Carisma 2014

DEVELOPMENT OF NOVEL MATERIALS AND STACK DESIGNS FOR PEM WATER ELECTROLYSERS

NOVEL consortium

PAUL SCHERRER INSTITUT PSI

Beneq

Johnson Matthey Fuel Cells
the power within

Fraunhofer ISE

New Materials Development (Electrocatalysts & Membranes)

Component development and testing

Increased understanding of lifetime and degradation

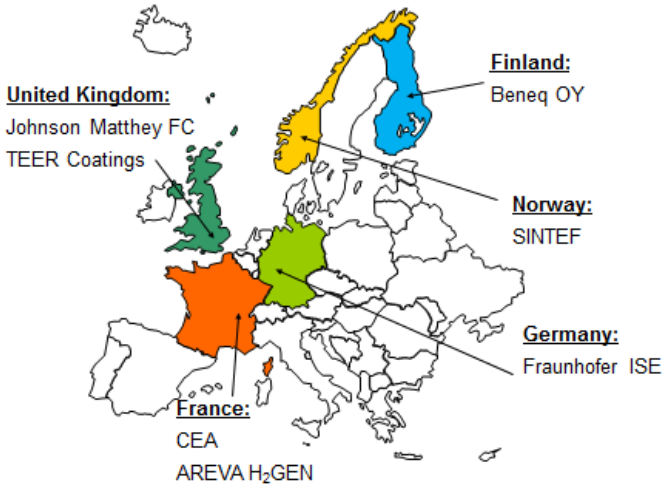
Stack and system design

SINTEF

TEER COATINGS LTD
innovation and experience

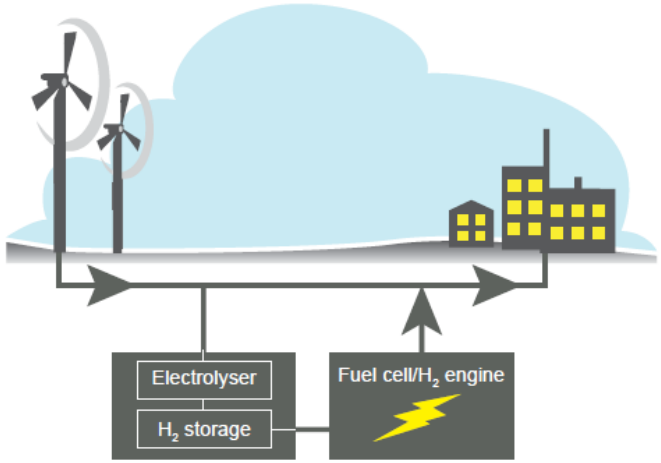
DE LA RECHERCHE À L'INDUSTRIE
cea

AREVA H_2Gen



NOVEL main objectives:

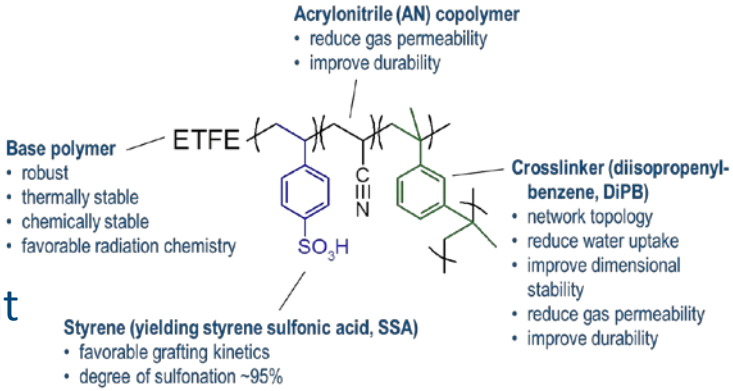
- Develop and demonstrate a PEM water electrolyser using beyond state of the art materials.
- 75% Efficiency (HHV), electrolyser stack cost < €2,500 / Nm^3h^{-1}, target lifetime of 40,000 h (< 15 μVh^{-1})

