Plasma Electrolytic Technologies
Oxidation, Depainting & Polishing

February 2018
Plasma Electrolytic Technologies

1. Plasma Electrolytic Oxidation
2. Plasma Electrolytic Depainting
3. Plasma Electrolytic Polishing
1. Plasma Electrolytic Oxidation Process Schematic

PEO can be conducted in a tank or a localized processing fixture.
PEO Coating Methods

1. Cell built around the part targeting specific areas

Localized Coating Fixture for Gears with mechanical masking

Electrolyte fluid is pumped constantly through the fixture during the coating process.

Plasma formed around part.

PEO coated Gear Teeth
Plasma Electrolytic Oxidation (PEO) Coating Properties

Nano-ceramic coating for Al, Ti and Mg alloys
- Diffusion coating with excellent adhesion – oxidation of the substrate
- Excellent corrosion resistance outperforming all Anodization Types
- High hardness (800-2000HV)
- 10X+ wear performance compared to Type III anodize
- **GREEN** process (water based) – no acids or harsh chemicals
- Low-temperature, non Line-of-Sight process

Uniform coatings for complex geometries
CeraTough™ PEO Coatings - Summary of Properties

### Hardness

<table>
<thead>
<tr>
<th>Material</th>
<th>Surface Hardness (HV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEO-Al</td>
<td>0.0002</td>
</tr>
<tr>
<td>PEO-Mg</td>
<td>0.0003</td>
</tr>
<tr>
<td>PEO-Ti</td>
<td>0.0005</td>
</tr>
<tr>
<td>Hard Anodize</td>
<td>0.0006</td>
</tr>
<tr>
<td>Ti-6-4</td>
<td>0.0006</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.0006</td>
</tr>
</tbody>
</table>

### Corrosion

Results: Unsealed PEO coating with 77 microns avg. thickness passed the ASTM G85 Annex 4 testing at 336 hours with no pits.

### Fatigue

Fatigue Test Comparison
PEO Ceramic vs. Type III Hard Anodize

![Fatigue Test Graph](image)

### Wear

Wear Rate (mm³/Nm)

- Ceratough-Al
- Anodize + SFL
- Anodize
## Summary of Properties of PEO Coatings

<table>
<thead>
<tr>
<th>Feature</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>New nano-structured ceramic diffusion surface treatment</td>
<td>High density (95%-99%+)</td>
</tr>
<tr>
<td>for Al, Ti, Mg, and other alloys</td>
<td></td>
</tr>
<tr>
<td>Non Line-of-Sight plasma process</td>
<td>Minimal fatigue debit</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>High hardness (800-2000HV)</td>
<td>High corrosion resistance</td>
</tr>
<tr>
<td>Low friction with outstanding wear performance</td>
<td>CeraTough™ is a Green Technology – no hazardous waste streams</td>
</tr>
</tbody>
</table>
2. Plasma Electrolytic De-Painting Processes

Conventional processes for De-Painting

◆ Chemical process:
  ➢ Non Line-of-Sight process
  ➢ Typically using hazardous methylene chloride, high remediation costs.

◆ Ultra-High Pressure Water Jet:
  ➢ Line-of-sight, fast process, Chemical post processing required.

◆ Media Blasting:
  ➢ Typically generates large amount of hazardous waste (except for CO₂ pellet media).
  ➢ Line-of-Sight Process, Chemical post processing required.

◆ Laser Technology:
  ➢ Line-of-Sight Process, Chemical post processing required.

OO-ALC has an estimated annual usage of Methylene Chloride of 8000 gallons and the estimated hazardous waste disposal is over 13,000 lbs.
Benefits of Plasma Electrolytic De-Painting (PEDP)

PEDP development so far conducted on AL, Steels and Inconel

- No pre-treatment is necessary
- Non-hazardous byproducts – weak water-based electrolyte
- Processing time is in between 2 and 7 min in a single process
- Does not affect the substrate
Plasma Electrolytic De-Painting
Process Schematic

Process Parameters:
- Electrolyte Composition
- Electrolyte Temperature
- Electrolyte Flow
- Counter electrode design
- Electrical Waveform – Voltage Limits, Current/Voltage Control
PEDP Progress on AL 7075:

