WELTEMP

Water electrolysis at elevated temperatures

(Contract number 212903)

Presented by Erik Christensen
Department of Chemistry,Technical University of Denmark

Coordinator: Niels J. Bjerrum

The Project and the Partners

www.weltemp.eu

FP7, Collaborative Project, small or medium-scale focused research project

Duration: January 1st, 2008 - April 30th, 2011

Total costs: 3.2 million Euro EC Funding: 2.4 million Euro

The Partners

Technical University of Denmark (Coordinator)	Denmark
Institute of Chemical Technology Prague	Czech Republic
Institute of Macromolecular Chemistry ASCR	Czech Republic
The Norwegian University of Science and Technology	Norway
IHT Industrie Haute Technologie SA	Switzerland
Acta S.p.A.	Italy
Tantalum Technologies A/S	Denmark
Danish Power Systems ApS	Denmark

Concept of Research

Elevated temperature
(steam or liquid?)
- To obtain higher efficiency

Requires New Materials Development:

Component:	*Replace/modify:*
Membrane	Nafion
Current collectors	Titanium
Bipolar plates	Titanium
Catalysts	IrO_2, RuO_2, Pt
MEAs → Electrolyser	

Targets and milestones

(1). Temperature-resistant polymer electrolyte membranes
· operational temperatures within 120 to 200°C
· ionic conductivity of 0.05 - 0.10 S/cm, durability over 5,000 hours
Obtained: 0.3S/cm at 150°C! - but long time testing lacks for proton conducting membranes.
However, *alkaline membranes* have shown quite encouraging results!

(2). Electrocatalysts:
· Anode with a noble metal loading of < 2 mg/cm² , cathode with noble metal loading of < 0.2 mg/cm²
with performance loss < 20 mV/h during a period of 5000 h.
Obtained: For the anode only pure IrO2 is stable, 1mg/cm² OK. Standard Pt electrode were used. Long time testing lacks

(3). Methods for preparation of membrane-electrode assemblies (MEAs) with targets of
· fabrication of MEAs of 10 cm diameter size, single cell performance of 1.55 V at 1.0 A/cm², operational temperatures 120-200°C
Obtained: 10.5 cm diameter size, 1.65 V at 1.0 A/cm² at 130°C

(4). Tantalum coated current collectors and bipolar plates based on titanium or alternative metals.
Obtained: Both made in steel coated with tantalum, and having excellent corrosion-, contact resistance- , and conductive properties.

(5). Design, construction and testing of a 1 kW prototype electrolyser, flexible modular design of 5 cells with active MEA area of 78 cm². Working temperatures above 120°C, pressurable to the range 20 bars to 70 bars.
Hydrogen production of 320 NL/h, single cell efficiency higher than 80 % on an LHV basis.
non-energy production cost of 1 EUR/kg of hydrogen, if mass produced.
Obtained: Two different modular design, the largest one pressurable to 70 bars, electrode area 87 cm², up to 18 cells can be joined and monitored individually. Working temperature up to 130°C.
However testing did not start before deadline of WELTEMP.

Concepts of Polymer Membrane Materials

1) PBI (polybenzimidazol)
   - Phosphoric acid doped (apparently not stable!)

2) PFSA (Perfluorosulfonic acid, *Nafion, Aquivion*)
   - The Ionic conductivity requires water to be present inside the structure.

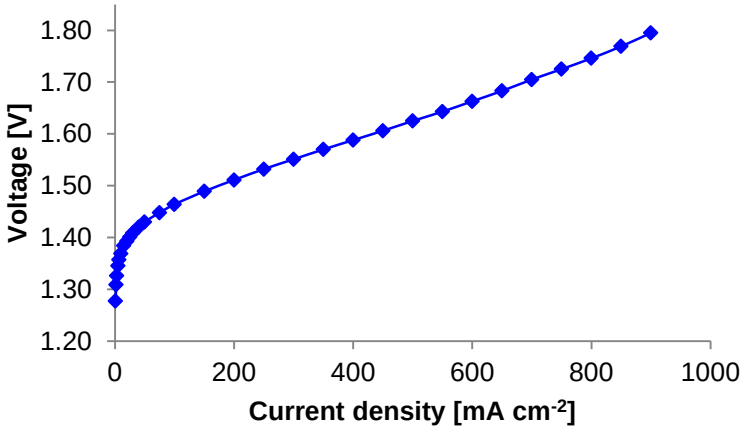
   - Water evaporates from the membrane at T > 100°C
     then three ways to go:

a) Modify Nafion/Aquivion by adding hygroscopic fillers (steam or liquid water)
b) Doping with H_3PO_4! (only steam feeding)
c) Pressurising the cell and working with liquid water

