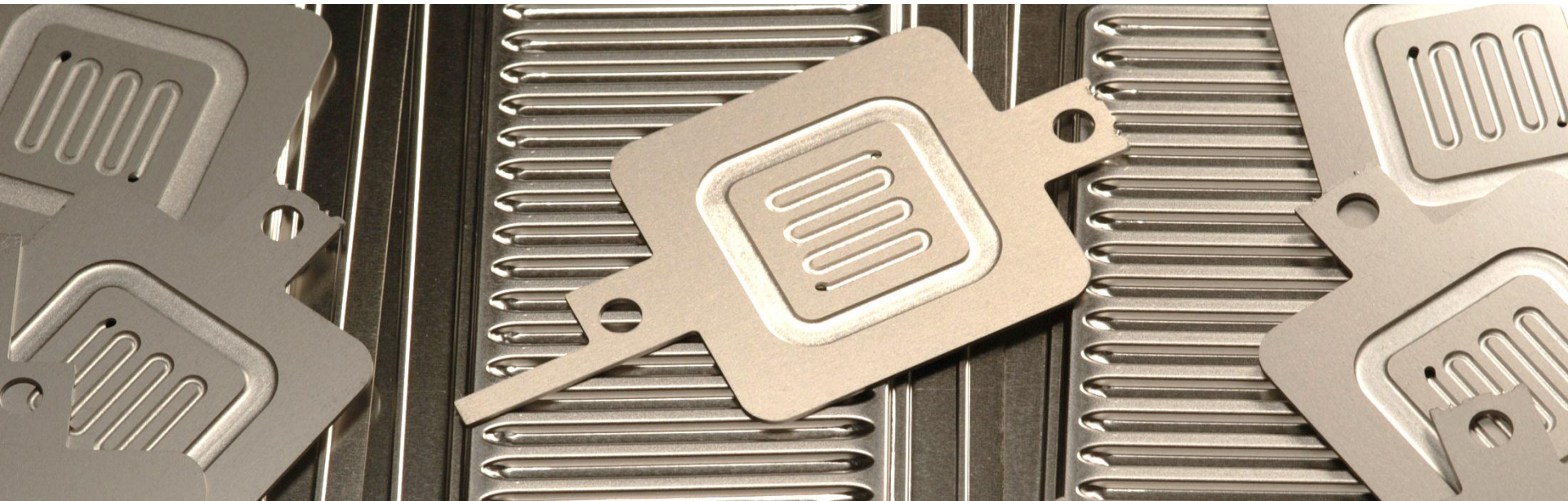
IMPACT COATINGS

Protective coating for stainless steel BPPs – high performance at low cost

Bipolar Plates for PEM technology – *coatings, manufacturing*, *test methods and parameters*
Fronius Manufacturing and Logistic Facilities, Sattledt, Austria, May 20th 2015

Henrik Ljungcrantz,
Impact Coatings AB, Linköping, Sweden
henrik.ljungcrantz@impactcoatings.se



Why Impact Coatings?

- Supplier of state-of-the-art PVD production technology
- Cost-efficient and environmentally sustainable solutions for coatings in the production flow
- Cut production cost and lead time
- Offers new coatings for energy, connector and decorative applications

About Impact Coatings AB

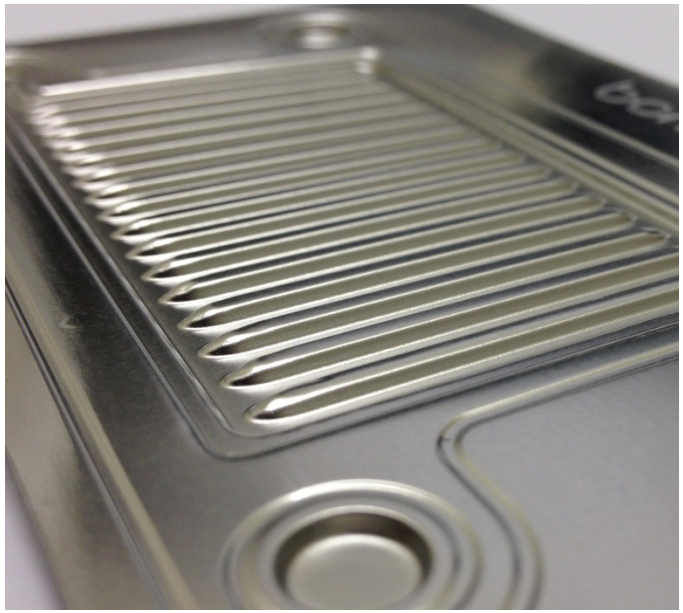
Headquarter: Linköping, Sweden

Public company (Nasdaq-OMX Stockholm, First North)

Supplier of industrial solutions for surface treatment, based on physical vapor deposition (PVD) technology

Offering: Equipment, Process knowhow, Materials

Bipolar plates (BPP)

