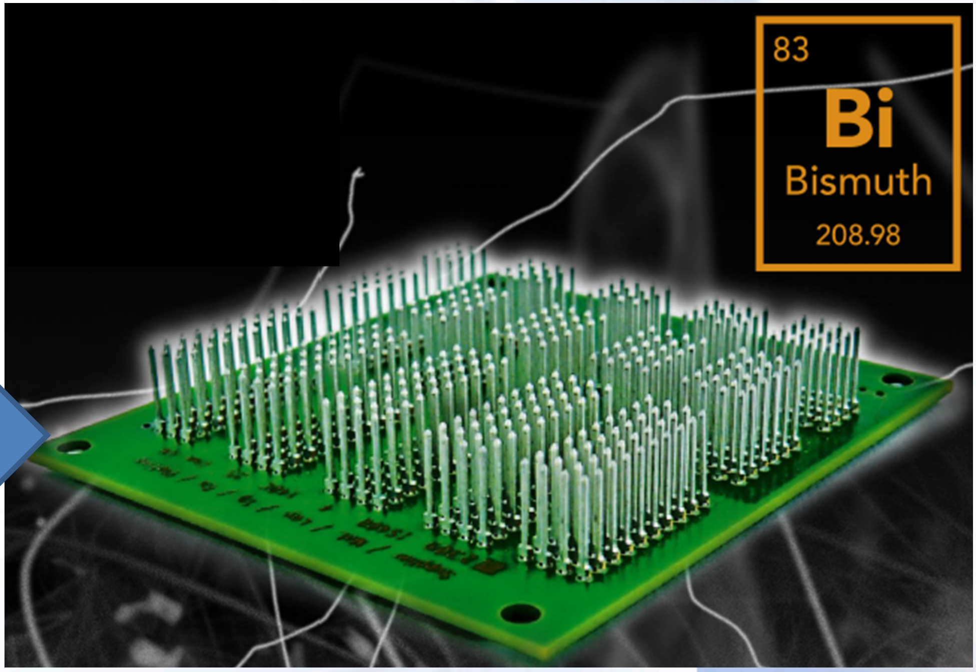
Continental plating surface portfolio includes **Indium**, **SnPb** (7+-3% Pb) with known legal restrictions and **matte Sn**.

	Ni (barrier layer) /µm	Plating surface /µm
Indium		
SnPb (7+-3% Pb)	2 ±1	0,7 ±0,4
Matte Sn		

Plating requirements are "whisker reduced", for detailed requirements see chapter 6.4 "Whisker analysis".

Press-Fit Pins
Bismuth Plating





<u>Bismuth</u> is also being considered as an option for certain press-fit applications

Source : "Litesurf –Tin-Free Electroplating for Press-Fit Technology," Frank Schabert TE Connectivity, Webinar presented March 2018

