# The Role Of Electroplates In Contact Reliability

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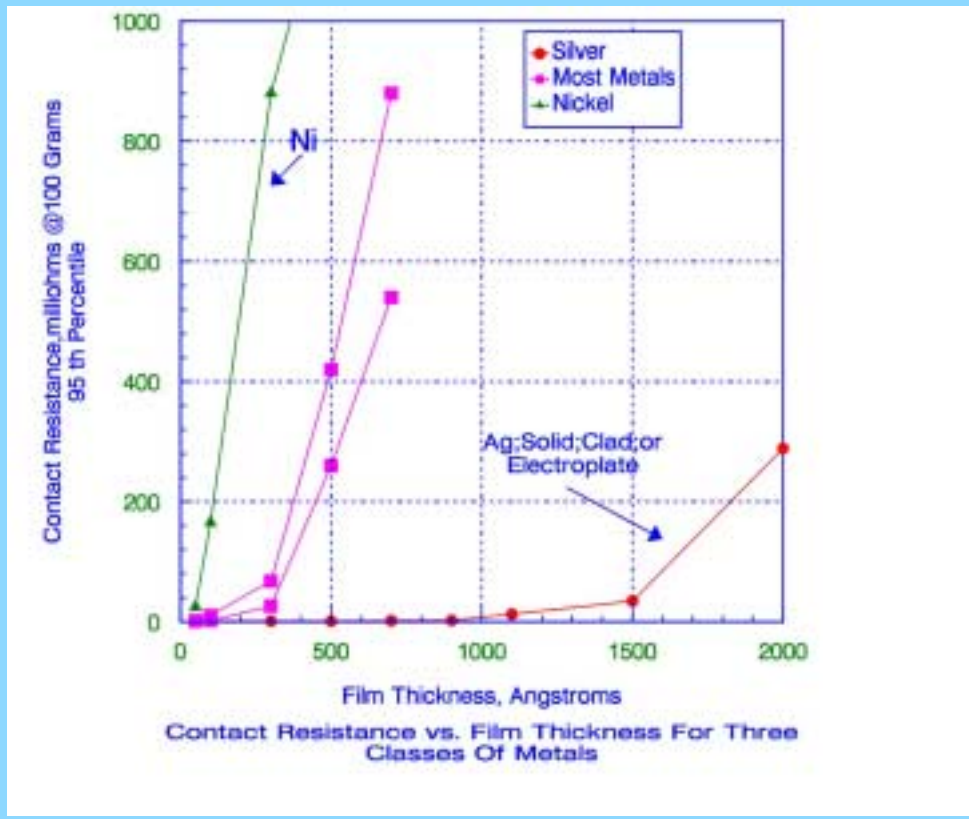
# Overview

- Electroplating Is A Process; i.e. It Should Not Be Viewed As Simply A Material
- The Performance Of An Electroplated Coating Will Depend On:
  - Material
  - Substrate(s)
  - Substrate Finish
  - Thickness

# Why Electroplates

- To Cover Up Otherwise Unacceptable/Reactive Surfaces
- Thin Films (>30-50 A) On Surfaces May Produce Very High RC
- Effects Of Surface Films Are Highly Dependent On:
  - Film Thickness
  - Materials/Film Chemistry

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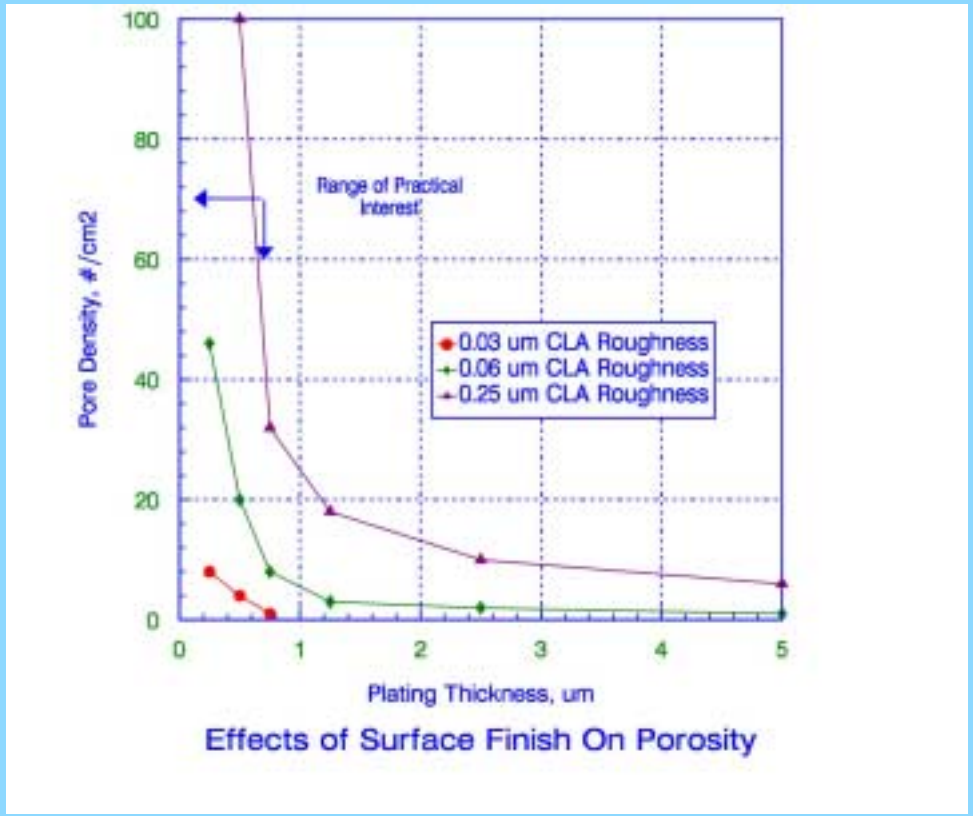
# Porosity – Effects Of Thickness And Roughness

- Substrate Roughness Has First Order Effect On Porosity In The Plated Coating
- In Reality Nearly All Plated Coatings At Practical Thickness Values Will Be Porous
- Porosity Is One Route To Corrosion



Effects of Surface Finish On Porosity

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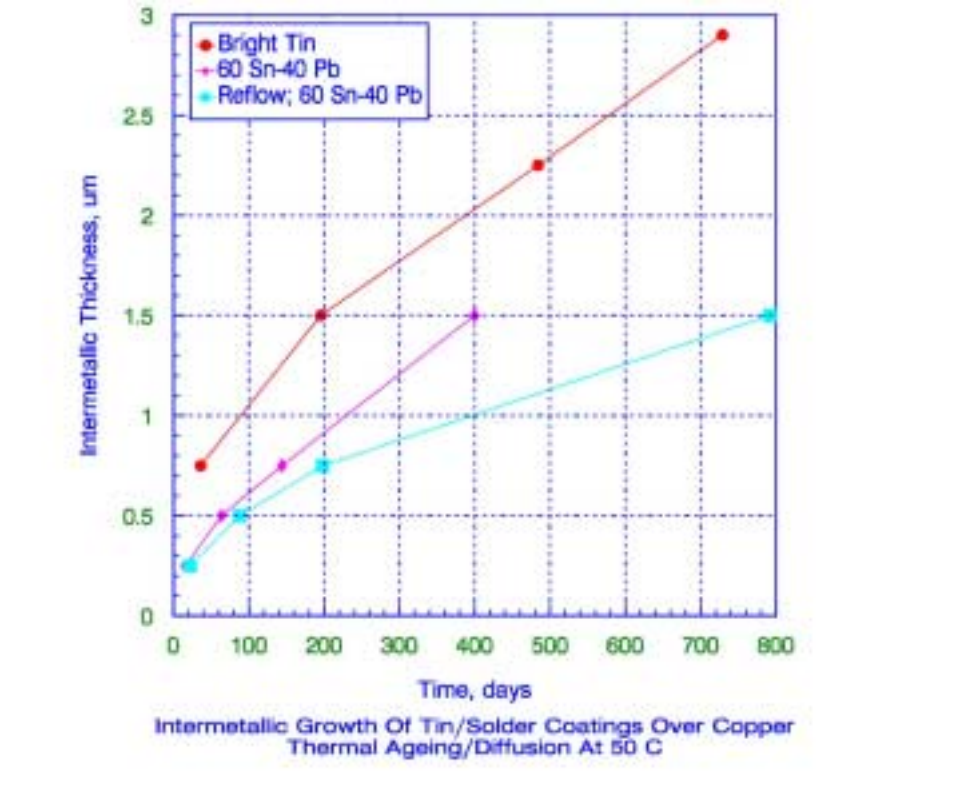
# Limitations Of Electroplated Coatings