0 min

0.5 min

2.0 min
PEDP AL 7075

7075 Al

Primer and topcoat removed as a single unit.
Microstructural Analysis

Before and After PEDP

Before

Base metal

Anodized layer

Epoxy and polyurethane-based
Painted layers:

resin

After

Base metal

Anodized layer

Painted layers: gone

resin

Anodized layer: ~ 8 microns, No changes observed
Analysis of Paint Fragments and Depainted Surface

- XRD analysis was done of the paint fragments to confirm no Al was present.
- EDS analysis of the Depainted Surface was conducted to confirm no constituents of the Paint and Primer were left behind on the surface.
PE Powder Coat removal
SEM-EDS Results

Before Treatment

After Treatment

SEM-EDS analysis

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight %</th>
<th>c %</th>
<th>Net Int. Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C K</td>
<td>75.34</td>
<td>86.64</td>
<td>22136.13.4</td>
</tr>
<tr>
<td>Ti L</td>
<td>13.79</td>
<td>3.98</td>
<td>119.21 11.02</td>
</tr>
<tr>
<td>O K</td>
<td>10.87</td>
<td>9.39</td>
<td>1446.23 9.81</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight %</th>
<th>c %</th>
<th>Net Int. Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C K</td>
<td>10.3</td>
<td>33.2</td>
<td>664.69 9.1</td>
</tr>
<tr>
<td>O K</td>
<td>2.68</td>
<td>6.49</td>
<td>433.08 7.62</td>
</tr>
<tr>
<td>Fe L</td>
<td>87.01</td>
<td>60.31</td>
<td>6404.71 2.76</td>
</tr>
</tbody>
</table>
Plasma Electrolytic De-Painting Process Summary

- Electrolyte is selected based on paint and alloy composition.
- Electrolyte conductivity is adjusted to optimize for plasma formation and paint removal.
- Electrolyte temperature control is important.
- Total current depends on part surface area.
- Current density requires further optimization.
- Maximum voltage limit is important.
- Waveform options: DC, Unipolar Pulsed DC, Bipolar Pulsed DC, Symmetric vs. Asymmetric.
- Energy consumption: Less than 1 kwh/dm².
3. Plasma Electrolytic Polishing

15-5 Stainless Steel

Before

After

<table>
<thead>
<tr>
<th>Ra</th>
<th>Rz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before polishing (left)</td>
<td>0.23</td>
</tr>
<tr>
<td>After polishing (right)</td>
<td>0.12</td>
</tr>
</tbody>
</table>
Plasma Electrolytic Polishing
AL 6061

(A) Al 6061 disc sample, before PECP process

Ra = 1.5 → 0.12 μm

(B) Al 6061 disc sample, after PE-Polishing process: 2 min single treatment, single rinse with water
Plasma Electrolytic Polishing
Inconel 600

Before

Ra = 3.2 – 4.5 μm
Rz = 10.1 – 11.1 μm

After 5 min PEP treatment:
A single microfinishing process

Ra = 0.13 – 0.18 μm
Rz = 2.0 – 2.5 μm
PE Polishing of Precision Tools

Before PEP

After PEP
Plasma Electrolytic Polishing for Additive Manufacturing

PEP for Surface as Printed (3D printed) Block

Before polishing

Ra = 8.5 μm

After polishing

Ra = 0.1 μm
**Plasma Electrolytic Polishing for Additive Manufacturing**

**Before polishing**

**After polishing**

Optical microscopic image, x500, Too rough? Hard to focus on the surface.

<table>
<thead>
<tr>
<th>Surface Roughness</th>
<th>Ra (µm)</th>
<th>Rz (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before polishing</td>
<td>8.7</td>
<td>33.5</td>
</tr>
<tr>
<td>After polishing</td>
<td>0.085</td>
<td>1.6</td>
</tr>
</tbody>
</table>
PE Polishing
CoCr alloy

Before PEP Process
Ra = 2.5-2.7 µm

After PEP Process for 3 minutes
Ra = 0.5 µm
Plasma Electrolytic Technologies is a new and emerging area.

PE Technologies are green – they do not create hazardous waste streams.

PE Technologies can be used for:
  - Providing Wear and Corrosion resistance Oxidation coatings.
  - Removal of Paint and Powder Coat.
  - Polishing of components.

More R&D is needed to understand impact and process optimization.
Contact Information

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