Hydrogen and Fuel Cell Conference, Vancouver, Canada
June 16rd-19th 2013

Development of low cost and durable PEM water electrolysers.

Research and demonstration activities in the FCH-JU projects NEXPEL and NOVEL.

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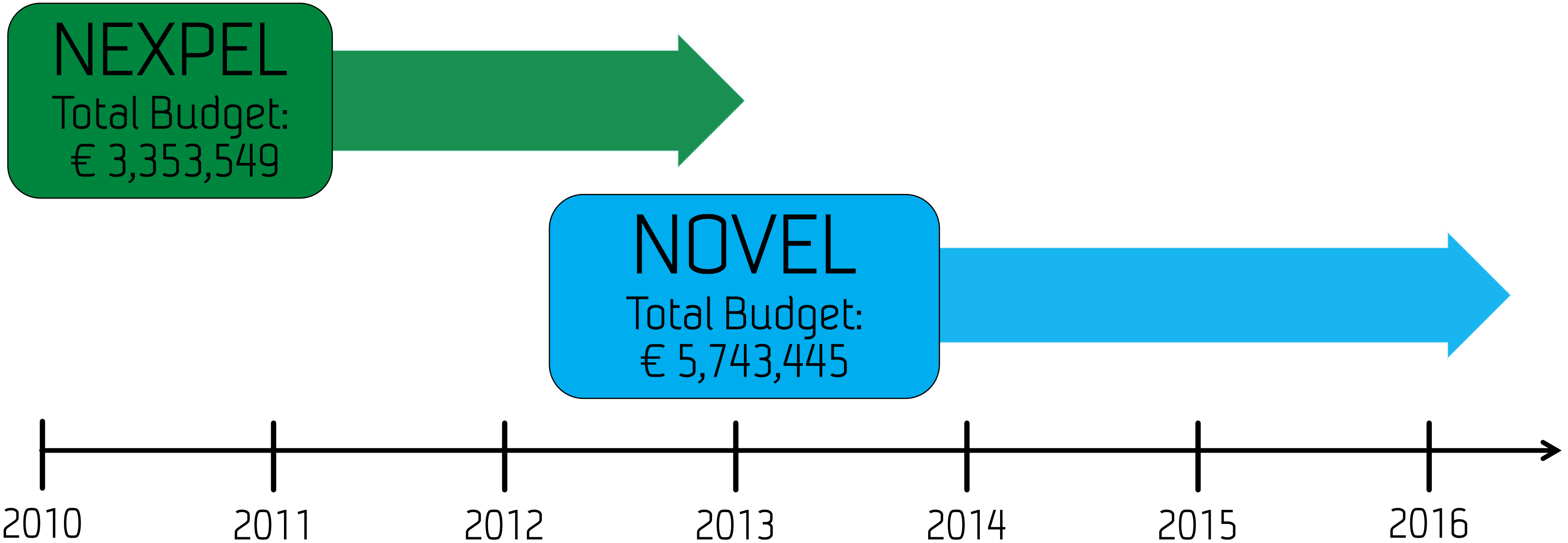
SINTEF Materials and Chemistry, New Energy Solutions
Trondheim, Norway

NOVEL

NEXPEL

NEXPEL & NOVEL - Main objectives and duration

- Develop and demonstrate a PEM water electrolyser integrated with Renewable Energy Sources (RES):
  - 75% Efficiency (LHV), H_2 production cost ~ €5,000 / Nm^3h^{-1}, target lifetime of 40,000 h



The NEXPEL consortium

New Materials Development (Electrocatalysts & Membranes) → Component development and testing → Stack and system design → System integration and testing with RES

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Funktionelle Membranen und Anlagentechnologie

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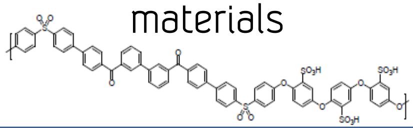
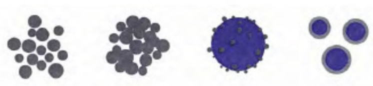
NEXPEL – Main results and achievements