- Thin (0.4 – 5 um)
  - Subject To Effects Of Diffusion From Substrate
    - Corrosion
    - Fretting
  - Subject To Wear And Reactive Metal Exposure
    - Corrosion
    - Fretting
- Porous
  - Subject To Corrosion

# Thermal Diffusion

- Substrate Metals May Diffuse To Or Near Surface Of Thin Coatings
- Effects May Be Rapid
- Coating Properties Will Be Altered
  - Hardness Will Increase
  - Chemical Reactivity Usually Increased

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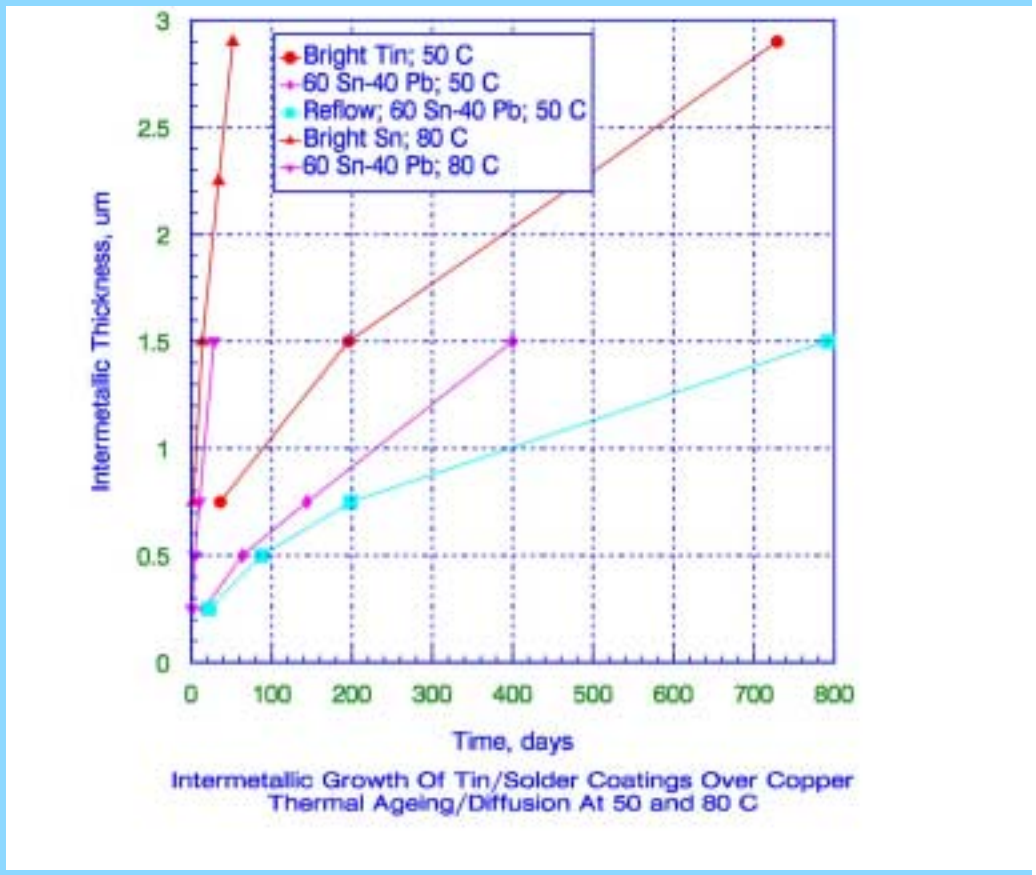

Intermetallic Growth Of Tin/Solder Coatings Over Copper Thermal Ageing/Diffusion At 50 and 80 C

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# The Contact Properties Of Silver Coatings

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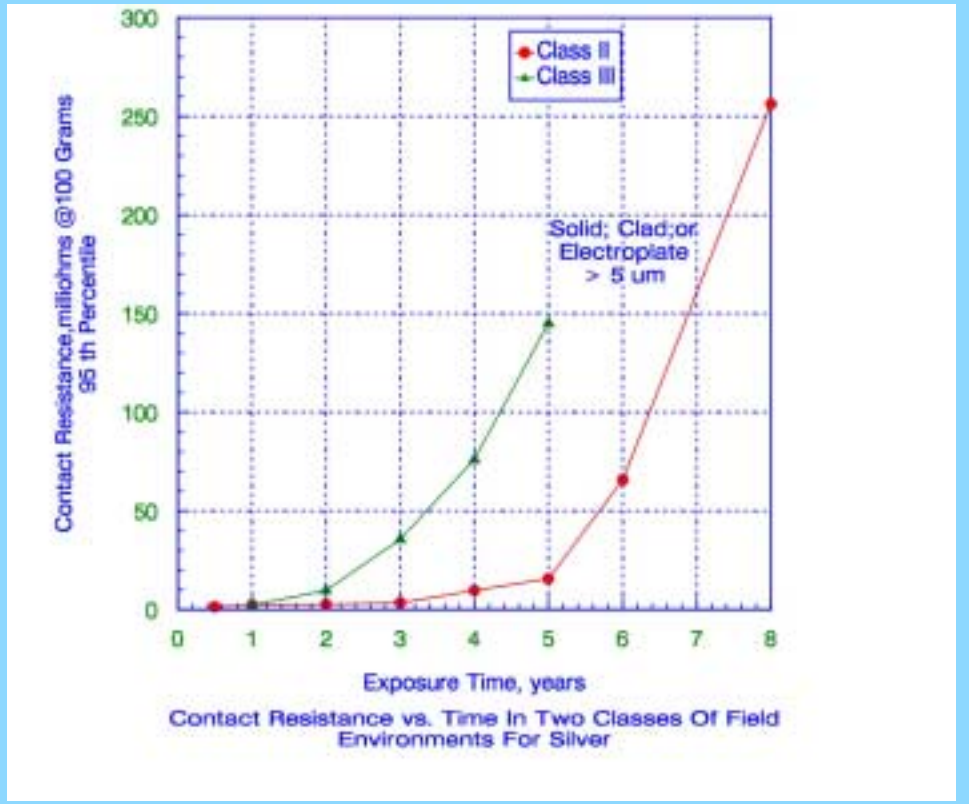
# Reaction Of Pure Silver In The Field

