Electrolytic Nickel-Phosphorus Plating
“Electrolytic Nickel-Phosphorus Plating“

Richard DePoto     C. Uyemura & Co.
Joerg Weber        Umicore Galvanotechnik
Klaus Leydecker    Umicore Galvanotechnik
Discussion

- **NIPHOS® E-Plated Nickel Phos:** Characteristics
- **E-Plated Nickel Phos:** Advantages
- **E-Plated Nickel Phos:** Reasons for Interest
- **E-Plated Nickel Phos:** Electrolyte Specifications
- **E-Plated Nickel Phos:** Layer Properties
- **E-Plated Nickel:** Applications / Markets
- **Summary:** Future Outlook
# Coating Characteristics

<table>
<thead>
<tr>
<th>Electroplated Alloy composition</th>
<th>Nickel</th>
<th>88 - 94 %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phosphorus</td>
<td>6 - 12 %</td>
</tr>
<tr>
<td></td>
<td>Diamagnetic</td>
<td>P &gt; 11 %</td>
</tr>
</tbody>
</table>

**Hardness**

550 - 600 HV, without heat treatment

**Abrasion**

2 mg/1000 strokes (Bosch-Weinmann)

**Ductility and Color**

Same as bright nickel

**Corrosion resistance**

Very good – Excellent
Advantages of E-Plated Nickel Phosphorus

- **Highly Competitive Processing Cost** - bath is simple to maintain, lasts a long time and has no heavy metals.

- **Robust Electrolyte** - wide processing window, tolerance to metal contamination.

- **Fast processing speed** - including Connector and reel to reel applications.

- **Corrosion Properties** - superior to Bright Nickel and Equal to Electroless Nickel.

- **Ultimate corrosion and diffusion barrier layer** - (e.g. AuCo, Ag, gradient % P layers and numerous electronic applications).

- **Diamagnetic properties** - will expand use in High Frequency Applications.

- Ideally Suited to **Improve the Current Chromium plating Process of Record (POR)**.
**E- Plated Nickel Phos: Advantages / Considerations**

**Why Interest over Electroless Nickel?**

**Electrolytic Nickel Phosphorus**

- Easy to maintain... insol / soluable anodes
- Lower Cost: operation and make-up
- Lasts a long time, stable bath
- Velocity ..fast plating time, reel to reel
- No heavy metals, halogenates or sulphur
- No plate out or tank passivation req
- Lower operating temperatures
- Wide window for metal contamination

- Improved throwing power
- Gradient Layers by adjusting Phos content to achieve enhanced performance in the same bath

**Electroless Nickel**

- Difficult to maintain
- Higher Cost: for operation and make-up
- Low MTO, freq dumps
- Slower plating time
- Heavy metals, halogenates
- Requires tank passivation
- Higher operating temperatures
- Susceptible to metal contamination

- Excellent throwing power all E-plated Nickel baths
- Fixed Phos content high or low
NIPHOS® - E-Plated Nickel Phos

Basic Electrolyte Solution
### Characteristics

<table>
<thead>
<tr>
<th>Nickel</th>
<th>80 g/l (70-90 g/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td>25 g/l (20-30 g/l)</td>
</tr>
<tr>
<td>pH-value</td>
<td>2.5 - 2.7</td>
</tr>
<tr>
<td>Temperature</td>
<td>60 °C</td>
</tr>
<tr>
<td>Current density</td>
<td>4.0 A/dm² Rack</td>
</tr>
<tr>
<td></td>
<td>1.5 A/dm² Barrel</td>
</tr>
<tr>
<td>Plating speed</td>
<td>0.4 µm/min</td>
</tr>
<tr>
<td></td>
<td>1.5 µm/min</td>
</tr>
<tr>
<td>Soluble or insoluble</td>
<td>(Pt/Ti) anodes can be used</td>
</tr>
<tr>
<td>Rack or Barrel</td>
<td>both plating options are available</td>
</tr>
</tbody>
</table>
Electrolyte Plating Characteristics

pH - Dependancy on P – content in the Layer (Rack, 4 A/dm²)
### Standard Connectors – Thickness Distribution in µm