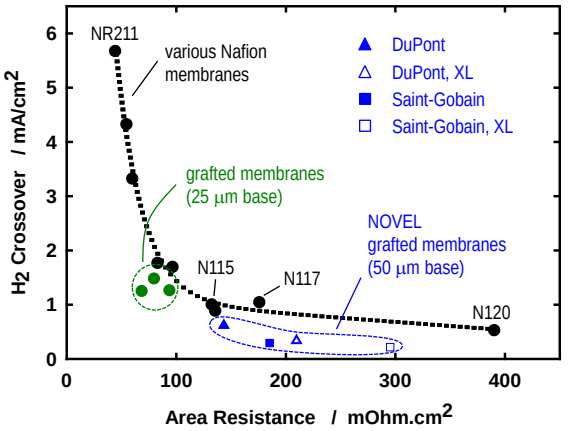


Approach

Technical highlights – novel membranes

- Develop lower cost membranes suitable for electrolyser operation at elevated temperatures
  - Radiation grafted membranes based on ETFE base polymer
  - Significant reduction in H_2 crossover at similar area resistance vs PFSA
- Several activities ongoing for further improvement of PFSA membranes for PEM electrolysers ongoing
  - Reduction in H_2 crossover and resistance
  - Lifetime improvements





Technical highlights support materials

$Ti_{1-x-y}Nb_xTa_yO_2$	$Ti_{1-x}Nb_xO_2$
(x,y) = 0.0125, 0.025, 0.050	x = 0.025, *0.050* 0.075, 0.10

Spray pyrolysis

Spray water based precursors into heated chamber

Ti-citrate complex (Ti-isopropoxide)

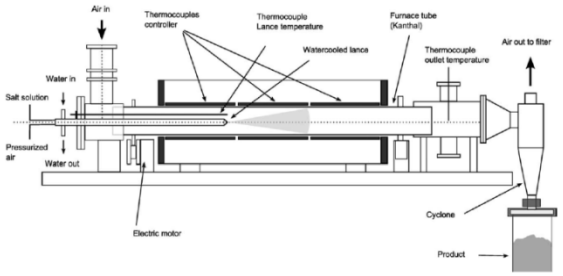
Nb-malic acid complexes

Hollow spherical particles with nanosized crystallites

Calcination + milling necessary

Several kg's pr day

SA = 30-50 m^2/g



Co precipitation

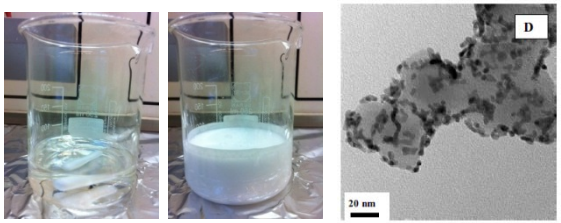
Ti-isopropoxide and Nb etoxide in isopropanol

Water -> hydrolysis (precipitation)