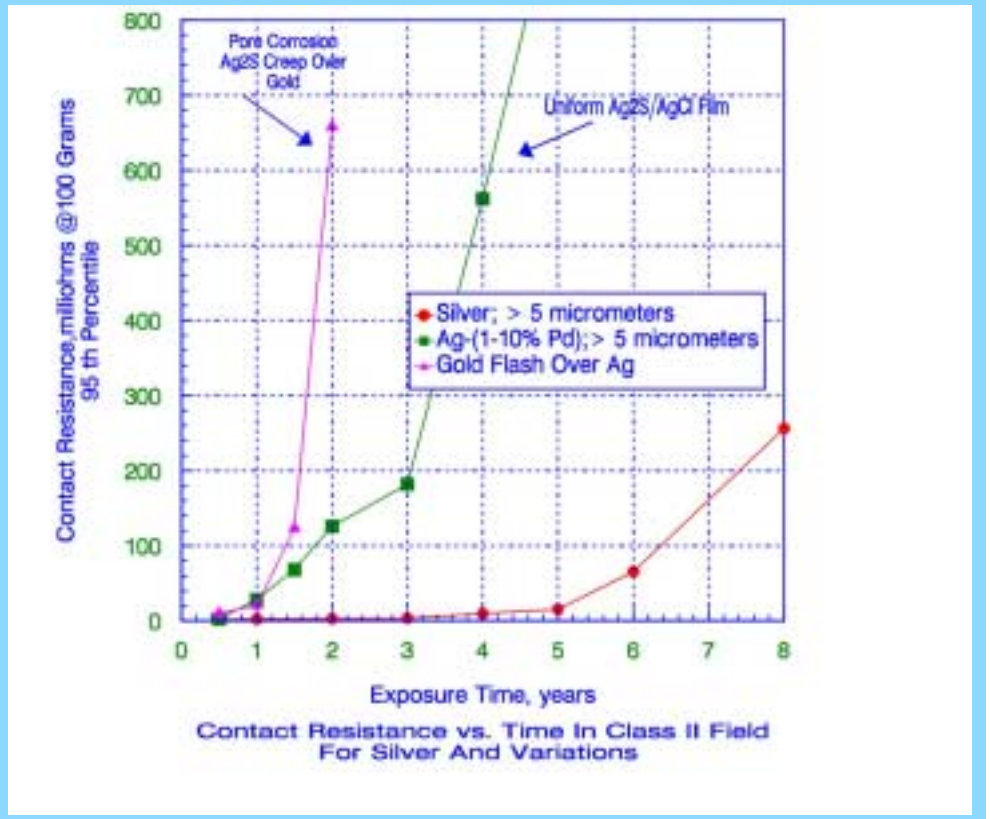
- Silver Is Unique Among Metals
  - Films Are Soft
  - Large Film Thickness Tolerable
- Characteristics/Performance The Same For Solid,Clad, Electroplate



Contact Resistance vs. Time In Two Classes Of Field Environments For Silver

# Performance Of Silver Modified By Electroplating

- Small Alloying Additions (Au,Pd, Cu, etc)
  - Adverse Effect On Properties
  - No Measurable Effect On Kinetics
- Effects Of Gold Flash
  - Porous By Definition
  - Accelerated Creep Of Ag2S
  - Very “Hard” Film
  - Very High Risk



Contact Resistance vs. Time In Class II Field For Silver And Variations

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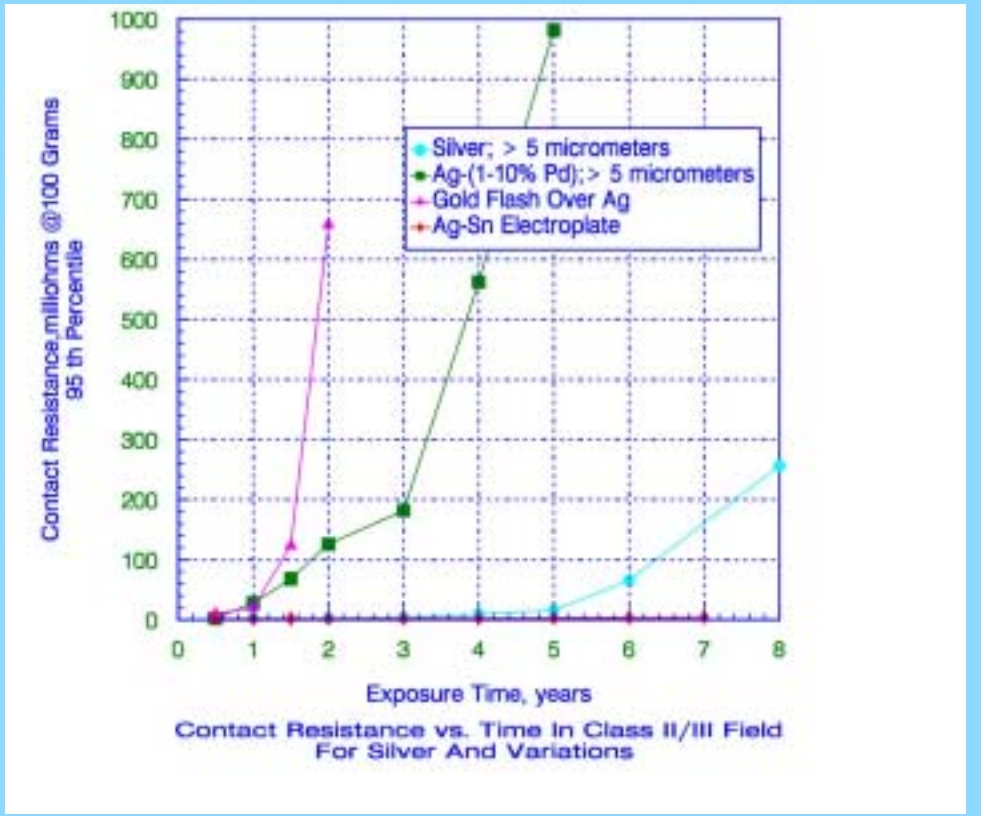
# Any Advances In Silver EP Technology ?

- Ag-20 Sn Alloy Electroplate (Heraeus, 1992) Has Shown Excellent Field And Laboratory Performance

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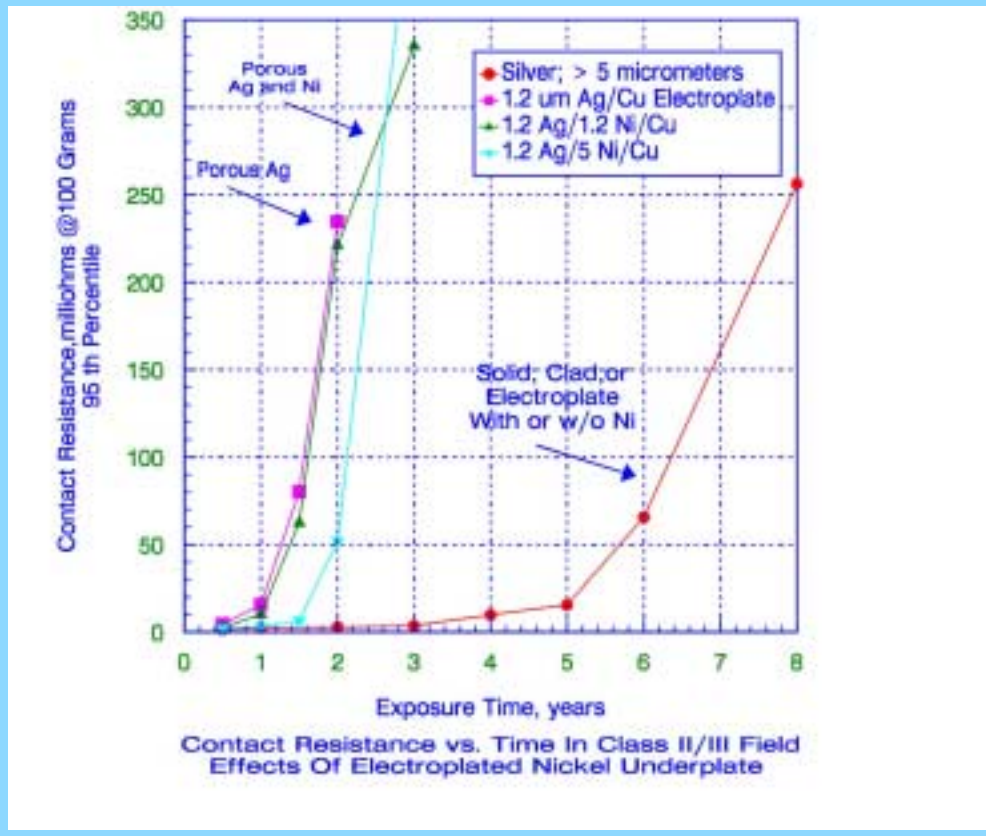
# Corrosion Of Porous Silver Electroplates