LITESURF – Bi Press-fit Plating Technology

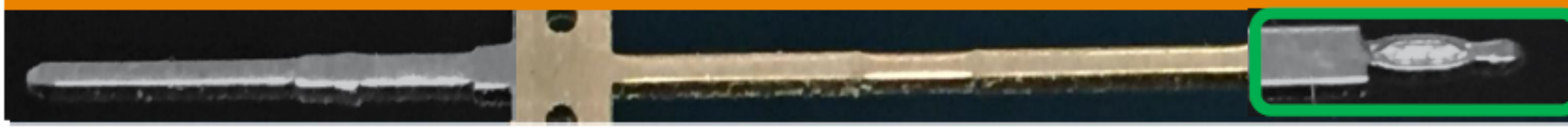
Sn/Ag/Au

Ni Barrier

Sn/Ag/Au over Ni as defined for mating side

Bi

Cu Alloy Base Material



Nickel Reduced

No Intermetallic

Lean Plating Solution

Press-Fit Connector Finishes Summary

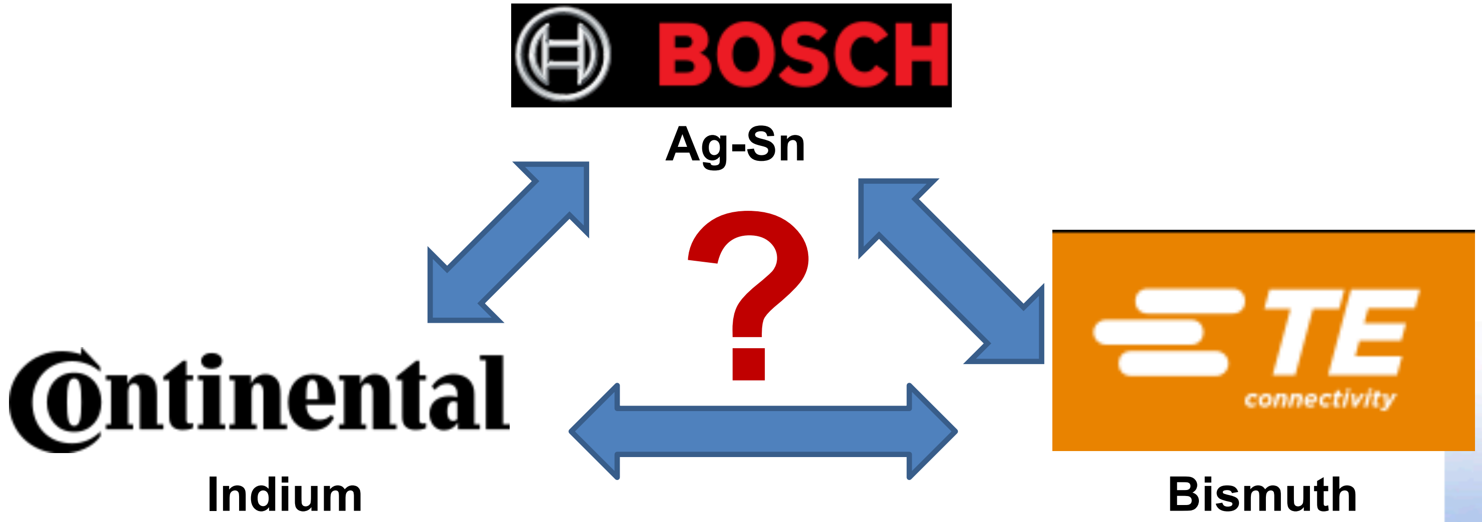
- Bosch has selected **Ag-Sn**
  - Several part types are specified with AgSn
- Continental has selected **Indium** as its preferred plating finish for press-fit pins
  - Several parts types are specified with In
    - Many connector manufacturers/plating companies are preparing In plating baths and/or samples for automotive companies
- Both Ag-Sn and In plating are “open” technologies; anyone can plate parts with AgSn for Bosch or In for Continental

Press-Fit Connector Finishes Summary

- TE has selected **Bismuth** as its preferred plating finish for press-fit pins
  - No known automotive suppliers have accepted Bi yet
  - "Proprietary plating process" developed by TE internally
    - Intended to be used solely on TE parts for several years
    - TE intends to license a chemistry supplier to blend and supply TE's Bi plating formulation to others at some future date
    - No known patents on the application of Bi, or plated articles with Bi, have been identified yet
  - Can others supply Bi plated parts using <u>alternative</u> Bi plating chemistry? Nobody knows and TE is not talking!!

Press-Fit Connector Finishes Conclusions

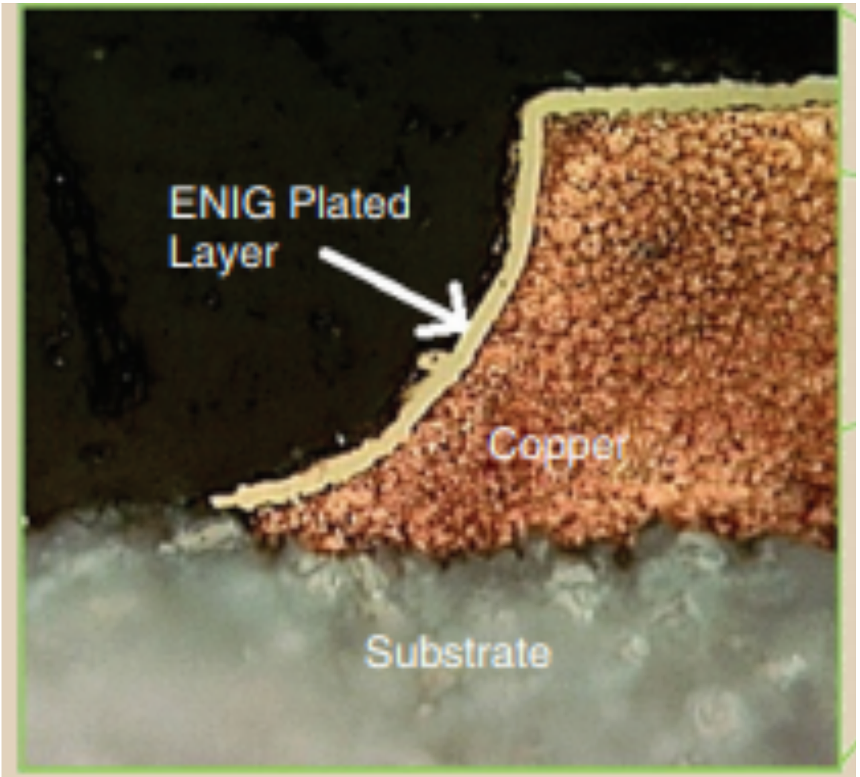
- Which finish will win out?????