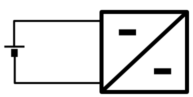
WP2 New membrane materials



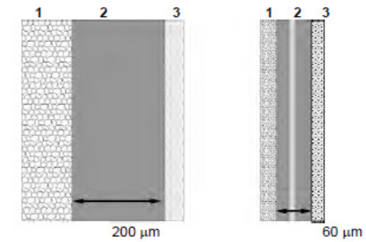
WP3 New catalysts



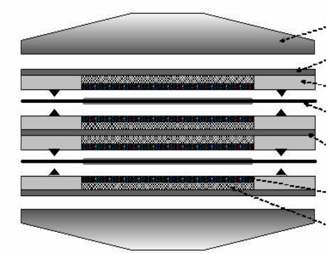
WP7 Improved DC-DC converter



WP4 Improved MEAs



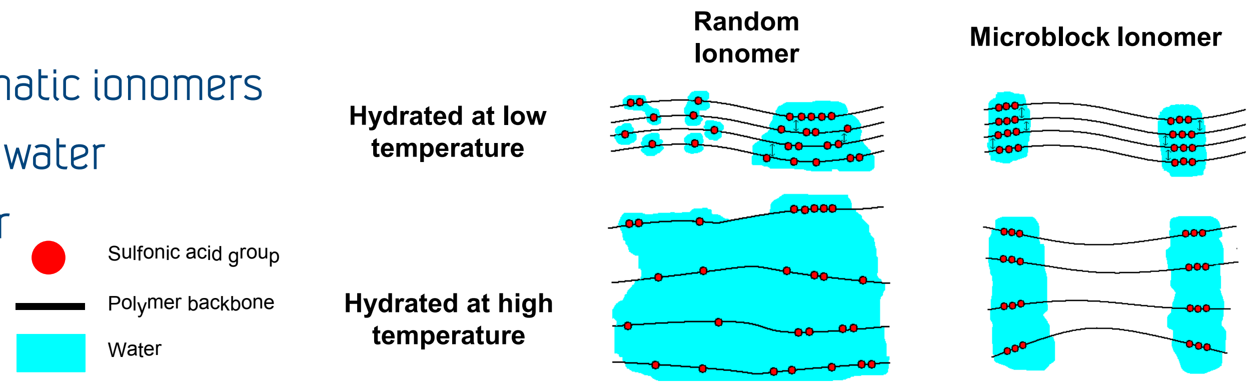
WP5&6 Novel stack design and new construction materials



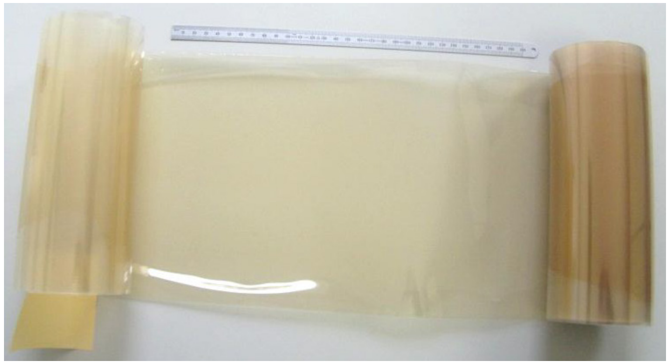
WP7 Integration with RES

WP 2 – New membrane materials

- Develop lower cost membranes suitable for electrolyser operation at elevated temperatures
  - Microblock polyaromatic ionomers
  - Reduced swelling in water
  - Lower gas crossover

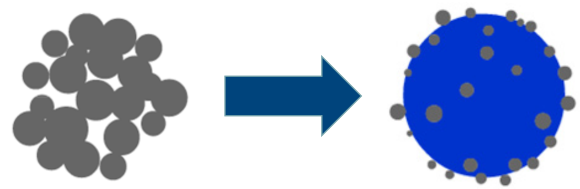


- A series of polyaromatic materials has been prepared
  - Proton conductivity of › 40 mS cm^{-2} (Nafion ~ 100 mS cm^{-2})
  - High mechanical stability (› 120 °C)
  - 10 g scale of ionomers produced
  - 5.5 m^2 membrane cast on continuous production line.