- Effects Of Porosity (or Other Defects) May Dominate Performance
- Nickel Underplates
  - Corrosion Rates Reduced
  - Favorable Rates May Be Offset By Hard/Tenacious Nickel Products



Contact Resistance vs. Time In Class II/III Field
Effects Of Electroplated Nickel Underplate

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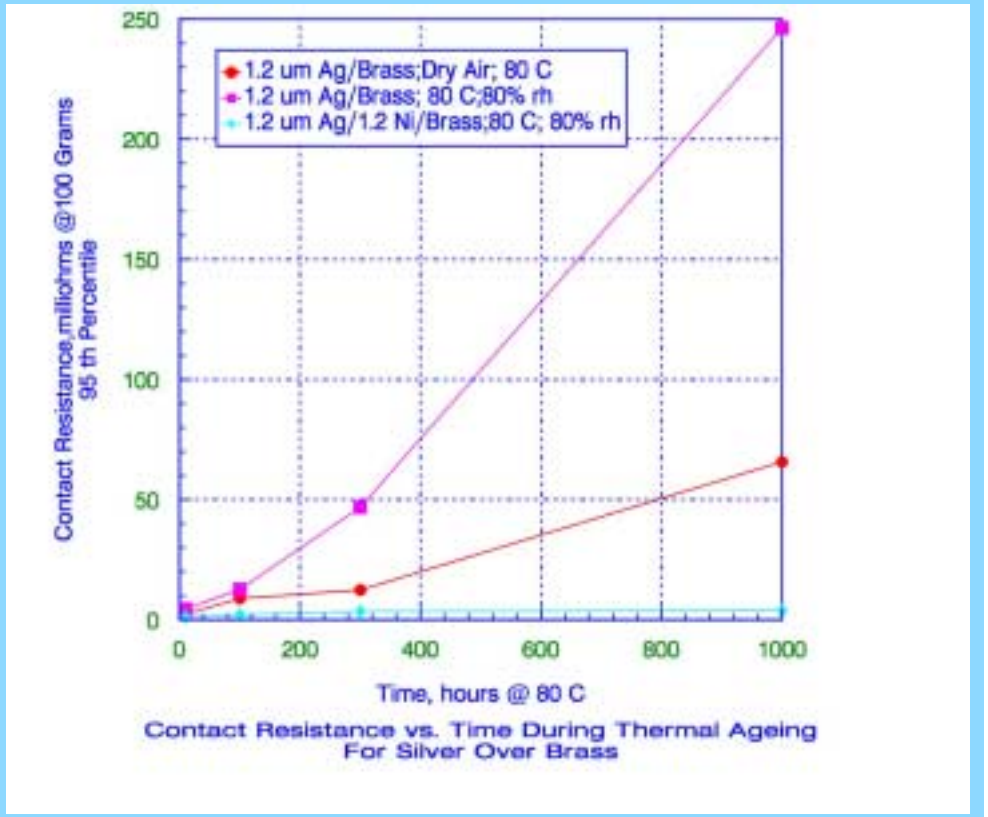
# Effects Of Substrate On Silver EP Performance – Effects Of Diffusion

- Diffusion Rate Of Zn Through Ag Very High
- Adverse Effects Even In Humid Air
- Major Benefit Of Nickel As A Diffusion Barrier

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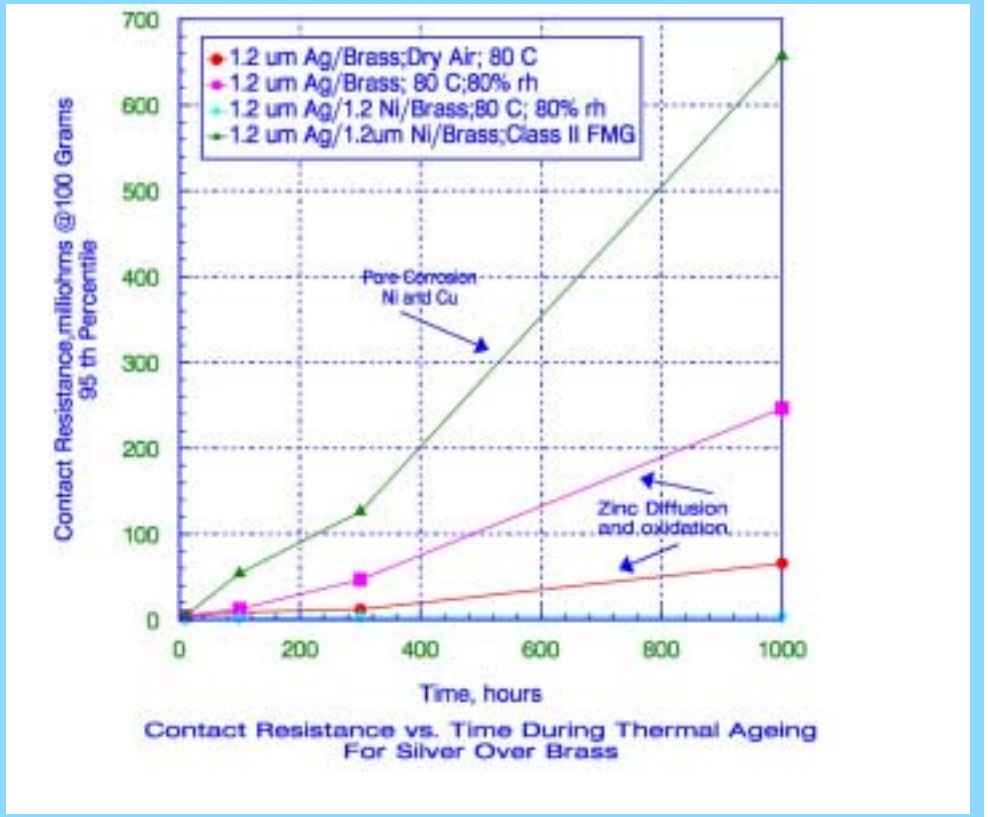
# Relative Effects Of Porosity Vs. Diffusion

- Effects Of Porosity May Be Overwhelming
- Nickel Is Good Diffusion Barrier
- Nickel Is NOT A Good Corrosion Barrier



Contact Resistance vs. Time During Thermal Ageing For Silver Over Brass

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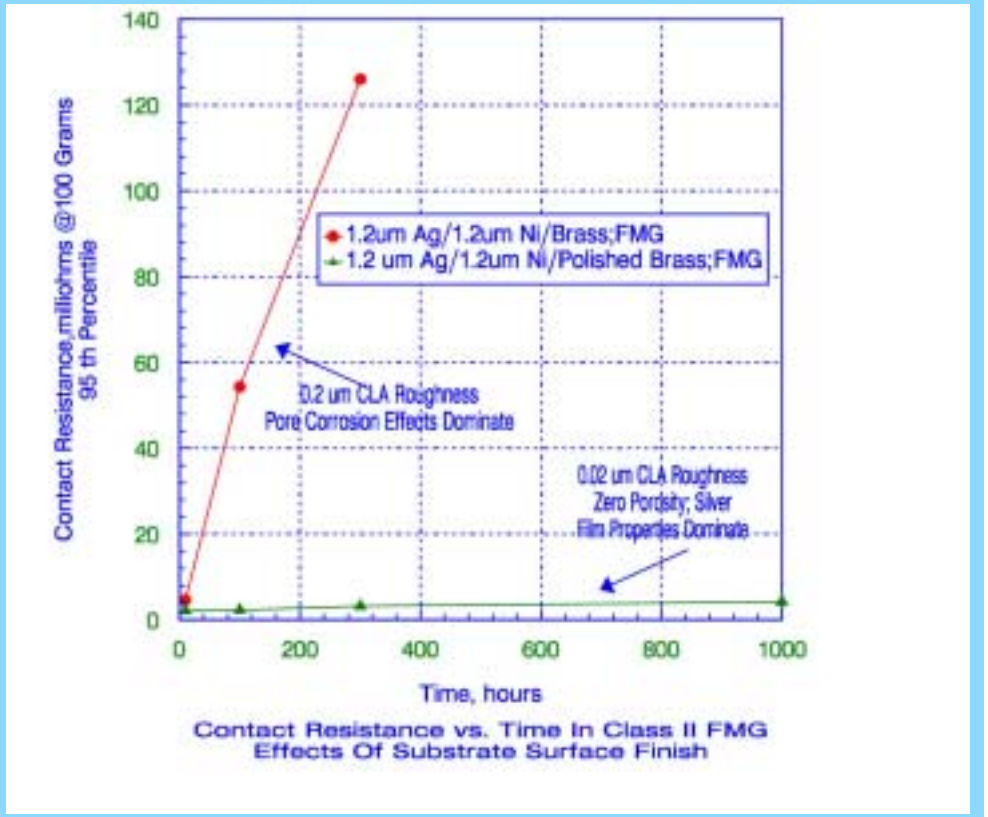
# Effects Of Substrate Surface Finish On Performance