Calcination necessary

Nanosized spherical particles

SA = 100 m^2/g

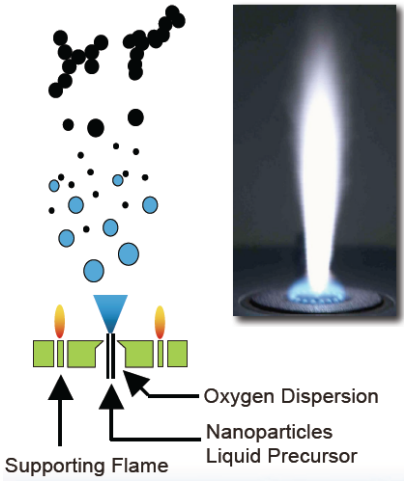


Flame Spray Pyrolysis

Alkoxides in flammable solvent

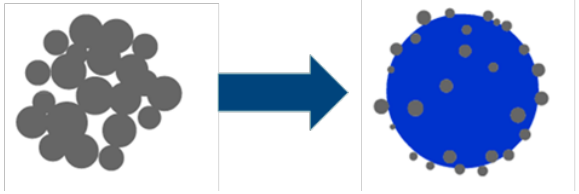
No post treatment necessary

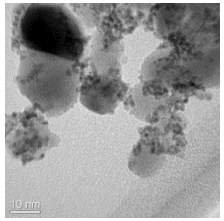
SA = 100 m^2/g

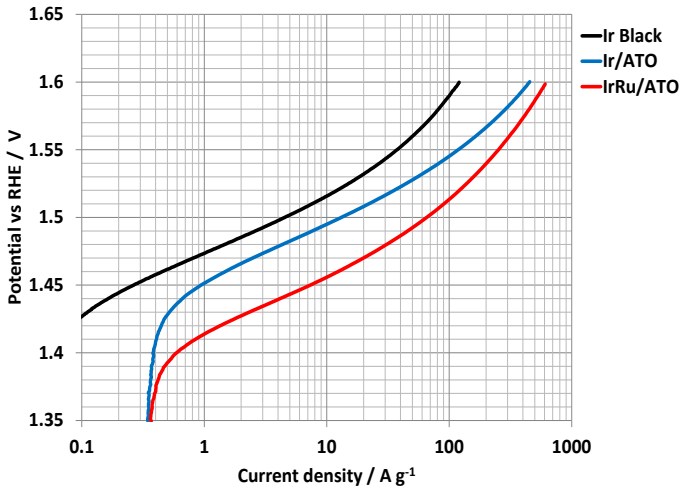


Technical highlights – catalysts

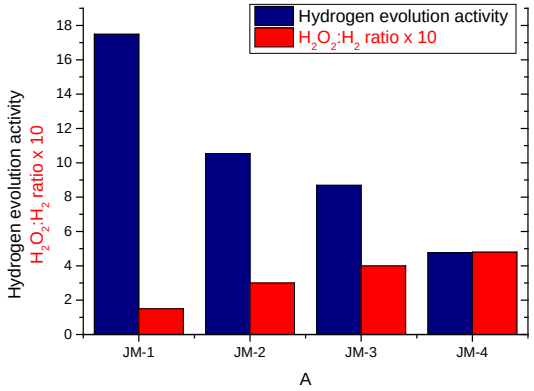
- Highly active oxygen evolution catalysts developed
  - 2 nm Ir and IrRu particles on conductive oxide supports
  - 3-25 times higher activity vs state of the art Ir catalysts





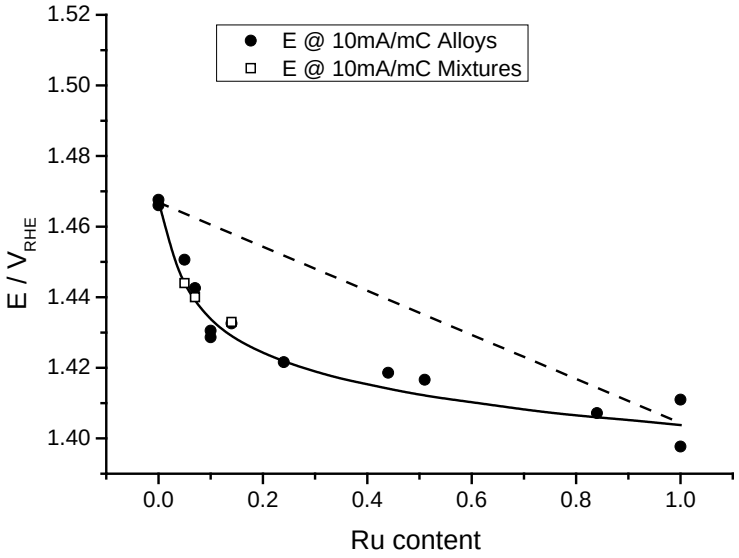


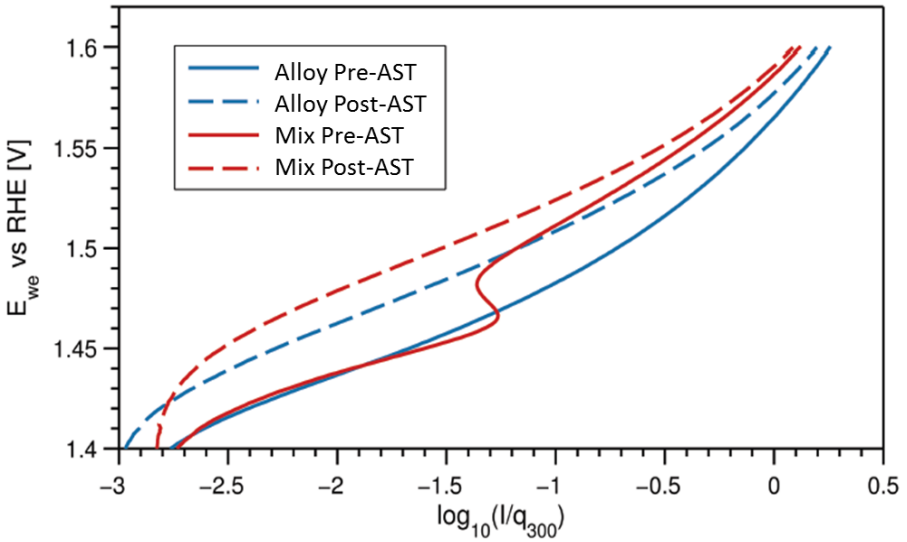
- Hydrogen evolution catalysts with high activity and low peroxide formation identified
  - Reduction in noble metal loading
  - Increased lifetime