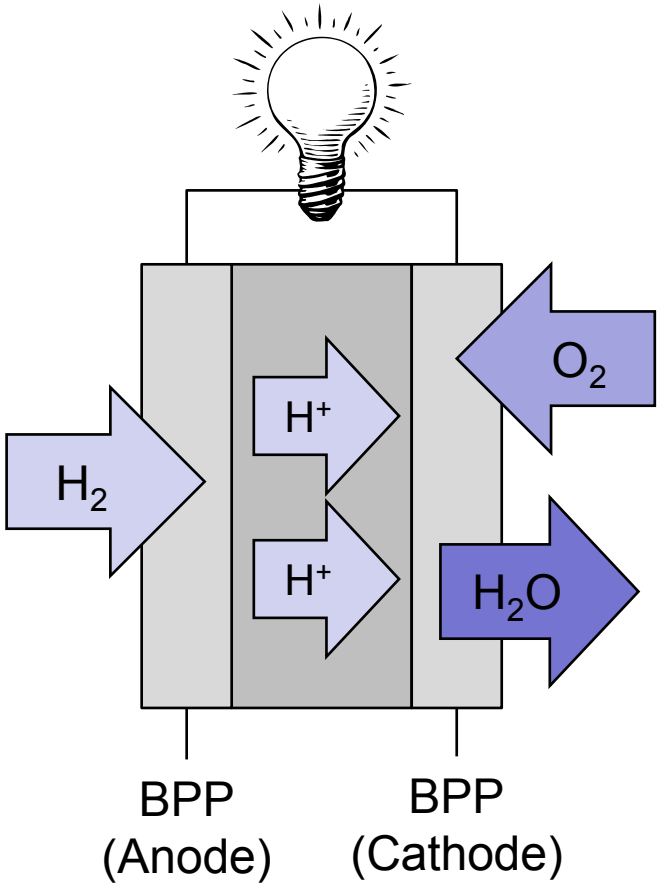


BPP functions

Cell separation
Current collection

Gas distribution
Structural integrity

Bipolar Plates Environment (PEM)



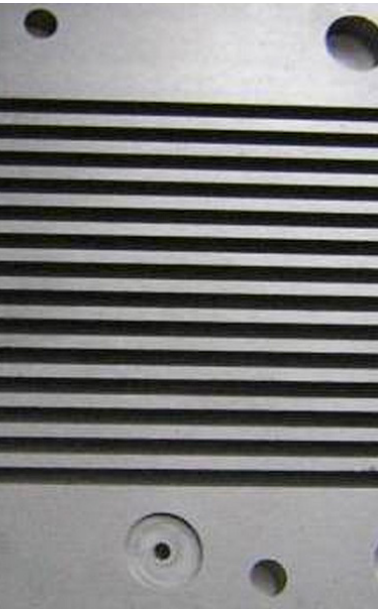
Acidic ($H_20 + H^+$), pH 2-3

Cell potential ~0.7 V

Elevated temperature, 80°C

} Corrosive environment

Bipolar plates Desired properties



Property	Graphite BPP	Metal BPP
Chemical stability	Good	Poor
Electrical conductivity	Good	Good
Durability	Poor	Good
Low volume/weight	Poor	Good
Mass producible	Difficult	Easy

Graphite BPP suitable for prototyping
Stainless steel BPP requires coating

Steel BPP Coating Challenge

US Department of Energy (DOE) BPP requirements

Functional

- Chemical stability: **<1 µA/cm2**
- Electrical conductivity: **20 mΩcm2**

Economical

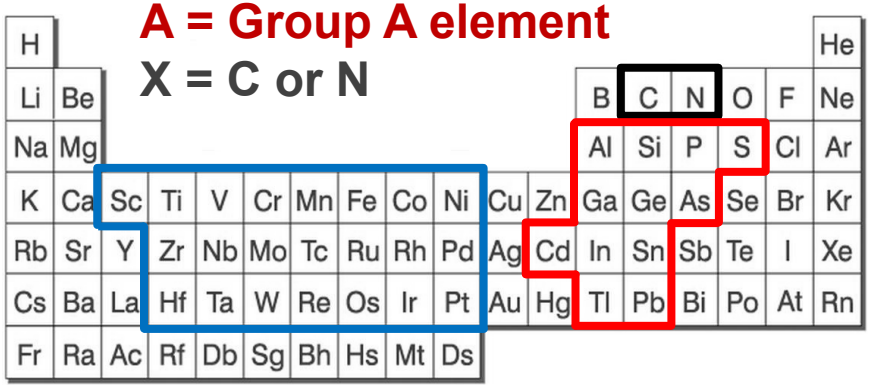
- Production cost (competed plates): **$3/kW**

The solution must be both functional and economically viable

Coating Design Strategy

MAX phases:

M = Early transition element
A = Group A element
X = C or N

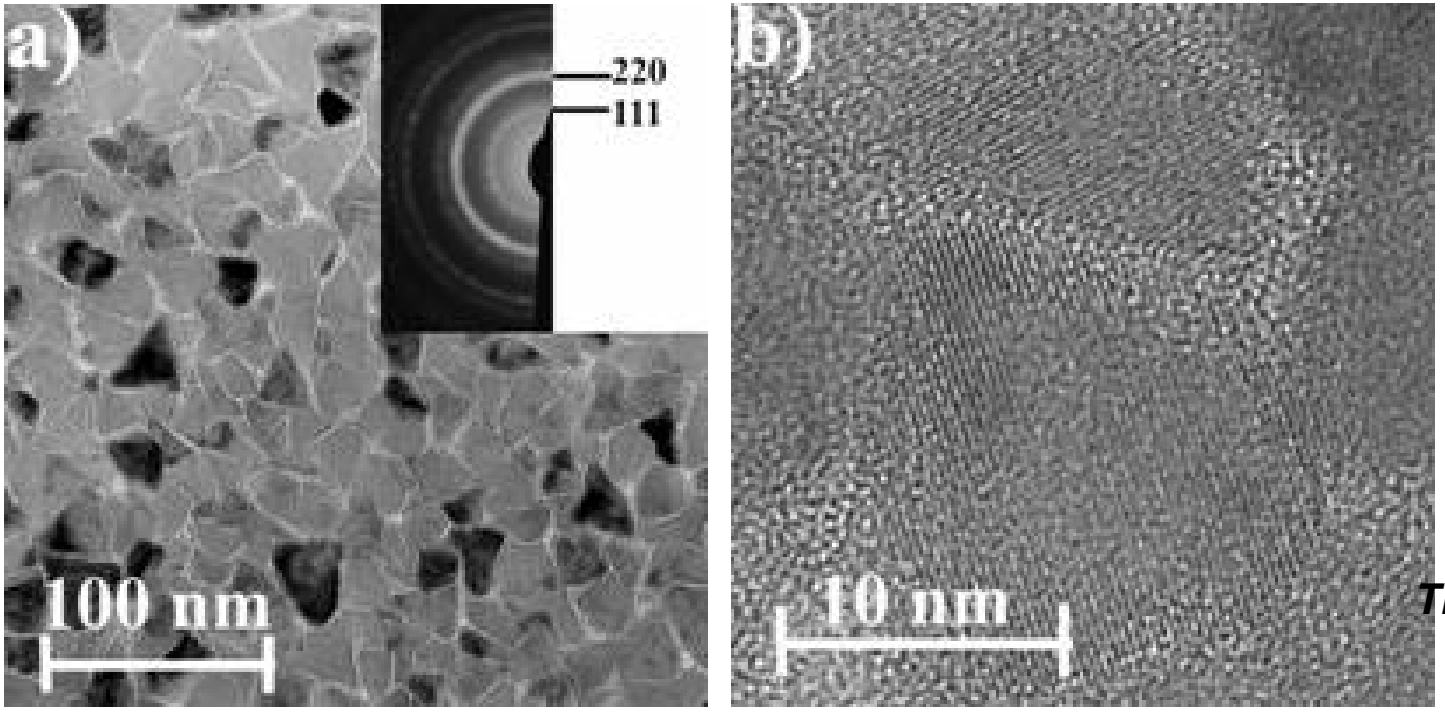


Ceramic MaxPhase™ from Impact Coatings

- **Ceramic alloy producible by PVD**
- **Corrosion resistant**
- **Electrically conductive**
- **Economic** and **environmentally sound**

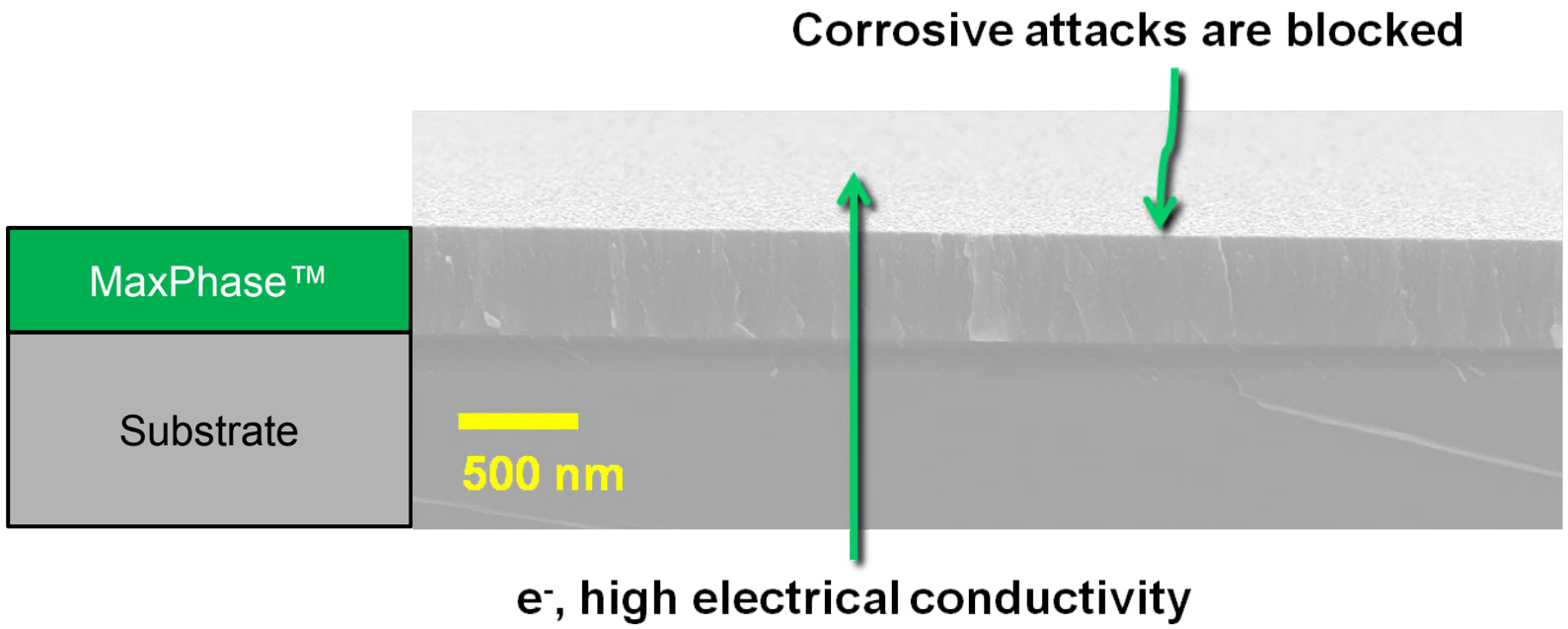
Microstructure of Ceramic MaxPhase

- Nano-composite film structure
  - Nano-crystalline grains
  - In Amorphous Matrix