- Initial Finish Prior To Plating May Dominate Porosity And, In Turn, May Dominate All Other Effects



Contact Resistance vs. Time In Class II FMG
Effects Of Substrate Surface Finish

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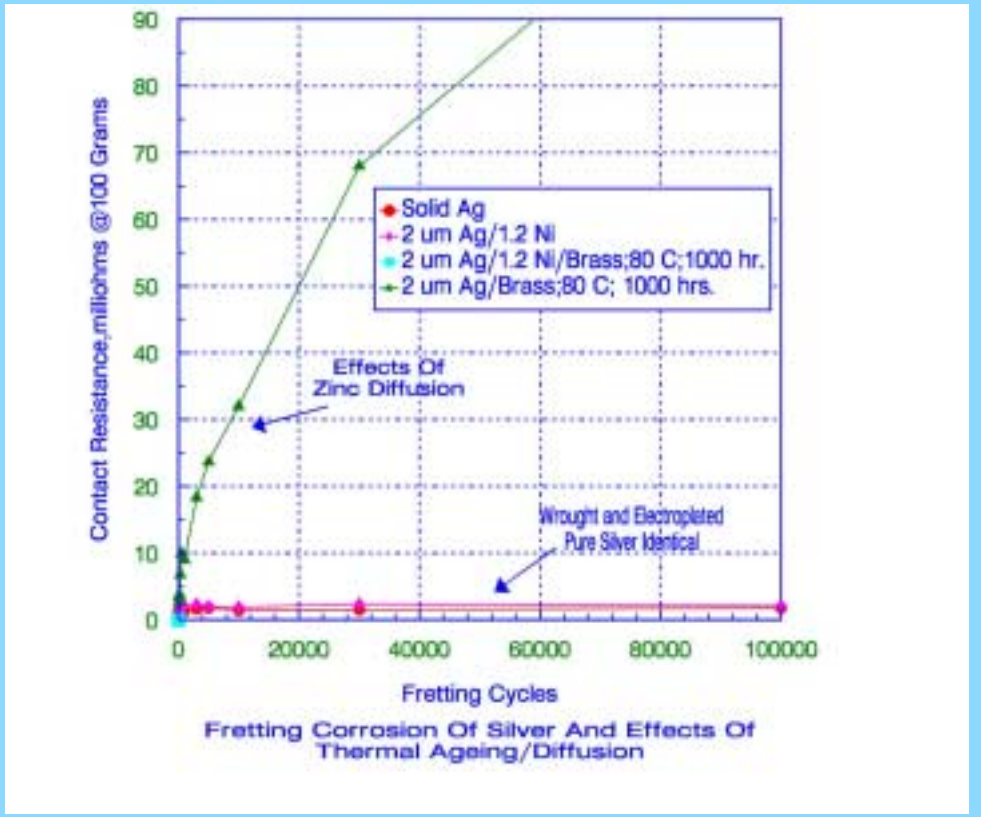
# Effects Of Diffusion/Property Changes On Fretting Corrosion

- Silver Surfaces Have Excellent Performance In Fretting
  - Little Effect Of Thickness
  - Little Effect Of Porosity
  - Little Effect Of Substrate, Process, or Most Measurables
- Diffusion May Degrade Performance By:
  - Surface More Susceptible To Oxidation
  - Surface Is Harder

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# Contact Properties Of Nickel

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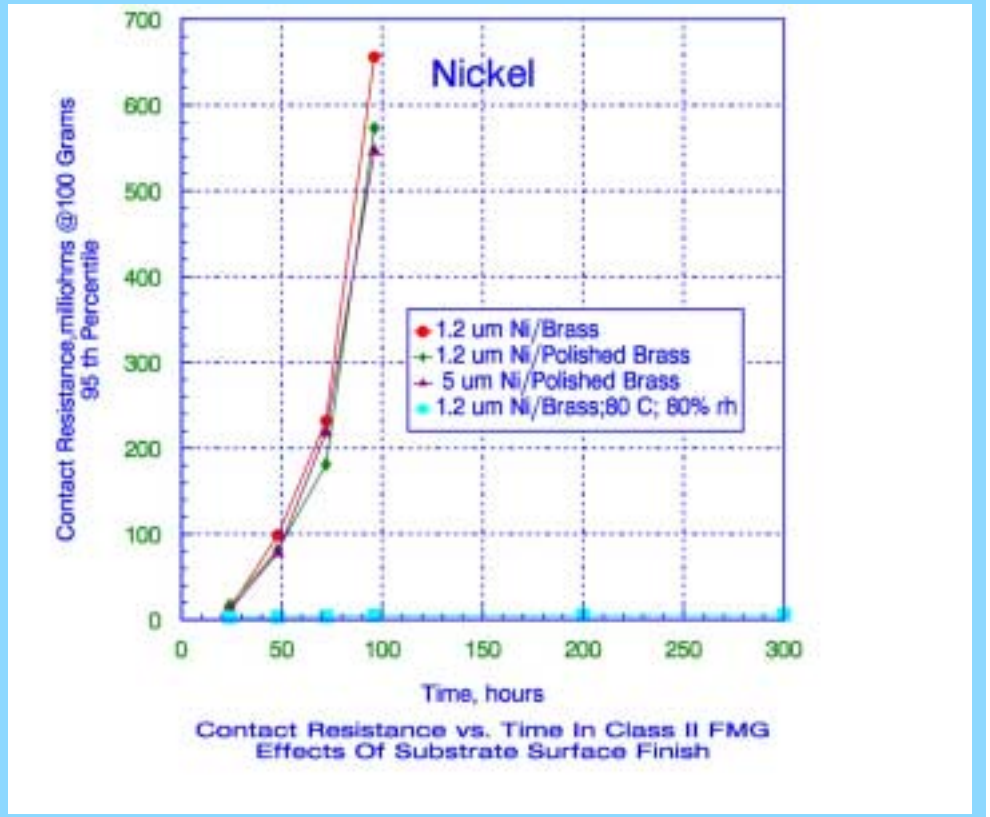
# Effects Of Environment On Nickel

- Performance Of Nickel Is Dominated By Properties Of Nickel
  - Little Effect Of Process
  - Little Effect Of Porosity Or Most Measurables
- May Have Acceptable Performance In "Clean" Environments
- Poor Corrosion Resistance
- Poor Fretting Resistance
- Should Be Used At Higher Forces And Non-Critical Applications
- Major Attribute As Diffusion Barrier