Technical highlights – catalysts

- Alloying Ru in Ir nanoparticles
  - Significant increase of activity with low Ru-addition
  - No reduction of Ru specific activity in alloys
    - Ru as active as in pure form
  - Significant improvement of Ru-stability compared to mixtures

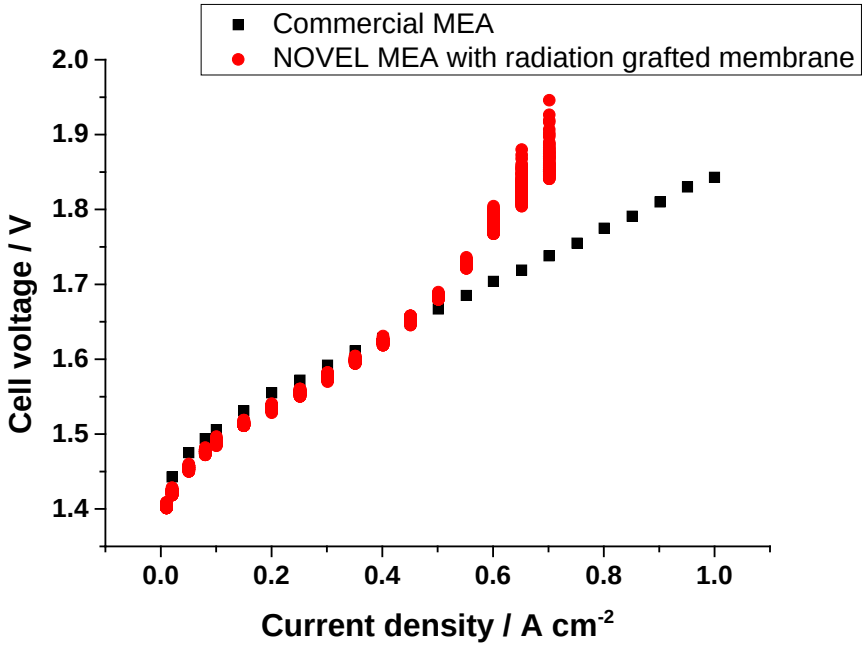




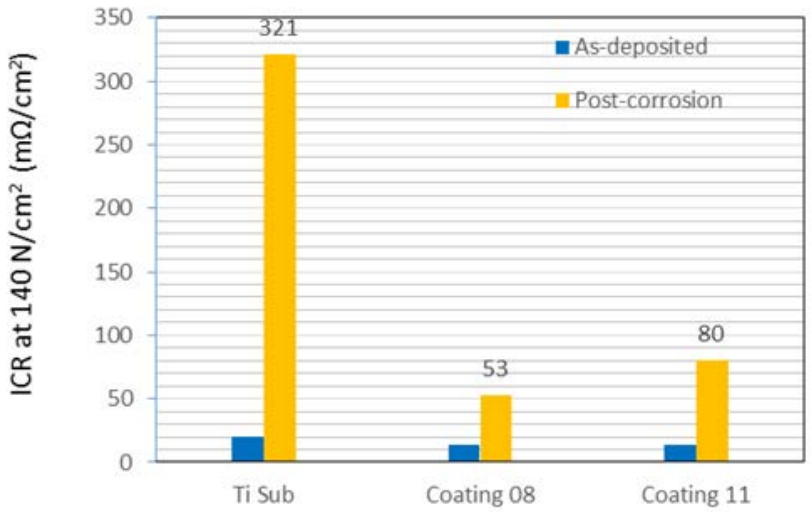
Technical highlights – MEA/CCM development

- Development of new MEAs ongoing
  - First iteration of radiation grafted membranes completed
  - Good performance at low current density
  - Transport limitations visible at higher currents

- Coating procedures developed for novel electrocatalysts and membranes
  - High flexibility, variations in membrane properties and catalysts loadings easily handled
  - Production of MEAs with varying size and shape
  - High reproducibility and control of layer structures