TEM images of MaxPhase

Introducing MaxPhase™ coatings for stainless steel bipolar plates



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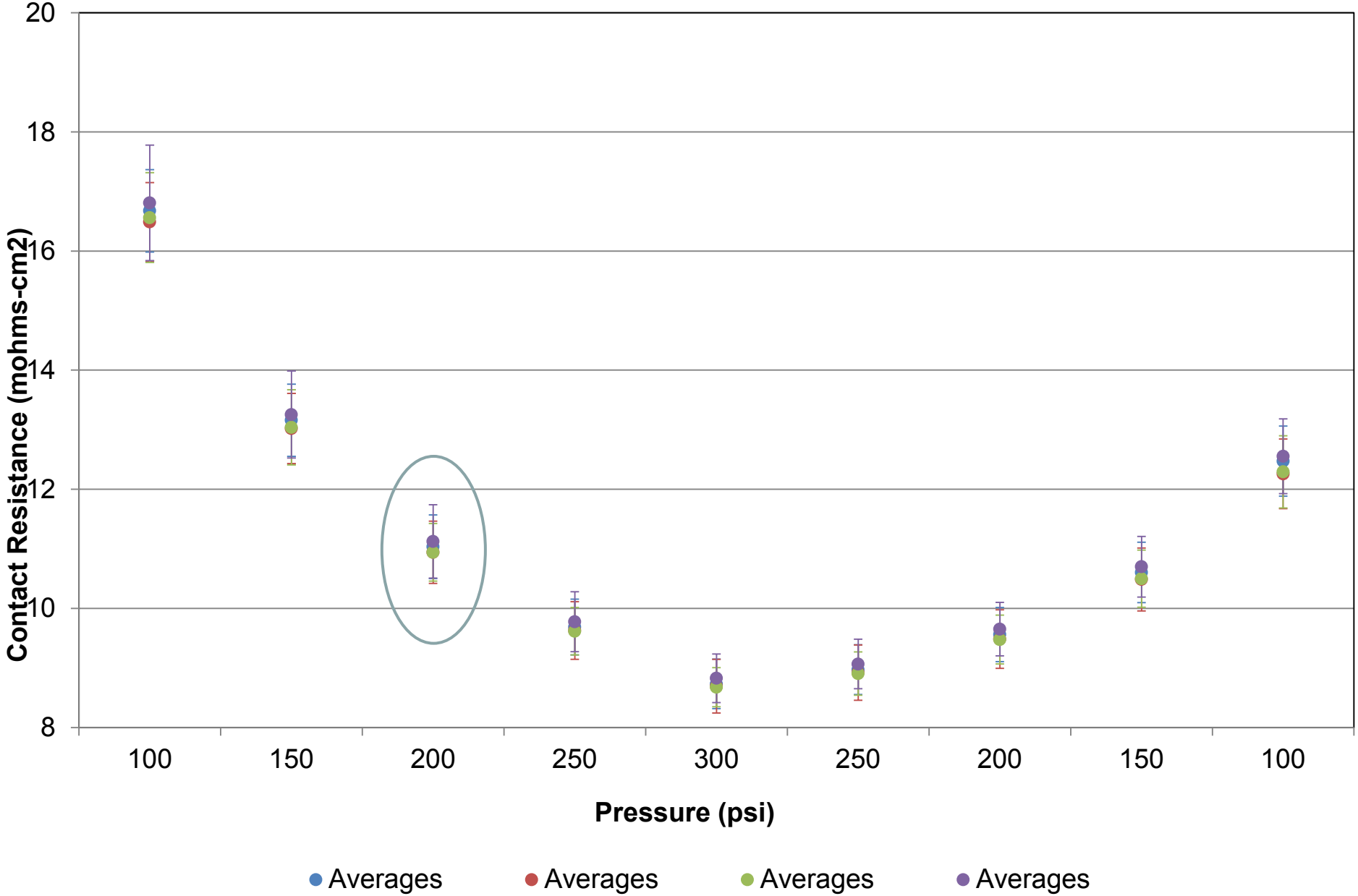
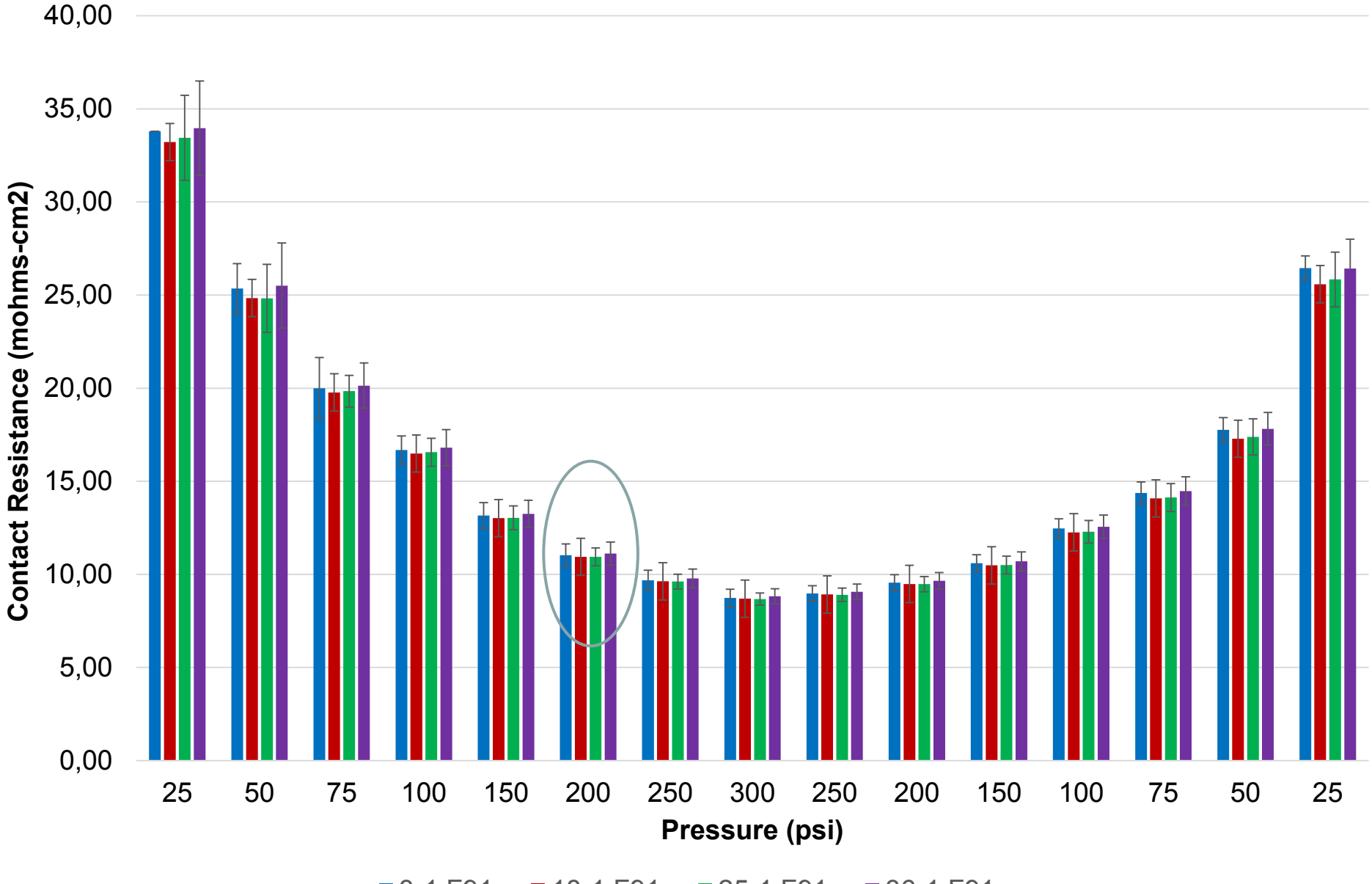
Initial Contact Resistance: Average Contact Resistance With 95% Confidence Interval

