Electro Ceramic Coatings and Non-Chrome Conversion - Coating

Dr. Lutz Hüsemann
Gothenburg, 20.05.2015
Contents

1. Formation and Properties of Electro Ceramic Coatings
2. Performance
   • Corrosion prevention
   • Friction reduction
   • Emissions reduction
3. Applications
4. Summary
5. The new non chrome etch-passivation - Bonderite M-NT 2040 R2
Plasma-Electrolytic-Deposition of TiO2 on light metals

Setup

- pH 2.5
- 25 °C
- 1-5 min

Step 2: Plasma Deposition

- O₂
- O⁺
- [Ti]⁻
- TiO₂

RECTIFIER
Formation of Electro Ceramic Coatings

Coating deposition

Plasma formation

1 - 3 minutes

Finished coating

May 20, 2015

Electro Ceramic Coatings – Dr. Lutz Hüsemann

Henkel
Electro Ceramic Coatings
Physical Properties

- Flexibility: Pass 1-2T bend (ASTM D 4145)
- Coefficient of friction (dry): Approx. 0.2 dry, like DLC
- Resistance against thermal shocks: 600°C for 84h, followed by a water quench at 5°C
  - X-cut + Erichsen cupping
  - no loss of adhesion / high flexibility
Electro Ceramic Coatings
Morphology and physical properties

Coating Structure
An amorphous coating exhibiting a porous upper layer
- Thickness: 3-50 µm
- Hardness: 300-1400Hv
- Applicable substrates:
  - Aluminium and alloys of
  - Aluminized steel
  - Titanium and alloys of
  - Magnesium and alloys of
- Application time: 60 seconds to 5 min.
- Temperature resistance up to 1100°C
Electro Ceramic Coatings
Thermal resistance – example

Drag racing (1/4 mile) events
- Nitromethane/methanol fuel
- 2000hp V8 engine

Normal engine life – 2 “passes”
- Typical failure mode is piston burn-through due to methanol and nitromethane burn temperature

Engine life with ECC pistons – more than 40 “passes”!
- No hot spotting
- No burn-through
- Carbon residue dramatically reduced
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Electro Ceramic Coatings
Performance

• Corrosion prevention

• Friction reduction

• Emissions reduction
<table>
<thead>
<tr>
<th>Pretreatment System</th>
<th>Salt spray test (DIN 50021 SS)</th>
<th>Salt spray test (DIN 50021 ESS) painted with cross hatch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>unpainted</td>
<td>Painted with cross hatch</td>
</tr>
<tr>
<td>Degreasing only</td>
<td>&lt; 24 h totally corroded</td>
<td>100 h strong corrosion creep</td>
</tr>
<tr>
<td>Yellow Chromat</td>
<td>1 000 h without corrosion</td>
<td>1 000 h no corrosion creep</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 000 h corrosion creep &lt; 1 mm</td>
</tr>
<tr>
<td>Green Chromat</td>
<td>500 h without corrosion</td>
<td>1 000 h no corrosion creep</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 000 h corrosion creep &lt; 1 mm</td>
</tr>
<tr>
<td>Chrome III coating</td>
<td>300 h without corrosion</td>
<td>1000 h no corrosion creep</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000 h corrosion creep &lt; 1 mm</td>
</tr>
<tr>
<td>Non Chrome conversion coating</td>
<td>200 h without corrosion</td>
<td>1000 h no corrosion creep</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000 h corrosion creep &lt; 1 mm</td>
</tr>
</tbody>
</table>
## Corrosion Prevention

Improved Corrosion Performance

<table>
<thead>
<tr>
<th>Al Alloy</th>
<th>Composition</th>
<th>SST (ASTM B117)</th>
<th>Scribe Creepage</th>
</tr>
</thead>
<tbody>
<tr>
<td>356</td>
<td>AlSi₅Mg</td>
<td>2000</td>
<td>Nil</td>
</tr>
<tr>
<td>5052</td>
<td>AlMg₃</td>
<td>4000</td>
<td>Nil</td>
</tr>
<tr>
<td>6061</td>
<td>AlMgSiCu</td>
<td>4000</td>
<td>Nil</td>
</tr>
<tr>
<td>6063</td>
<td>AlMgSi₀.₅</td>
<td>5000</td>
<td>Nil</td>
</tr>
<tr>
<td>7005</td>
<td>AlZnMgCu₂</td>
<td>1000</td>
<td>Nil</td>
</tr>
<tr>
<td>Clad- 2024</td>
<td>AlCuMg₅</td>
<td>3000</td>
<td>Nil</td>
</tr>
</tbody>
</table>

2000 h 356 Cast Alloy

7000 h 356 Cast Alloy + Powder Paint

5000 h 6063

4000 h 5052 Aerospace Honeycomb
Corrosion Prevention
Marine Field Trial

Field Trial: Results after 6 months sea water exposure

Cr(VI)-Pretreatment, Primer and Topcoat

ECC: No scribe creepage, excellent corrosion resistance!