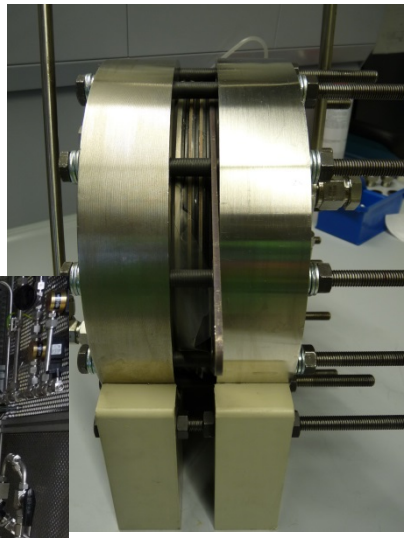


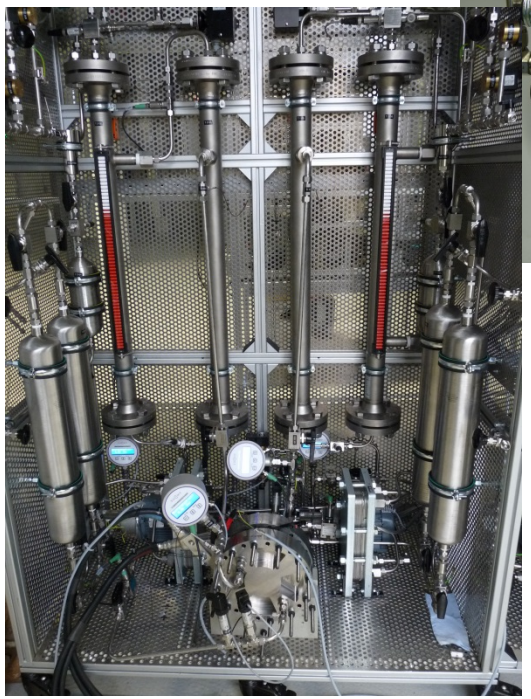
Technical highlights – coatings for bipolar plates



Stack design

- Stack design for high pressure operation established
  - New sealing concepts
  - Optimisation of fluid pressure drop and thermal management
  - First 3-cell short stack constructed
  - Baseline tests before introduction of novel components in 2015
- Fraunhofer stack test bench used
  - Maximum current: 510 A
    Maximum voltage: 80 V
    Maximum el. power: 15000 W
    Maximum T: 80 °C
    Maximum circulation flow :8 l/min