<table>
<thead>
<tr>
<th>Connector used</th>
<th>White Bronze</th>
<th>Nickel-Phosphorus</th>
<th>Bright Nickel</th>
<th>Bright Tin</th>
<th>Gold on NiP</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,13</td>
<td>5,82</td>
<td>5,26</td>
<td>3,64</td>
<td>0,24</td>
<td></td>
</tr>
<tr>
<td>2,88</td>
<td>3,92</td>
<td>3,34</td>
<td>3,06</td>
<td>0,23</td>
<td></td>
</tr>
<tr>
<td>2,76</td>
<td>2,74</td>
<td>2,07</td>
<td>1,94</td>
<td>0,21</td>
<td></td>
</tr>
<tr>
<td>2,56</td>
<td>2,76</td>
<td>1,52</td>
<td>2,52</td>
<td>0,21</td>
<td></td>
</tr>
<tr>
<td>2,60</td>
<td>2,86</td>
<td>1,52</td>
<td>1,85</td>
<td>0,20</td>
<td></td>
</tr>
<tr>
<td>2,91</td>
<td>3,21</td>
<td>1,48</td>
<td>2,28</td>
<td>0,21</td>
<td></td>
</tr>
<tr>
<td>3,12</td>
<td>4,05</td>
<td>2,72</td>
<td>2,81</td>
<td>0,22</td>
<td></td>
</tr>
<tr>
<td>3,41</td>
<td>6,42</td>
<td>9,75</td>
<td>4,06</td>
<td>0,20</td>
<td></td>
</tr>
</tbody>
</table>
## Electrolyte Tolerance to Impurities

### 2X - 4X Improvement

<table>
<thead>
<tr>
<th>Electrolyte Type</th>
<th>Tolerance to Impurities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel-Phosphorus</td>
<td>Zn and Cu up to 200 mg/l</td>
</tr>
<tr>
<td>Bright Nickel</td>
<td>Zn und Cu up to 50 - 100 mg/l</td>
</tr>
<tr>
<td>Electroless Nickel</td>
<td>Zn und Cu up to 25 - 50 mg/l</td>
</tr>
</tbody>
</table>
NIPHOS®

Deposit Layer Properties
# NIPHOS® - Layer Properties

## Base Characteristics E-Plated NiP

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus content:</td>
<td>11 – 13%</td>
</tr>
<tr>
<td>Hardness:</td>
<td>appr. 550 HV Heat Treat to 1300 HV</td>
</tr>
<tr>
<td>Corrosion and Wear Resistance</td>
<td>Excellent</td>
</tr>
<tr>
<td>Color:</td>
<td>Stainless Steel like appearance</td>
</tr>
<tr>
<td>Leveling Power:</td>
<td>Retains Brightness</td>
</tr>
</tbody>
</table>
Hardness Comparison

Hardness of Different Coatings

- Bright nickel
- PdNi 20
- NIPHOS®
- Electroless nickel
- Bronce white
- Bronce yellow
- Matt nickel
- Brass
- Silver
- Copper
- Tin
- TinZinc

<table>
<thead>
<tr>
<th>Material</th>
<th>HV 0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright nickel</td>
<td>600</td>
</tr>
<tr>
<td>PdNi 20</td>
<td>600</td>
</tr>
<tr>
<td>NIPHOS®</td>
<td>570</td>
</tr>
<tr>
<td>Electroless nickel</td>
<td>550</td>
</tr>
<tr>
<td>Bronce white</td>
<td>550</td>
</tr>
<tr>
<td>Bronce yellow</td>
<td>400</td>
</tr>
<tr>
<td>Matt nickel</td>
<td>300</td>
</tr>
<tr>
<td>Brass</td>
<td>170</td>
</tr>
<tr>
<td>Silver</td>
<td>100</td>
</tr>
<tr>
<td>Copper</td>
<td>100</td>
</tr>
<tr>
<td>Tin</td>
<td>50</td>
</tr>
<tr>
<td>TinZinc</td>
<td>50</td>
</tr>
</tbody>
</table>
Wear - Bosch-Weinmann

Emery paper (Swiss standard 6/0), 300 g weight

 Superior Wear Resistance

<table>
<thead>
<tr>
<th>Material</th>
<th>mg/1,000 strokes</th>
</tr>
</thead>
<tbody>
<tr>
<td>NiP</td>
<td>2</td>
</tr>
<tr>
<td>PdNi 20</td>
<td>2,5</td>
</tr>
<tr>
<td>Nickel</td>
<td>3</td>
</tr>
<tr>
<td>Bronce yellow</td>
<td>4</td>
</tr>
<tr>
<td>Tin</td>
<td>6</td>
</tr>
<tr>
<td>Sn/Zn</td>
<td>6,2</td>
</tr>
<tr>
<td>Bronce white</td>
<td>7</td>
</tr>
<tr>
<td>Fine gold</td>
<td>8,5</td>
</tr>
<tr>
<td>Brass</td>
<td>10</td>
</tr>
<tr>
<td>Gold-cobalt</td>
<td>14</td>
</tr>
<tr>
<td>Silver</td>
<td>16</td>
</tr>
</tbody>
</table>