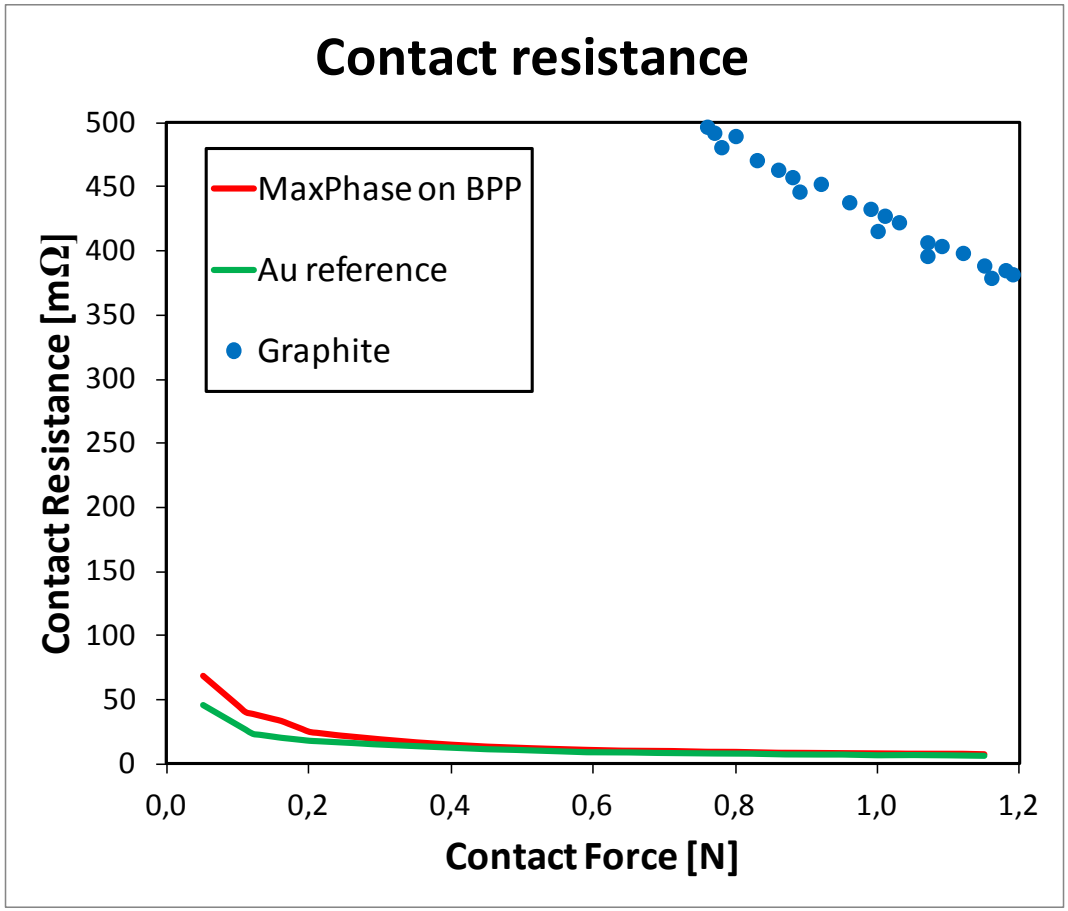


Initial CR for Samples 3, 18, 25 and 36



Single Point Au Probe Contact Resistance

- In-house capabilities for rapid feedback in coating development
- Contact resistance close to Au
- No detectable surface oxidation



