CHLOR-ALKALI COATINGS
AND
REFURBISHMENT SERVICES

By Dr Derek C Armstrong
KEY FACTS

INEOS manufactures all its own coatings

All INEOS coatings can be tailored to customers membrane cycles

Anodes – 8, 10, 12 years
Cathodes – 8, 10, 12, 15, 16 years

INEOS coatings are currently installed in the following electrolyzers

- INEOS
- UHDE
- AK
- MGC

INEOS HAS BEEN MANUFACTURING CHLOR ALKALI ELECTRODES FOR 118 YEARS
INEOS ANODE COATINGS
Anode Coatings

- A layer of conductive, catalytic material applied to the surface of a titanium anode to promote chlorine evolution at low voltage

- Applied in layers followed by stoving (thermal decomposition)

- Key components are RuO$_2$, IrO$_2$

- Voltage performance dependent on surface area

- Surface shows a ‘cracked’ structure

- Lost by 2 mechanisms
  - Mechanical loss
  - Alkaline wear
## Anode Coatings – Features to consider in Coating Selection

<table>
<thead>
<tr>
<th>Feature</th>
<th>What is it?</th>
<th>Impact ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-potential</td>
<td>Additional voltage generated by the surface resistance of the coating</td>
<td>Higher over potentials mean higher power consumption- adds to operating cost</td>
</tr>
<tr>
<td>Alkali Wear Resistance</td>
<td>Resistance to loss of Ruthenium, the critical catalytic element, during operation</td>
<td>High alkali wear = short anode life, or more expensive anodes as suppliers add more RuO₂</td>
</tr>
<tr>
<td>High Chlorate in brine</td>
<td>ClO₃⁻ is produced as a by product of Cl₂ production</td>
<td>Potentially environmentally damaging and discharge may be limited</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Higher chemical usage in chlorate destruction system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Higher rates of corrosion in caustic evaporators as higher levels of chlorate in caustic soda.</td>
</tr>
</tbody>
</table>
INEOS ANODE coatings have been designed to provide a chlorine over-voltage of 20-30mV lower than typical commercial coatings. This represents a 1% power saving for customers (eg based on $80 per MWh a 100kte plant would save $120k/year)
INEOS Anode Coating – LOW ALKALINE WEAR

INEOS ANODE coatings have been designed to provide significantly superior alkaline wear performance over other commercially available chlor-alkali anode coatings.

With the move to zero gap where the membrane lies directly up against the membrane good alkaline wear resistance in very important for coating life as the surface of the membrane is alkaline.
INEOS Anode Coating – LOW CHLORATE IN BRINE

<table>
<thead>
<tr>
<th></th>
<th>INEOS</th>
<th>Competitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorate (g/l)</td>
<td>0.05</td>
<td>0.3</td>
</tr>
<tr>
<td>Hypochlorite (g/l)</td>
<td>0.8</td>
<td>1.5</td>
</tr>
</tbody>
</table>

INEOS ANODE coatings have been designed to provide a very low level of chlorate (and hypochlorite) in brine.

This translates to less chemical usage for chlorate destruction but more importantly lower chlorate in caustic, stopping evaporator corrosion.
INEOS CATHODE COATINGS
Cathode Coatings

- A layer of conductive, catalytic material applied to the surface of a cathode to promote hydrogen evolution at low voltage.

- Key components are many and vary dependent upon the supplier. 
  e.g. RuO$_2$, Raney nickel, Pt group metal oxides, Nickel Oxides, sulfides, carbides.

- Applied using a range of techniques depending upon the coating type. 
  e.g. “spray-bake”, electro deposition, plasma spray, electroless plating, catholyte additive.

- Total coating thickness 200 microns to >1 micron depending upon type.

- Best have a high ratio of catalytic area to apparent area.

- Loss mechanisms are
  - Wear
  - Reverse current dissolution
  - Poisoning

SEM of INEOS cathode coating – 4K magnification
Typical Progression of Cathode Coating Wear

- Non-precious metal coatings normally last 4-8 years
- INEOS precious metal coating shows virtually no loss (warrantied for 16 years)
- >18 years experience in our FM mono-polar technology
- 13 years experience on BICHLOR™ with no measurable loss
High resistance to reverse currents

The INEOS CATHODE Coating has an exceptionally high resistance to reverse currents making it the ideal cathode coating for all zero gap electrolysers.
## Features of INEOS Cathode Coatings in summary

<table>
<thead>
<tr>
<th>Feature</th>
<th>INEOS vs Competitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over potential</td>
<td>In trials in other technologies INEOS’ over potential at start-up is the same as non precious metal coatings but demonstrates better performance over a longer lifecycle.</td>
</tr>
<tr>
<td>Resistance to reverse currents at shutdown</td>
<td>INEOS cathode coatings lose no catalyst when subjected to reverse current. Non precious metal coatings are known to be attacked by reverse currents</td>
</tr>
<tr>
<td>Resistance to impurity poisoning</td>
<td>High surface area minimises the sensitivity to impurity damage. Any poisoning that does occur tends to be reversible (e.g. at shutdown)</td>
</tr>
<tr>
<td>Lifetime</td>
<td>Experience indicates INEOS cathode coatings will last for &gt;16 years Proven in FM mono-polar electrolysers over 18 years, 13 years (and counting) without weight loss in BICHLOR™ bipolar electrolysers</td>
</tr>
</tbody>
</table>
INEOS REFURBISHMENT CAPABILITY
INEOS Refurbishment Facility

- A new purpose built facility commissioned in Q1 2013.
- First delivery within 4 weeks from initial receipt of pans.
- Smaller batches can be accommodated in a shorter lead time.
- In addition to modular type electrolysers, different types of structures may be processed for example mercury and large fly screen meshes.
Refurbishment Process

- Receipt and identification
- Pre-work inspection & assessment (Recorded in database)
- Refurbishment - Repair (Mesh, Flange and Pan repair)
- Surface preparation
- Coating
- Final quality inspection
- Packing & Dispatch
Inspection
Expert Welding

Fine ‘jewellery’ type welding by experts
Refurbishment – Flange and electrode damage/corrosion

- Flange corrosion
- Crevice corrosion
- Corrosion at compression points
- Corrosion of louver
Louvre Replacement

Sections of corroded louvre are removed and replaced
Inlet Repair

Corrosion to outlet pipe
Inlet Repair

Completed Repair
Key Steps – Surface Preparation

ANODE

CATHODE
Pan/Element Washing
In-Pan/Element Coating
In-Pan/Element Coating

Flange protected by coating
Final Inspection
Finished Product – Preparing for Shipment
INEOS Technologies

SUMMARY

INEOS CAN PROVIDE :-

- **STATE OF THE ART COATINGS**
  - Long life
  - Robust against wear, reverse currents and impurities
  - Low over voltage

- **COMPREHENSIVE RE-COATING AND REFURBISHMENT SERVICE**