Amorphous NiP morphology
Contact Resistance

- Substrate: Brass
- Layer thickness: 2 µm NiP
- Exposure testing: 125 °C for 250 h, 500 h
- Test tip: Platinum
- Test force: See diagram
- Limit for practical use: < 10 mOhm at 200 cN for non-ferrous metals
- NiP / AuCo suitable as contact material!
Solderability / Welding

**Solderability**

Exposure testing: 16 hours at 155 °C
Flux: Type 2542, Alpha-Metals
Solder: SnPb (60/40), 230 °C

**Results**

- ZCT (Zero Crossing Time in (sec))
  - 2.1 s (NiP)
  - 2.0 s (NiP + AuCo)

**Welding**

- NIPHOS® very good
- Bright Nickel poor, due to high carbon content of the layers
Corrosion Resistance
Layer thickness NiP 2 - 3 µm, substrate: brass

Salt Spray Test (DIN 50021, 120 h)
- No corrosive attack
- Iridescent discoloration of the surface

Kesternich Test (DIN 50018, 5 cycles)
- No attack
- Discoloration of the surface

Pollution Gas Test (EN 60068-2-60, method 4, 10 days)
- Minimal attack on the layer
- Loss of brightness

Rapid T Change (IEC 68-2-14, -30 °C/125 °C, 1 h each, 10 cycles)
- No visible changes
Salt Spray Test (DIN 50021, 120 h)

"Standard connectors"
The connectors were exposure-tested in inserted form and individually

Top
- 2 - 3 µm NIPHOS® 966

Bottom
- 2 - 3 µm NIPHOS® 966
- 0.2 µm AURUNA® 526
Kesternich Test  (DIN 50018, 5 cycles)

"Standard connectors"

The connectors were exposure-tested in inserted form and individually

Top

- 2 - 3 µm NIPHOS® 966

Bottom

- 2 - 3 µm NIPHOS® 966
- 0.2 µm AURUNA® 526
Pollution Gas Test (EN 60068-2-60, method 4, 10 days)

"Standard connectors"
The connectors were exposure-tested in inserted form and individually

Top
- 2 - 3 µm NIPHOS® 966

Bottom
- 2 - 3 µm NIPHOS® 966
- 0.2 µm AURUNA® 526
Rapid Temperature Change
(IEC 68-2-14, -30 °C/125 °C, 1 h each, 10 cycles)

"Standard connectors"
The connectors were exposure-tested in inserted form and individually

Top
- 2 - 3 µm NIPHOS® 966

Bottom
- 2 - 3 µm NIPHOS® 966
- 0.2 µm AURUNA® 526
Contact / Connector System Applications

Benefits

- Reduced Gold thickness
- Replace Palladium Nickel
- Reduce Nickel Thickness

• Reduced Gold thickness
• Replace Palladium Nickel
• Reduce Nickel Thickness

Improved
Summary / Comparison of different layer sequences for Connectors

Gold
- Very expensive

Palladium or Palladium-Nickel / Goldflash (Gold acts as a type of lubricant)
- Great variation of the Palladium-price
- Often smell of ammonia
- Extremely sensitive to cyanide
- “Brown powder” effect

Nickel-Phosphorus / Goldflash
- Inexpensive
- Easy to maintain
- No ammonia odor
Electroplated Nickel Phosphorus Applications

- Improved corrosion resistant and diffusion layer under e.g.
  - Gold
  - Chromium (Cr3+ or Cr 6+)
  - Palladium / Nickel
  - Ruthenium

- Substitution and Elimination of electrolytic nickel (completely or partly) especially Marine and Sea climate applications

- Substitution of electroless nickel (if parts are "simple") especially hydraulics

- Lead-frames /Connectors (with AuCo as final layer)

- Solar-cell carriers (corrosion resistance)
Stainless Steel Finish after 6 Month Field Test

Zirconium - PVD

NIPHOS® 966
Shock Absorber & Piston Rod Applications

**Old demand: 120 h Salt Spray**
- Plated with 20 – 30 μm Cr

**New demand: 480 h Salt Spray**
- 10 – 20 μm NiP + 20 – 30 μm Cr or
- 10 – 20 μm NiP + 5 μm Cr or
- 10 – 20 μm NiP
In the POP field, NIPHOS® is used in the sequence:

ABS / Cu or Ni / Ni (bright or matt + bright) / NiP / Cr

The NIPHOS®-layer replaces strange combinations of up to 4 different Nickel-layers.