3) Anion conducting membranes (alkaline ”PEM” electrolysis)

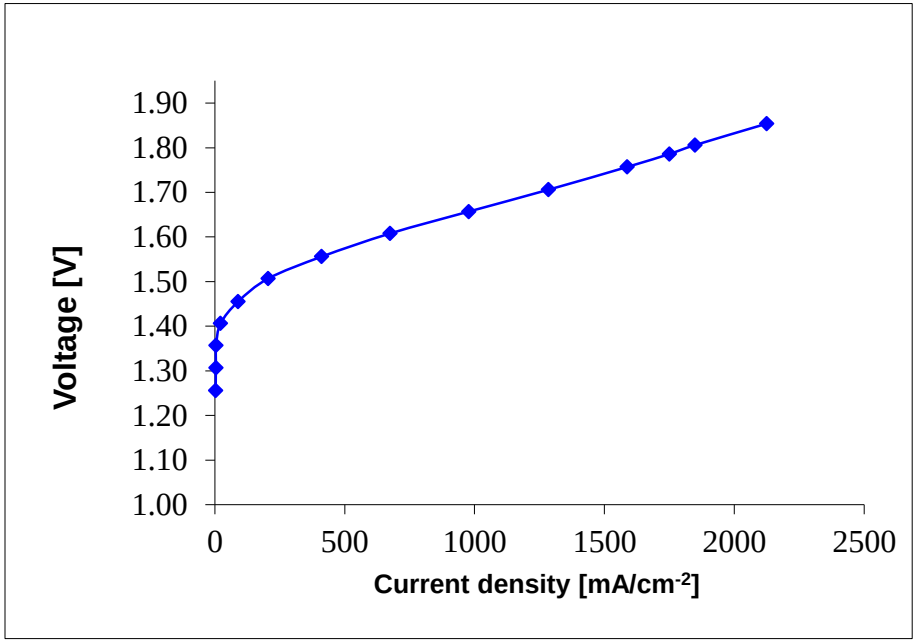
Steam- or Pressurized Water Electrolysis?

STEAM electrolysis:
PFSA Membrane (Aquivion)
doped with H_3PO_4



Anode: 0.98 mg/cm2 IrO_2, Cathode 0.34 g/cm2 Pt, GDL 0.5mm Ta coated steel felt, Aquivion membrane, 63microns thick,
Temperature 130°C, Atmospheric Pressure

Pressurised LIQUID water electrolysis
PFSA Membrane (Aquivion)

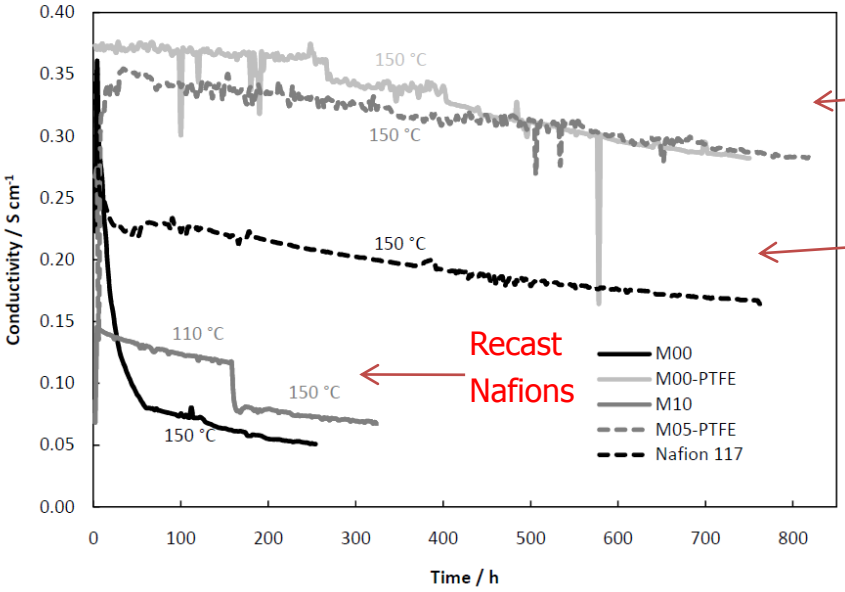


Anode: 1.72mg/cm2 IrO_2, Cathode 0.80 g/cm2 Pt, GDL 0.5mm Ta coated steel felt, Aquivion membrane, 60 microns thick,
Temperature 120°C, Pressure 3 bar