Contact Resistance vs. Time In Class II FMG
Effects Of Substrate Surface Finish

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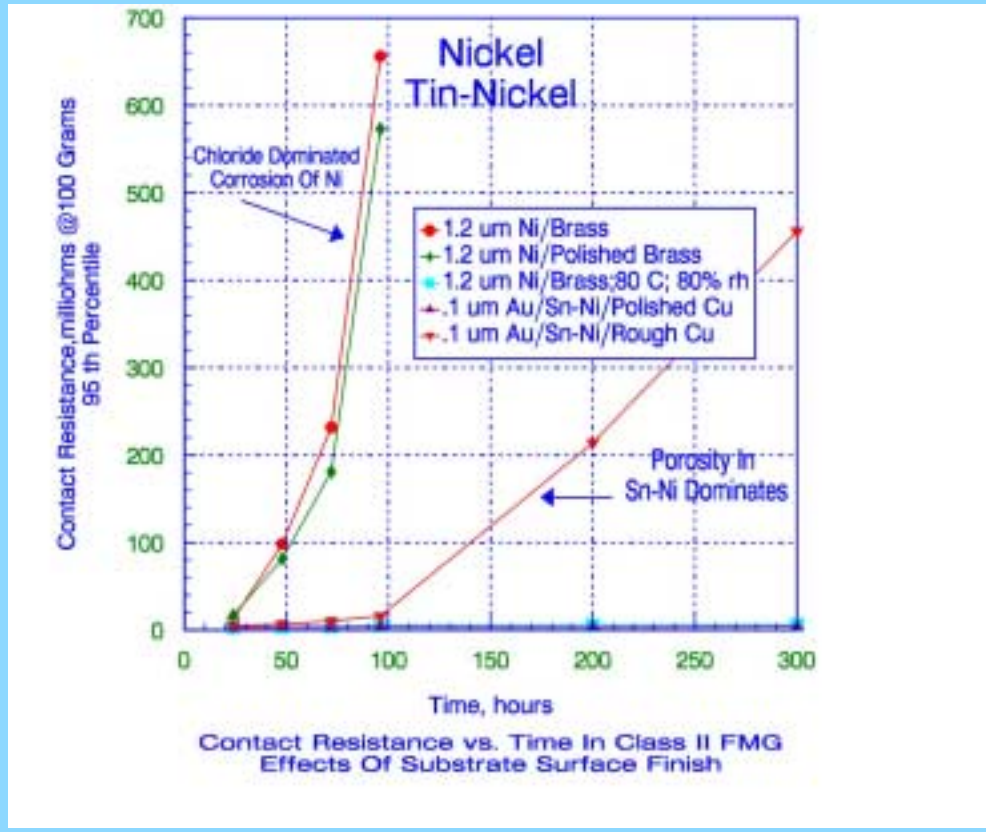
# Corrosion Of Nickel And Tin-Nickel

- Tin-Nickel EP Is Probably The Only "Advance" In Nickel Plating For Contacts
  - Excellent Corrosion Resistance
  - Very High RC
- Gold-Flashed Sn-Ni Has:
  - Excellent Corrosion Resistance
  - Low RC
- Porosity Effects May Again Dominate Performance
- Interesting "Laboratory" Material; Not Very Practical For Modern Processes



Contact Resistance vs. Time In Class II FMG
Effects Of Substrate Surface Finish

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# Contact Properties Of Tin And Solder Electroplates

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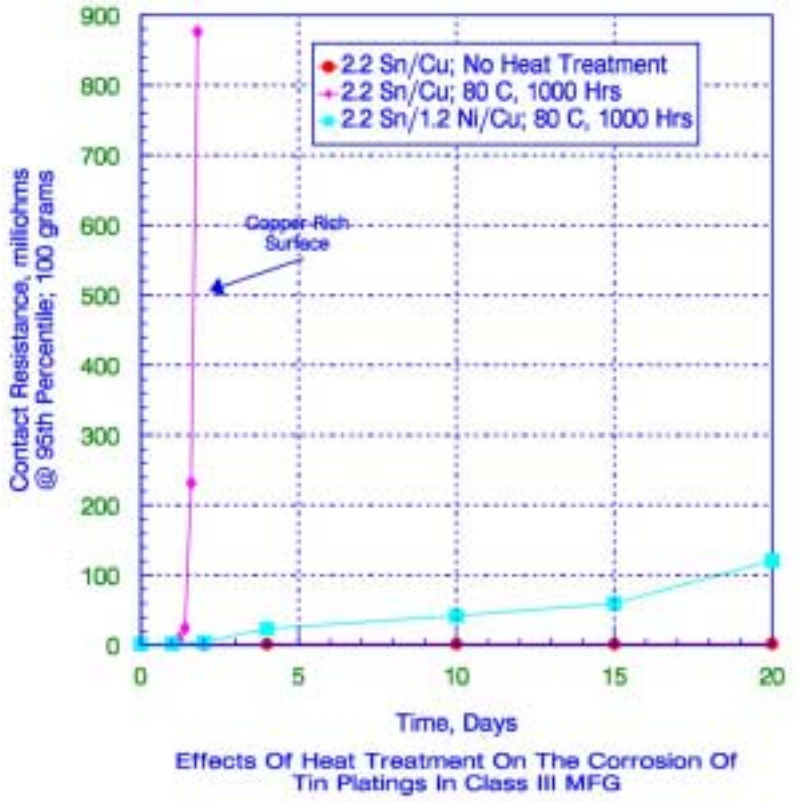
# Corrosion Of Tin And Tin-Lead

- Thick/Non-Porous Coatings Are Highly Corrosion Resistant In Field And Lab
- Corrosion Product Creep Rates Are Very Low Over Tin Surfaces
- Conclusions For Sn and Sn-Pb Are The Same
- Diffusion May Radically Decrease Corrosion Resistance
- Nickel Barriers Are Very Effective But Diffusion May Still Limit Time-Temperature Performance




Effects Of Heat Treatment On The Corrosion Of Tin Platings In Class III MFG

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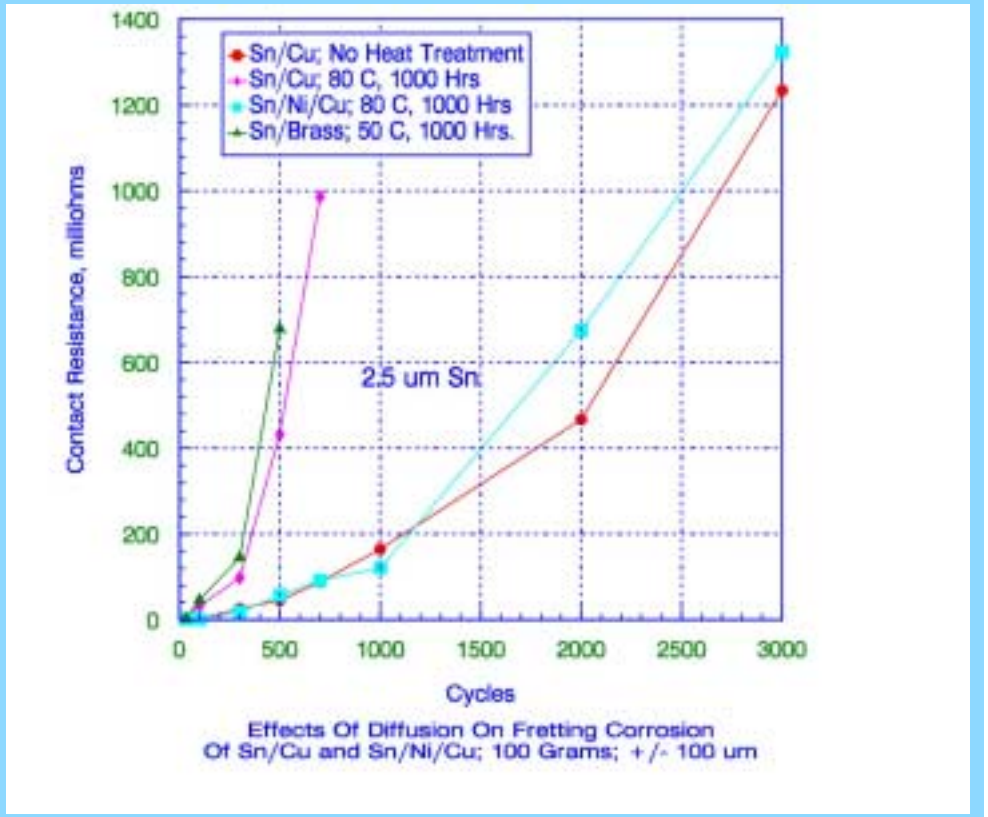
# Fretting Corrosion Of Tin – Effects Of Diffusion