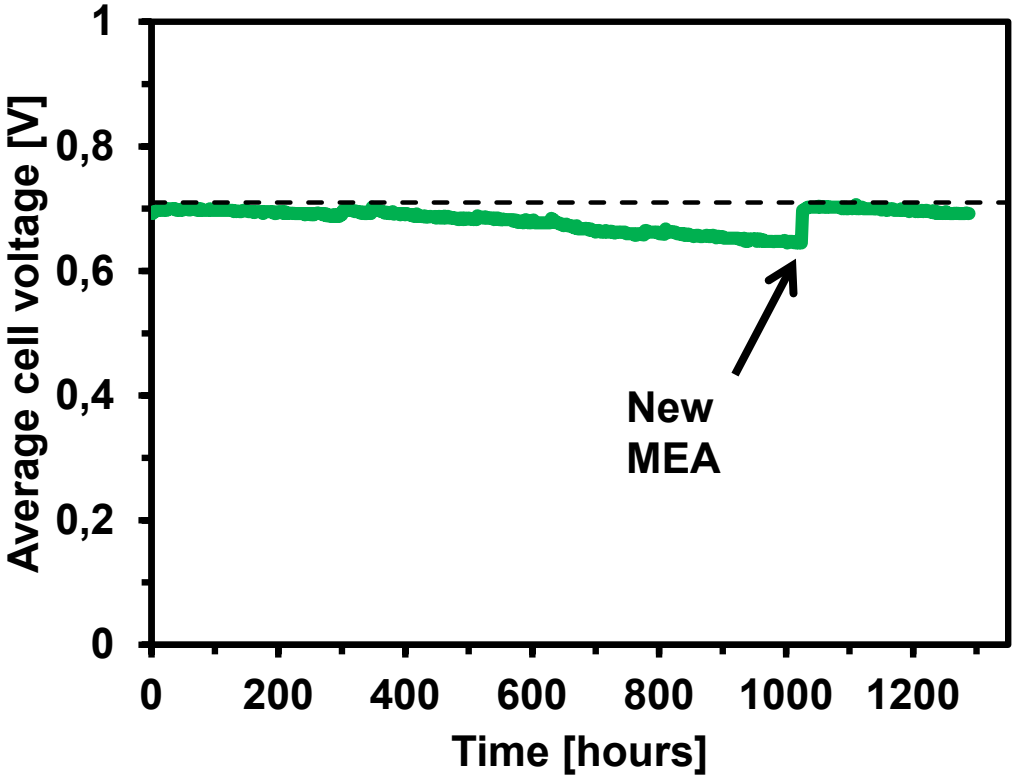
Ceramic MaxPhase™ stack performance

MEAs replaced after 1100hrs

- No degradation attributed to coating detected

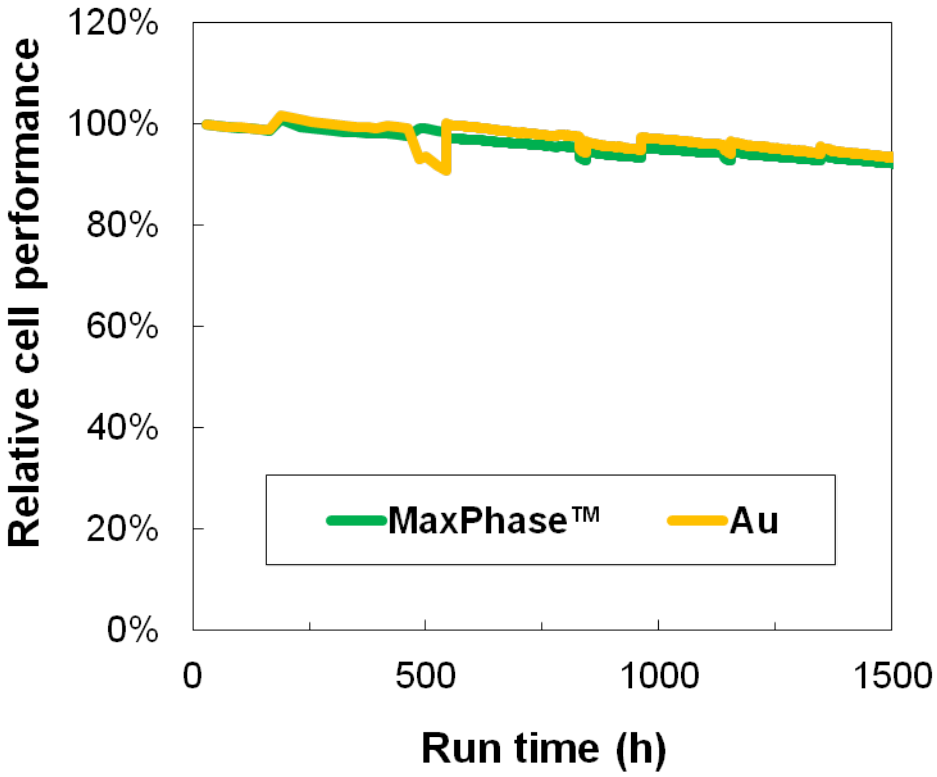
Short stack

Current density: 0.5 Acm^{-2}



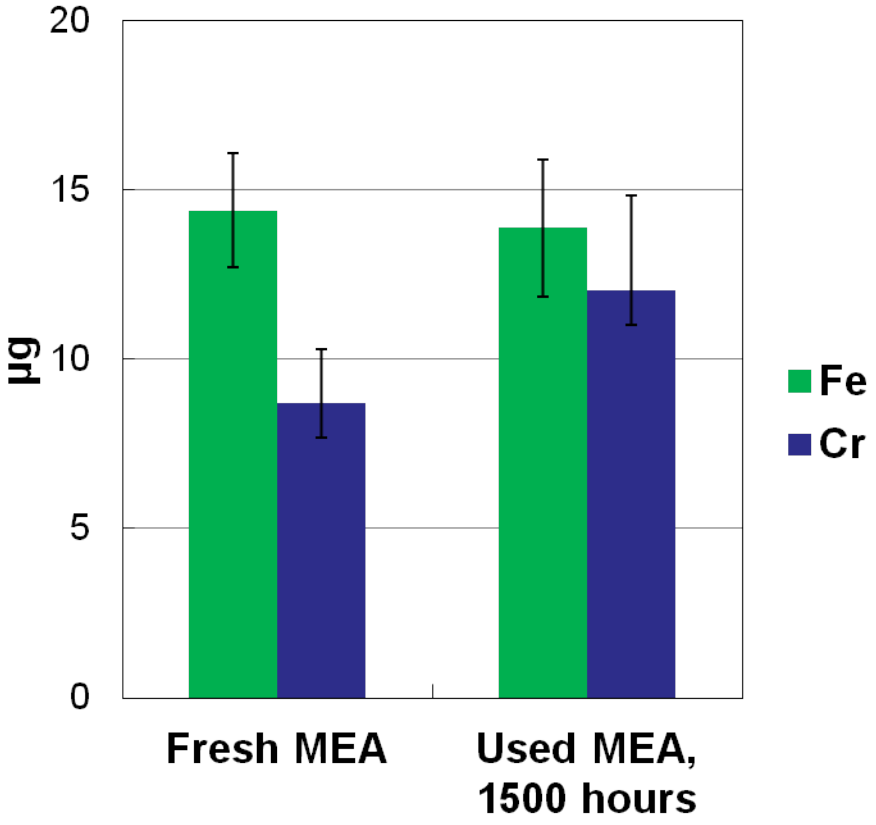
In Situ Stack test – comparison to Au coating

- Performance after 1500 hours 93 %
- The MaxPhase coated BPP provide similar performance as the gold coated BPP