1. Ionic conductivities of membranes
2. Tantalum coated steel to replace titanium

Membrane materials

Reinforcement is important

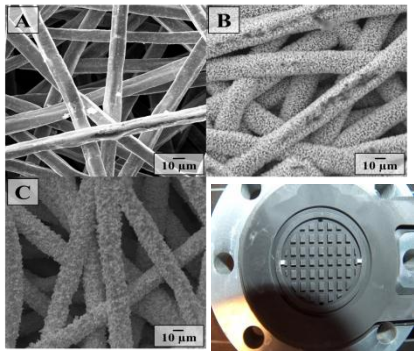


Nafion +PTFE

Nafion 117

Recast Nafions

150°C, 6 bar, 100 % RH



Flowplates and anodic current collectors ("GDL"):

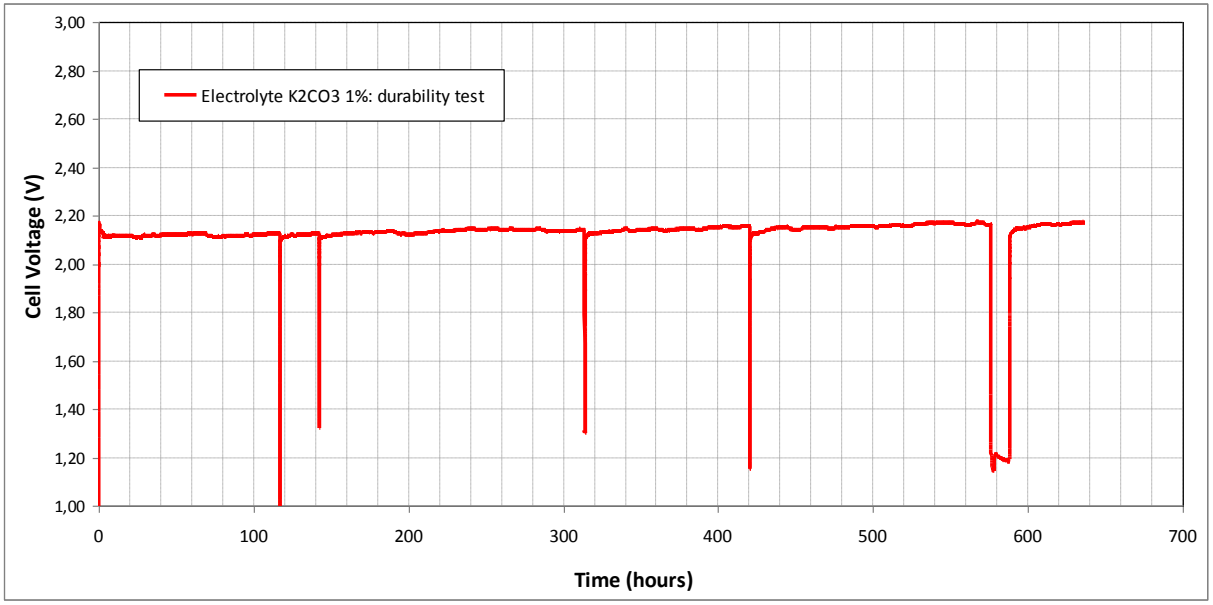
Titanium not stable – replaced by tantalum coated steel

CVD: Chemical Vapor Deposition

$2TaCl_5\,(g) + 5H_2(g) \rightarrow 2Ta + 10HCl(g)\uparrow$

Alternative concept: Alkaline MEAs

Durability issue ?



Life test (> 600 h) obtained with the ACTA alkaline MEA 475 mA/cm^2), T_{cell} = 40 ° C.
Now more than 6000 h!