- Exposure/Treatment/Conditions That Reduce The Effective Thickness Of The Soft Tin Coating Will Degrade Performance
- Process, Substrate, Porosity, Alloying Additions, or About Any Other Measurables Will Have Second Order Effects Other Than On Diffusion



Effects Of Diffusion On Fretting Corrosion Of Sn/Cu and Sn/Ni/Cu; 100 Grams; +/- 100 um

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# Contact Properties Of Gold Electroplates

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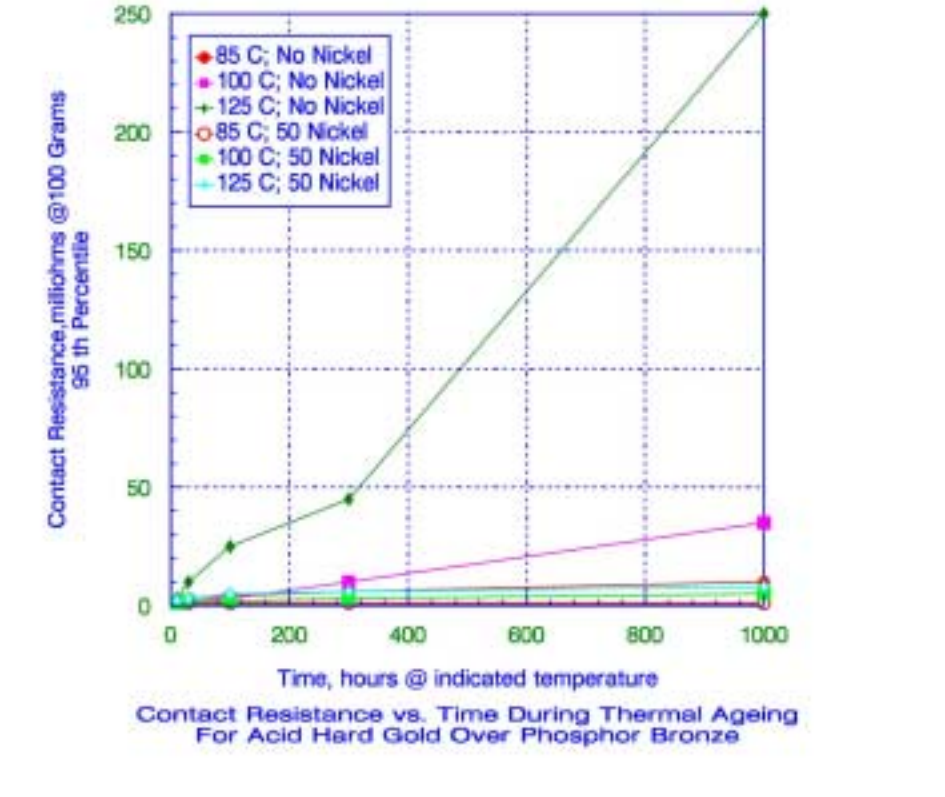
# Thermal Ageing Effects On Gold Electroplates; Effects of Nickel Underplate

- Two Contributions To Degradation
  - Diffusion Of Copper + Oxidation
  - Oxidation of Cobalt In Gold
- Diffusion and Copper Oxidation Significant >85 C w/o Nickel
- Nickel Barrier May Extend Temperature Limit To ~ 125 C

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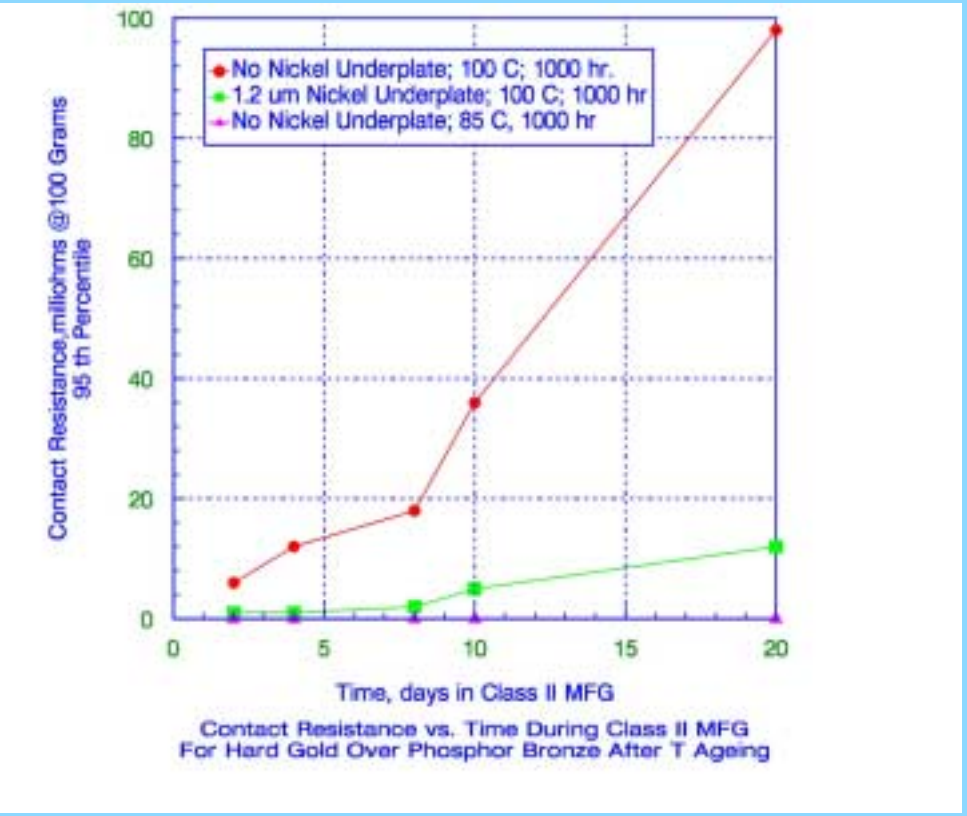
# Effects Of Diffusion On Corrosion; Very Low Porosity Gold Platings

- Copper Diffusion May Make Plating Very Susceptible To Environmental Corrosion
  - ~85 C Limit w/o Nickel
- Nickel Underplate May Raise Temperature Limit To 100+ C Range
- Other Underplates Such As Palladium or Pd-Ni May Increase Limit Into 125-150 C Range

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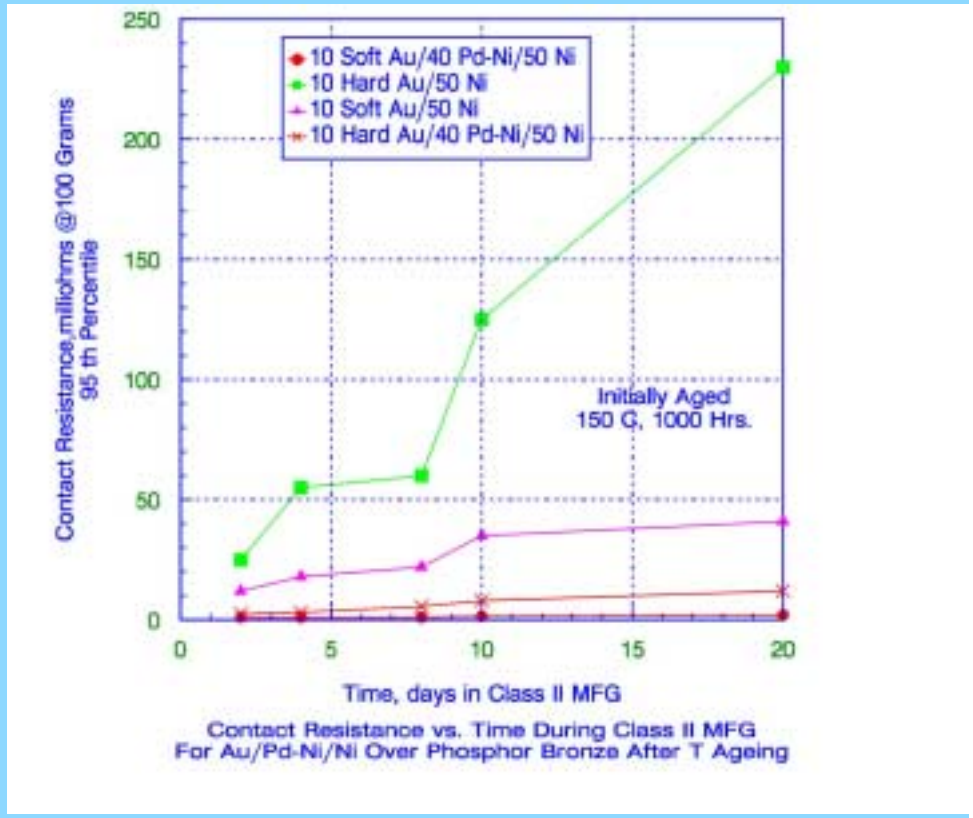
# Effects Of Diffusion On Corrosion; Very Low Porosity Gold Platings