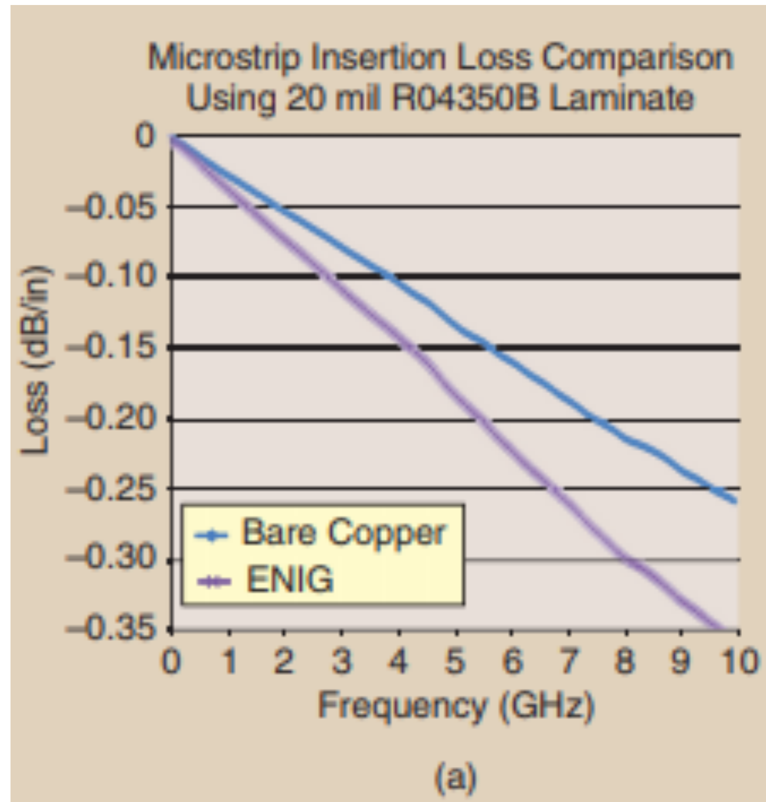


High Frequency Applications (5G)

Beyond Ni/Au:
High Frequency Applications

Signal Loss vs. PCB Final Finish





(a)

<u>Nickel</u> deposit is the source of signal loss in high frequency applications

Source: "Ambiguous Influences Affecting Insertion Loss of Microwave Printed Circuit Boards" John Conrood, IEEE Microwave Magazine, Issue 1527-3342/12

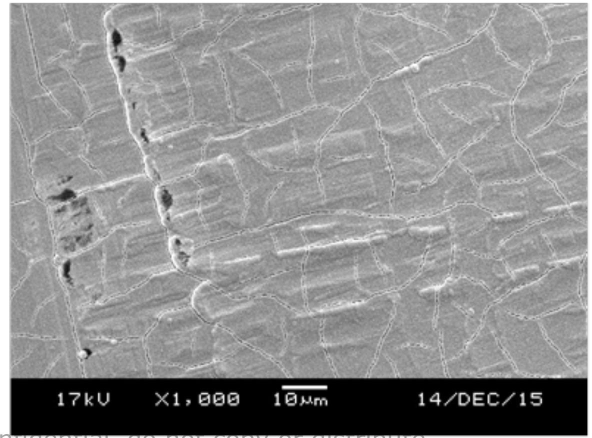
Connector Finishes for High Frequency Applications (5G)

- Ni-free barrier layer is required
- Good conductivity and corrosion resistance for final finish
- Palladium (Pd) is a suitable deposit that can function as both a barrier layer and a final finish
  - Barrier layer effectiveness requires relatively high thickness (>0.75-1.0 µm)
  - HOWEVER electroplated Palladium is notorious for micro-cracking at high thickness
- Solution : micro-crack free Palladium

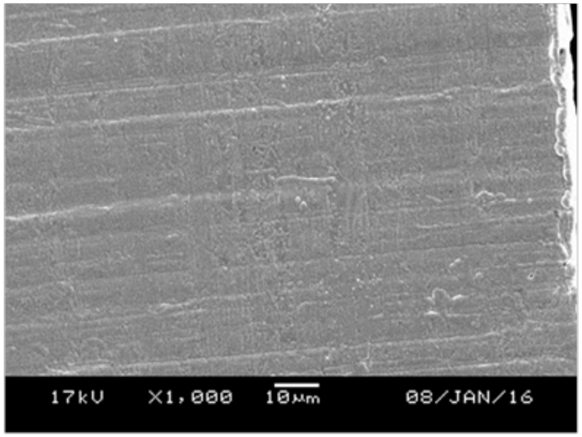
Low Stress/High Ductility Palladium

- Low stress deposits
  - No spontaneous microcracking up to 4 µm Pd thickness
  - No bending cracks (up to 2µm)
- Neutral pH / no ammonia smell
- Wide current density range
- Stable electrolyte
  - >5 MTO bath life, with periodic c-treatment

Conventional Pd-Cracked



High Ductility Pd- No cracks



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Beyond Ni/Au: Summary

(III) Post-Treatment →
- Techniseal on Ag
- AgSn/In/Bismuth (press-fit)

(II) Au or other Layer(s) → **Au or Alternative(s)**
- Silver
- Rhodium/Rh Alloys
- Palladium

(I) Barrier Layer → **Ni or Alternative(s)**
- GE Ni / GE NiW
- Cobalt-Tungsten

Palladium

Substrate

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Beyond Ni/Au: Conclusions

- Rapid changes are occurring in an industry where conventional Ni/Au has been used for 4 decades
- Alternative finishes are being considered and/or implemented, including exotic materials never before considered feasible in a connector application
- We expect additional changes will occur as connector finish technology needs to keep up with the demands of the other interconnects and/or use environments

Thank you!

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