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

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## Discussion

<table>
<thead>
<tr>
<th>NIPHOS® E-Plated Nickel Phos:</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Plated Nickel Phos:</td>
<td>Advantages</td>
</tr>
<tr>
<td></td>
<td>Reasons for Interest</td>
</tr>
<tr>
<td>E-Plated Nickel Phos:</td>
<td>Electrolyte Specifications</td>
</tr>
<tr>
<td>E-Plated Nickel Phos:</td>
<td>Layer Properties</td>
</tr>
<tr>
<td>E-Plated Nickel:</td>
<td>Applications / Markets</td>
</tr>
<tr>
<td>Summary</td>
<td>Future Outlook</td>
</tr>
</tbody>
</table>
## Coating Characteristics

<table>
<thead>
<tr>
<th>Property</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electroplated Alloy composition</td>
<td>Nickel 88 - 94 %</td>
</tr>
<tr>
<td></td>
<td>Phosphorus 6 - 12 %</td>
</tr>
<tr>
<td></td>
<td>Diamagnetic (P &gt; 11 %)</td>
</tr>
<tr>
<td>Hardness</td>
<td>550 - 600 HV, without heat treatment</td>
</tr>
<tr>
<td>Abrasion</td>
<td>2 mg/1000 strokes (Bosch-Weinmann)</td>
</tr>
<tr>
<td>Ductility and Color</td>
<td>Same as bright nickel</td>
</tr>
<tr>
<td>Corrosion resistance</td>
<td>Very good – Excellent</td>
</tr>
</tbody>
</table>
Advantages of E-Plated Nickel Phosphorus

- **Highly Competitive Process 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?

<table>
<thead>
<tr>
<th>Electrolytic Nickel Phosphorus</th>
<th>Electroless Nickel</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Easy to maintain... insol / soluble anodes</td>
<td>• Difficult to maintain</td>
</tr>
<tr>
<td>• Lower Cost: operation and make-up</td>
<td>• Higher Cost: for operation and make-up</td>
</tr>
<tr>
<td>• Lasts a long time, stable bath</td>
<td>• Low MTO, freq dumps</td>
</tr>
<tr>
<td>• Velocity ..fast plating time, reel to reel</td>
<td>• Slower plating time</td>
</tr>
<tr>
<td>• No heavy metals, halogenates or sulphur</td>
<td>• Heavy metals, halogenates</td>
</tr>
<tr>
<td>• No plate out or tank passivation req</td>
<td>• Requires tank passivation</td>
</tr>
<tr>
<td>• Lower operating temperatures</td>
<td>• Higher operating temperatures</td>
</tr>
<tr>
<td>• Wide window for metal contamination</td>
<td>• Susceptible to metal contamination</td>
</tr>
<tr>
<td>• Improved throwing power</td>
<td>• Excellent throwing power all E-plated Nickel baths</td>
</tr>
<tr>
<td>• Gradient Layers by adjusting Phos content to achieve enhanced performance in the same bath</td>
<td>• Fixed Phos content high or low</td>
</tr>
</tbody>
</table>
NIPHOS®- E-Plated Nickel Phos

Basic Electrolyte Solution
Characteristics

- Nickel: 80 g/l (70-90 g/l)
- Phosphorus: 25 g/l (20-30 g/l)
- pH-value: 2.5 - 2.7
- Temperature: 60 °C
- Current density: 4.0 A/dm² Rack
  1.5 A/dm² Barrel
- Plating speed: 0.4 µm/min
  1.5 um/min
- Soluble or insoluble (Pt/Ti) anodes can be used
- Rack or Barrel: both plating options are available
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**

<table>
<thead>
<tr>
<th>Base Characteristics E-Plated NiP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus content:</td>
</tr>
<tr>
<td>Hardness:</td>
</tr>
<tr>
<td>Corrosion and Wear Resistance:</td>
</tr>
<tr>
<td>Color:</td>
</tr>
<tr>
<td>Leveling Power:</td>
</tr>
</tbody>
</table>
Hardness Comparison

Hardness of Different Coatings

<table>
<thead>
<tr>
<th>Coating</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>Bronze white</td>
<td>550</td>
</tr>
<tr>
<td>Bronze 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

NiP
PdNi 20
Nickel
Bronce yellow
Tin
Sn/Zn
Bronce white
Fine gold
Brass
Gold-cobalt
Silver

mg/1,000 strokes

Amorphous NiP morphology

2
2,5
3
4
6
6,2
7
8,5
10
14
16

0 5 10 15 20
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

Results
- 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

“Previous“

“Improved“

- Ni + AuCo
- Ni + PdNi + AuCo
- Ni + NiP + AuCo

Basematerial CuSn6
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>Material Description</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 °C, 1 hour</td>
<td>240</td>
<td>48</td>
<td>1</td>
</tr>
</tbody>
</table>
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 and
- 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
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