- Diffusion of Nickel May Limit Reliability >125 C
- Soft Au Will Mitigate Effects
- Other Underplates/Barriers May Increase Temperature Life And Improve Corrosion Resistance
- Au Flash/Pd-Ni May Give Optimum Properties And Good Wear Resistance



Contact Resistance vs. Time During Class II MFG
For Au/Pd-Ni/Ni Over Phosphor Bronze After T Ageing

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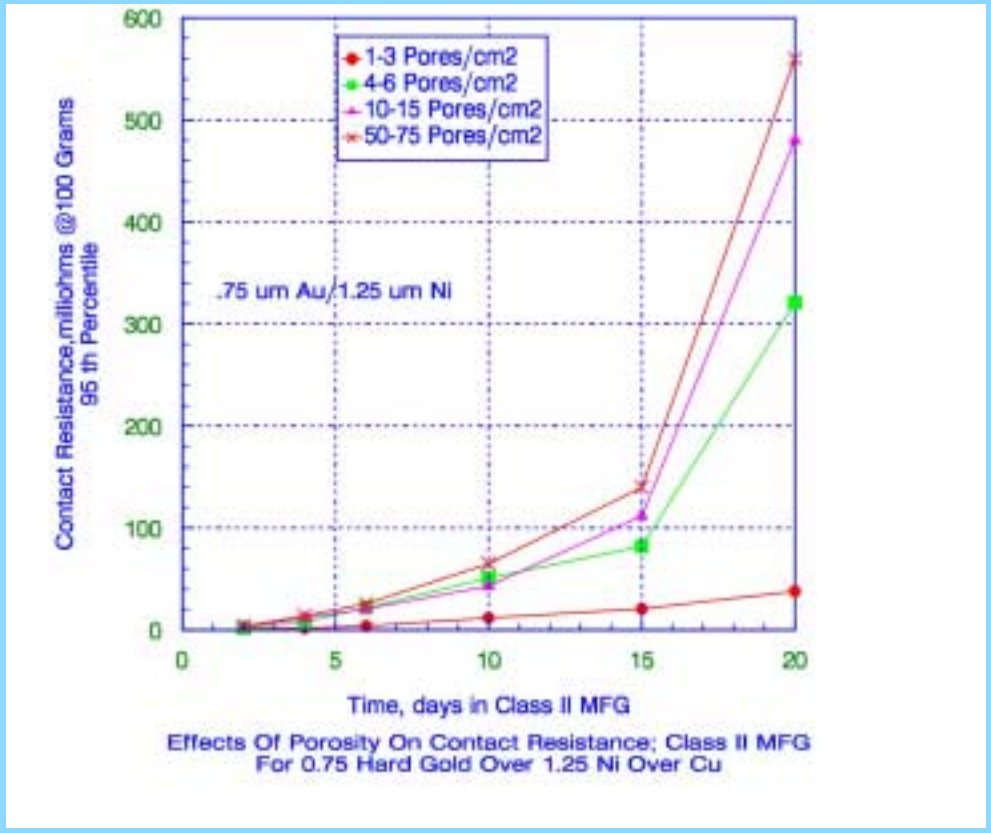
# Effects Of Porosity On Corrosion

- Porosity May Have Overwhelming Effect
- Effects On Rc Due To:
  - Corrosion Kinetics of Underplates (Cu vs. Ni)
  - Mechanical Properties Of Films
- First Few Pores May Have Dominant Effect



Effects Of Porosity On Contact Resistance; Class II MFG For 0.75 Hard Gold Over 1.25 Ni Over Cu

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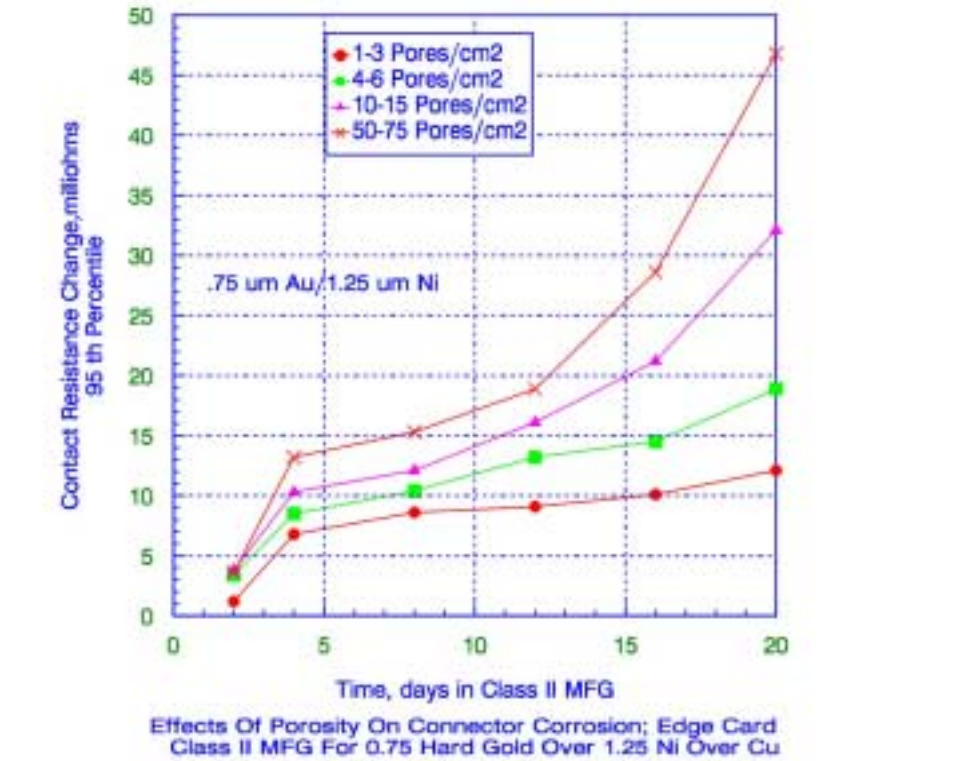
# Effects Of Porosity On Mated Connector Corrosion

- Extent of corrosion at mated interfaces small but real
  - Thin film effects
  - Shielding effects by housing
- Non Linear Effect Of Pore Density
- Results Can Be Modified By
  - Underplating
  - Surface Finish
  - Connector Type/Shielding
  - Lubrication



Effects Of Porosity On Connector Corrosion; Edge Card Class II MFG For 0.75 Hard Gold Over 1.25 Ni Over Cu

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# Summary and Conclusions

- Electroplates Cannot Be Viewed As Simply A Metallic Coating
- Electroplates Must be Viewed As Part Of A System Consisting Of In Order Of Priority:
  - Metallic Coating
  - Porosity
  - Substrate Metal
  - Thickness
- System Reliability Is Difficult To Predict
  - Realistic Test Protocols Necessary
  - Lubrication Or Other Protection Schemes May Dominate Reliability Considerations For Performance Of Low Cost Systems