Performance problem: Main issue is ionomer for catalyst layer preparation (Teflon was used).
Active non-noble metal catalysts were developed for both anode and cathode!

Correlation of the project with the corresponding Application Area

Weltemp – Application Area:

”Hydrogen Production & Distribution”

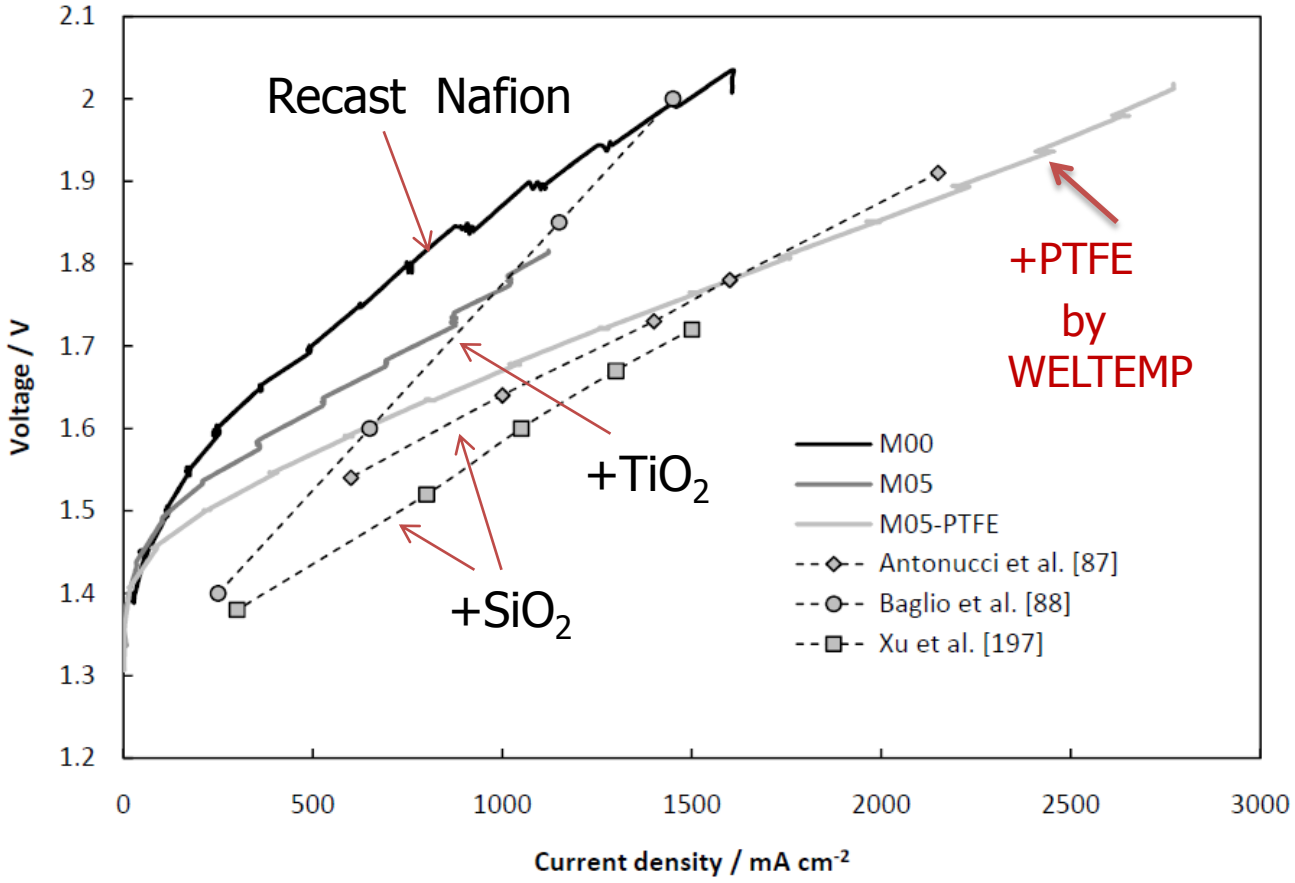
(Innovative hydrogen production and supply chains)

Weltemp: A survey of various types of electrolyser technologies: *Acidic PEM, Alkaline PEM, Liquid water feeding, steam electrolysis.*