Electro Ceramic Coating with Topcoat
Lightweight Design Options
Exhaust Manifold

- Replacement of cast iron by aluminum with Electro Ceramic Coating → 36Kg reduction in weight!!

Also excellent resistance to harsh acids/high temperature possible with sealer on top of ECC coating
Electro Ceramic Coatings
Corrosion protection – conductivity

No or low conductivity

- Protect against galvanic corrosion
  - Sheet treated with yellow chromate (7000 alloy)
  - Rivet treated with ECC (2024 alloy)
- after 700 h NSS
  - No galvanic corrosion
Electro Ceramic Coatings
Adhesion Enhancement by Function of Pores

1. Clean & Shot Blast
2. Fe/ Mo/ C Composite Thermal Spray

1. ECC
2. Fe/ Mo/ C Composite Thermal Spray

1. Clean & Shot Blast
2. TiO₂ Thermal Spray

1. ECC
2. TiO₂ Thermal Spray
Electro Ceramic Coatings
Friction Reduction

SEM image - Coating Morphology

Function of pores for oil retention

Model
- Sliding part
- Oilfilm
- ECC

Aluminum
Electro Ceramic Coatings
Emissions reduction - Piston ring groove coatings

- Upper ring groove ECC-coated
- 50% less blow-by during run-in phase, no micro-welding observed
- Very uniform coating thickness

<table>
<thead>
<tr>
<th>Coating thickness</th>
<th>Evenness</th>
<th>Roughness Ra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>4.0 ± 0.5 µm</td>
<td>&lt; 0.6 µm</td>
</tr>
<tr>
<td>Sample 2</td>
<td>10.5 ± 1.5 µm</td>
<td>&lt; 1.6 µm</td>
</tr>
</tbody>
</table>

- ECC exhibits an even coating in box sections reducing blow by
- Most electrolytic coatings exhibit dove tailing leading to performance issues
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Electro Ceramic Coatings
Commercial application examples

- Marine outboards / stern-drives
- Marine engines and exhaust parts
- EGR-parts for heavy trucks
- Serial production of pistons for small engines
- Cookware (e.g. Titanium Twister)
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Electro Ceramic Coatings (ECC)

Summary

- ECC offers a simple and reliable coating process for light metals
- Coating and waste water are free from heavy metals
- Unsealed ECC offer market leading corrosion protection for standard alloys
- Sealed ECC allow use of high strength alloys in highly corrosive environments
- Structure and physical properties of Electro Ceramics are ideal for friction applications
- Polished ECC perform to a high standard in friction testing
- ECC shows exceptional wear resistance
- Uniformity of Electro Ceramics offer benefits over electrolytic competitors for complex part geometries
- Thermal properties are beneficial for fast heat transfer
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BONDERITE M-NT 2040 R2
change from Cr(VI) to non chrome

Change of Yellow or Green chromate processes to non chrome „Bonderite M-NT 2040 R2“ process means:

- No change for the water supplies
  - No additional Di water
  - No change in the piping

Use as “etch passivation process” means:

- For green chromate lines no change in the pretreatment steps necessary
  - Processes only with alkaline etch passivation without deoxidizing are possible*

* This is possible for GSB certificates; Qualicoat request a acid step before the conversion. The discussion with the technical committee is ongoing.
For long lines with alkaline etching and deoxidizing the conversion of the line can be done in two steps:

From:

To:

This means that they can run for the time till the sunset* of Cr(VI) both processes parallel!!

* sunset date for Cr(VI) – September 2017
BONDERITE M-NT 2040 R2
Short line – high flexibility

BONDERITE M-NT 2040 R2 can be used as a Cleaner/Coater-Process:

- BONDERITE M-NT 2040 R2 with surfactant as Cleaner
- BONDERITE M-NT 2040 R2 as Coater

or:
- BONDERITE C-IC DX-255 A acidic etch degreasing (with surfactant)
- BONDERITE M-NT 2040 R2 (etch passivation)

Between the “traditional” process and the “Cleaner/Coater” approach many variation are possible!
Thank you!

See you at F03:50

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