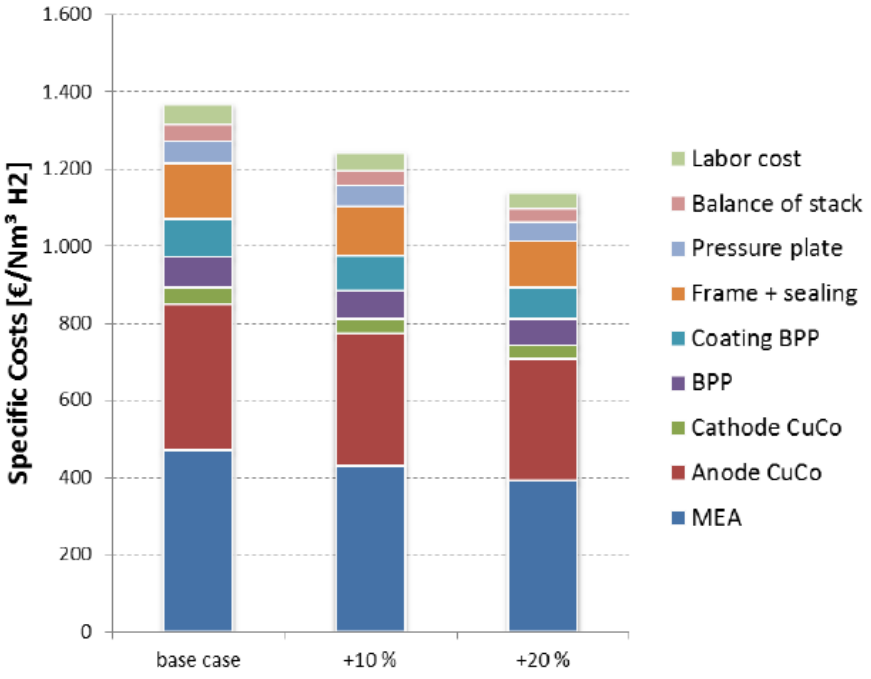


Cost break down – NOVEL Stack design

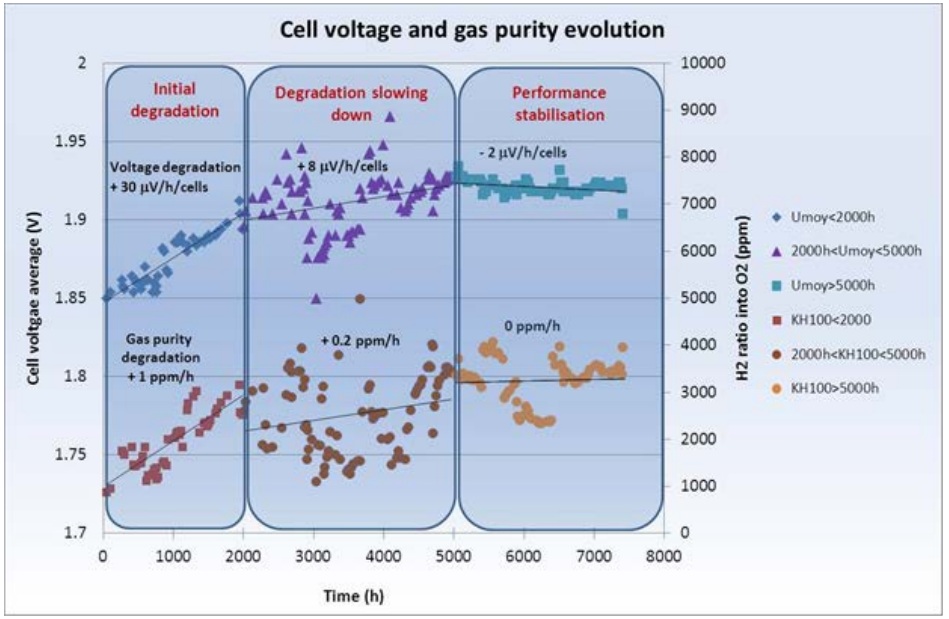
- Stack design with thin Ti sheets as bipolar plates
  - Non-precious metal coatings
- 600 cm^2 active electrode area
- 50 Nm^3h^{-1} production rate
- 1.8 V nominal cell voltage @ 2 Acm^{-2}
- Annual production of 100 stacks

- Anode current collector and MEA manufacturing major cost drivers.

- Target cost of 2500 € / Nm^3h^{-1} is reached.

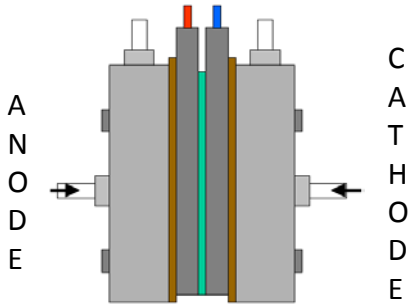


Lifetime evaluation and degradation mechanisms



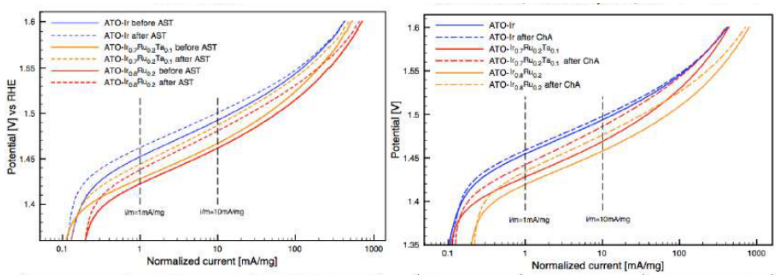
Lifetime evaluation and degradation mechanisms

- AST protocols for electrolyser components developed/defined



1,55 V - **5h**

(1,35-1,55 V) 10 000 cycles @ 1V/s - **1h**



Catalyst	ΔE @ 1 mAmg^{-1}	ΔE @ 10 mA mg^{-1}
Ir	8	8
$Ir_{0.7}Ru_{0.2}Ta_{0.1}$	16	20
$Ir_{0.8}Ru_{0.2}$	15	19

Catalyst	ΔE @ 1 mAmg^{-1}	ΔE @ 10 mA mg^{-1}
Ir	5	5
$Ir_{0.7}Ru_{0.2}Ta_{0.1}$	14	17
$Ir_{0.8}Ru_{0.2}$	15	18

Figure 4: comparison of accelerated stress tests on anodic catalysts performance evolution: 5 hours at constant voltage / 1 hour under potential cycling ; according to [8].