PEM: decentralized units *Alkaline: Centralized units*

For large scale use in the nearer future according to govenmental plans, alkaline technologies will be important! (f.ex. Denmark: 50 % of total electricity consumption from sustainable sources in 2020 => Large electricity storage capacity will be needed already in 2020)

Comparison of performances of modified Nafion MEAs,120ºC and 2-3 bar



High performances are obtained, but labscale PEM at 80° C are comparable

Bottlenecs/ Additional Topics

Gaps/bottlenecks in RTD&D:

- Not yet any replacement for IrO_2 in PEMEC´s in sight
  – limits (acidic) PEM to smaller units.
- Deposition of metallic corrosion products on Pt cathode

Underestimated topics:

- Anion conductive membranes, and ionomers for MEA electrodes.
- For high pressure PEMEC: metal foam-like materials for flowpatterns (mechanical support for membranes)
- Inorganic proton conducting materials and ”intermediate temperature” electrolysers (÷ IrO_2 and Pt?!)

Training and Education Dissimination

Water electrolysis for sustainable hydrogen production has become a subject of considerabely increased priority in the teaching at the WELTEMP university groups.

- at bachelor as well as at master student level
- important basis for future increased activity within the field (academic and commercial)

Phd students educated at all univ. partners

Many conference presentations and peer reviewed papers – more to come!

Participation in various open house arrangements etc.

Technology Transfer/collaboration - and future activities

Cooperation with other EU-projects:

Organisation of Workshop in 2012 with Primolyzer and Nexpel
(Primolyzer uses Tantalum coatings from WELTEMP)

New activities derived from WELTEMP -I:

Ongoing new project: Danish Councill for Strategic Research supports a project on ”Medium Temperature Water Electrolysis” (MEDLYS), involving all three Danish Weltemp partners (Inorg. proton conductors, 200-400^{o}C)

There is synergy with a Danish-Chinese center working within inorganic proton conducting materials

A proposal for a new collaborative project under Energy/Future Emerging Technologies was recently submitted, includes Weltemp partner NTNU in Norway (Inorganic proton conducting electrolytes)

Technology Transfer/collaboration-II and future activities

New activities derived from WELTEMP -II:

A contact to the Technological Institute of Argentina was established:

A proposal within the IRSES framework is planned to be submitted,

will include Weltemp partners ICTP and IMC in Czech Republic.

(Membrane electrolysers, proton conducting and anion conducting membranes)

It is expected that a new proposal to the Commission, involving most of the Weltemp partners, will be submitted (when time schedule of the partners and a suitable call coincide)

A cooperation between DTU and a major European manufacturing company on collaboration on R&D within alkaline water electrolysis technology have been initiated.

Future Project Perspectives

Development of reinforced PFSA membrane continues

Tantalum coated steel felt is further developed and delivered to various partners or customers

MEA preparation technique devlelopment is continuing financed by other sources (including catalyst supports, catalyst preparation methods, possible new catalysts)

Activities towards development of large scale alkaline electrolysers working at elevated temperatures and pressures will have high priority among the partners

Anion conducting membranes and ”alkaline PEM electrolysers” appear promissing!
- may eliminate the need of noble metals!

We suggest higher priority in future FCH JU - or similar - Programmes

An Announcement:

Collaboration and dissemination:

- A Weltemp-PrimoLyzer workshop took place on 16th of Nov. 2010 in DK

- An international electrolysis workshop is being organized on May 10-11, 2012 in Copenhagen

  Content:
  - Technical overview – International initiatives
  - The challenge: Stationary energy storage and energy for transportation
  - The solution: Hydrogen production by electrolysis
  - Technical presentations

  Organized by:

PRIMOLYSER
IRD Fuel Cell Technology
NEXPEL
SINTEF
WELTEMP Water Electrolysis at Elevated Temperatures 7 A project under the Seventh Framework Programme (FP7) 2007 - 2013
DTU

National Danish funded projects:
Medlys (FI 10-093906)
HyProvide the PEM track (EUDP)
Next Generation Alkaline Electrolysis (HT)

HYDROGEN AND FUEL CELLS
THE DANISH PARTNERSHIP

New Energy World JU
fuel cells & hydrogen for sustainability

Danish Agency for Science Technology and Innovation
Ministry of Science, Innovation and Higher Education
EUDP
Højteknologifonden

Thank You for your attention!