- After the test the MEA was change and the performance was back at 100%



Post-analysis of metals in membrane

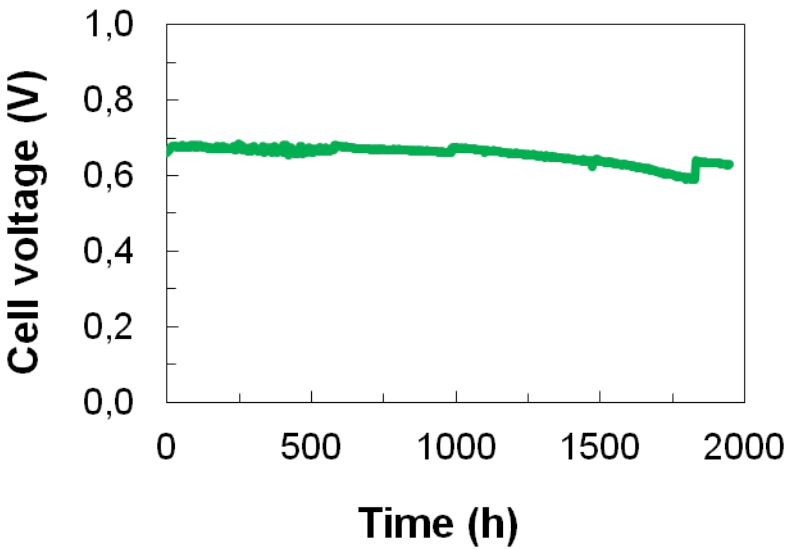
- The Fuel Cell membrane catalytic ability is degraded by steel corrosion products such as Fe and Cr
- No detectable difference in Fe or Cr content in the membrane between a fresh one and one used for 1 500 hours