The advantage is, that NIPHOS® dramatically improves the corrosion resistance of the whole system; this is important in automotive applications, when the CASS-test has to be passed.

In traditional Systems, Cr was plated on top of bright Nickel. Cracks in the Cr-layer caused localized corrosion and attack of the Ni-layer.

The use of NiP before Cr-plating will stop this corrosion.
NIPHOS® under Chromium

after 5 cycles
kesternichtest

triple nickel / chromium    double nickel / NIPHOS® / chromium
CASS Testing for Chrome

- Cr 20 µm, 6 h
- Cr 35 µm, 6 h
- Ni 10 µm + Cr 10 µm, 72 h
- EN 10 µm + Cr 10 µm, 240 h
- Niphos 10 µm + Cr 10 µm, 240 h
- Niphos 20 µm, 168 h
- Niphos heat treated 20 µm, 48 h
### Summary of Corrosion and Aging Tests

<table>
<thead>
<tr>
<th></th>
<th>NSS</th>
<th>CASS</th>
<th>Corrodkote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium (20 µm)</td>
<td>16</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Chromium (35 µm)</td>
<td>24</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Nickel (10 µm) + Chromium (10 µm)</td>
<td>&gt; 336</td>
<td>72</td>
<td>2</td>
</tr>
<tr>
<td><strong>Electroless Ni (10 µm) + Chromium (10 µm)</strong></td>
<td>&gt; 336</td>
<td>slightly after 96 h</td>
<td>10</td>
</tr>
<tr>
<td><strong>Electrolytic NiP (10 µm) + Chromium (10 µm)</strong></td>
<td>&gt; 336</td>
<td>slightly after 168 h</td>
<td>10</td>
</tr>
<tr>
<td>Electrolytic NiP (20 µm)</td>
<td>&gt; 336</td>
<td>slightly after 168 h</td>
<td>7</td>
</tr>
<tr>
<td>Electrolytic NiP (20 µm) Heat treated 400 ºC, 1 hour</td>
<td>240</td>
<td>48</td>
<td>1</td>
</tr>
</tbody>
</table>
Credentials of E-Plated NiP for Connectors

The combination NIPHOS® and Au/Co (0,2 µm) has passed the measurements of the contact resistance after storage at different conditions according to

- **IEC 1076-4-104**
- **Bellcore GR-1217-CORE** (125 mating cycles // 10 days storage in mixed gas conditions // 125 mating cycles)
Summary: Advantages of E-Plated Nickel Phosphorus

- **Highly Competitive Processing Cost** - bath is simple to maintain, lasts a long time and has no heavy metals

- **Robust Electrolyte** - wide processing window, tolerance to metal contamination

- **Fast processing speed** - including Connector and reel to reel applications

- **Corrosion Properties** - superior to Bright Nickel and Equal to Electroless Nickel

- **Ideally Suited to improve the current chromium plating Process of Record (POR)**

- **Ultimate corrosion and diffusion barrier layer** - (e.g. AuCo, Ag, gradient % P layers and numerous electronic applications)

- **Diamagnetic properties** - will expand use in High Frequency Applications
Uyemura USA
240 Town line Rd
Southington, CT 06489
Phone 860-793-4011
customerservice@uyemura.com

Umicore Galvanotechnik GmbH
Klarenbergstraße 53-79
73525 Schwäbisch Gmünd
Phone: + 49 - 71 71 / 6 07 - 01
Fax: + 49 - 71 71 / 6 07 - 2 88
galvano@eu.umicore.com
www.umicore-galvano.com

UYEMURA Corporate Headquarters:
3990 Concours, #425 • Ontario, CA 91764 • ph: (909) 466-5635
UYEMURA Tech Center:
240 Town Line Road • Southington, CT 06489 • ph: (860) 793-4011
For sales and product information, click here