ICP-AES, 6 samples, 95 cm^2

In Situ Stack Test: 2000 hours

- Test performed by PowerCell Sweden AB
- S1-series short stack with MaxPhase coated BPP
- Stable performance for 2000 hours



- Reformate fuel with 25 ppm CO
- Galvanostatic 500 mA/cm^2 operation
- 70 °C operating temperature
- 80% RH

More info on PowerCell Sweden AB
www.powercell.se

Production solutions

INLINECOATER™

Coating of pre-formed BPP
Both sides simultaneously

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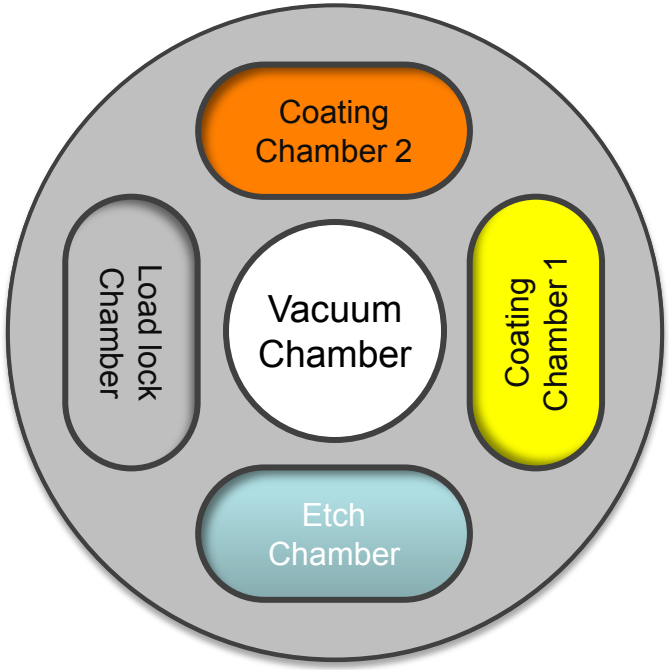
INLINECOATER™

4:Coating Chamber
- Sputtering; e.g. DC, HiPIMS
- Arc evaporation



1: Load lock Chamber
- evacuation in 10 – 20 sec

3: Coating Chamber
- Sputtering; e.g. DC, HiPIMS
- Arc evaporation

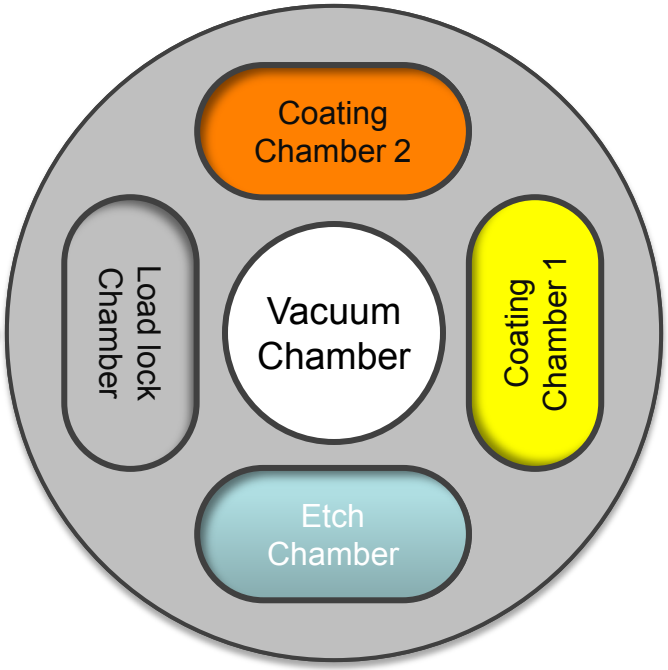
2: Etch Chamber
- Nobel gas or metal ion

IMPACT COATINGS

INLINECOATER™

Continuous feed from conveyor and robot

Continuous outfeed from conveyor and robot



Cost calculation

The calculation includes:

- Investment
- Personnel
- Running cost
- Service
- Consumer materials

Let’s see if we can meet the United States Department of Energy (DOE) cost target!

MaxPhase on BPP - cost

- Cost per BPP (0.1 m^2) < 0.5€
- Capacety in one deposition system 1 000 000 – 2 000 000

Ceramic MaxPhase™ today

Qualified for:

- Proton exchange membrane fuel cell (PEMFC)
- Direct methanol fuel cell (DMFC)

Typical applications:

Stationary

Transportation

Portable

Image sources: microchp.nl h2euro.org fuelcells.org

Conclusions

- **MaxPhase™ coatings perform as good as gold coatings**
- **MaxPhase™ is qualified for bipolar plates (BPP)**
  - over 5,000 hours in stack test
- **MaxPhase cost on BPP, <0.5 €/kW**
- **Meets US Department of Energy target for 2020 !**
- **Impact has both deposition processes and deposition systems for lean production integration**
- **Impact** offers coating service and turn key PVD production systems