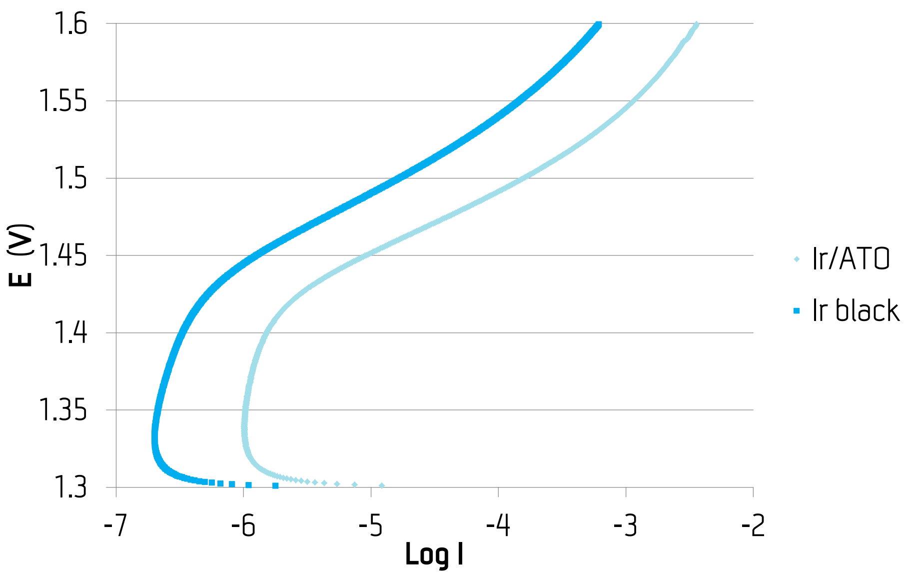
WP 3 New catalyst materials

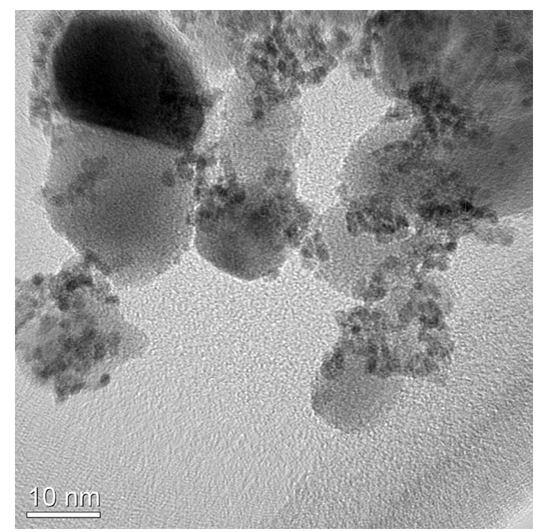
- Highly active oxygen evolution catalysts developed
  - 2 nm Ir particles on Antimony Tin Oxide support (20wt% Ir)
  - 300% higher activity than state of the art catalysts
  - Scaled up synthesis (~30g catalyst batch size)



Sintered mono dispersed particles

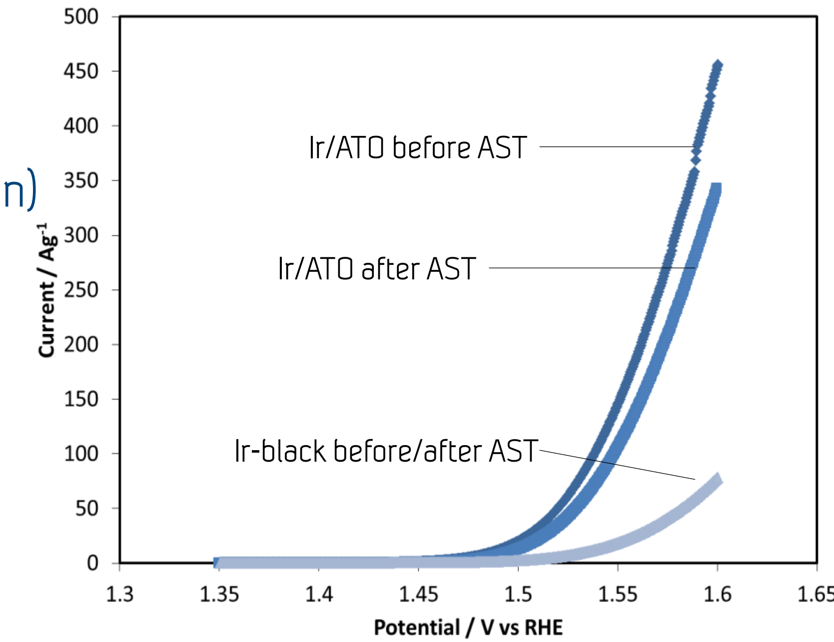
Supported particles

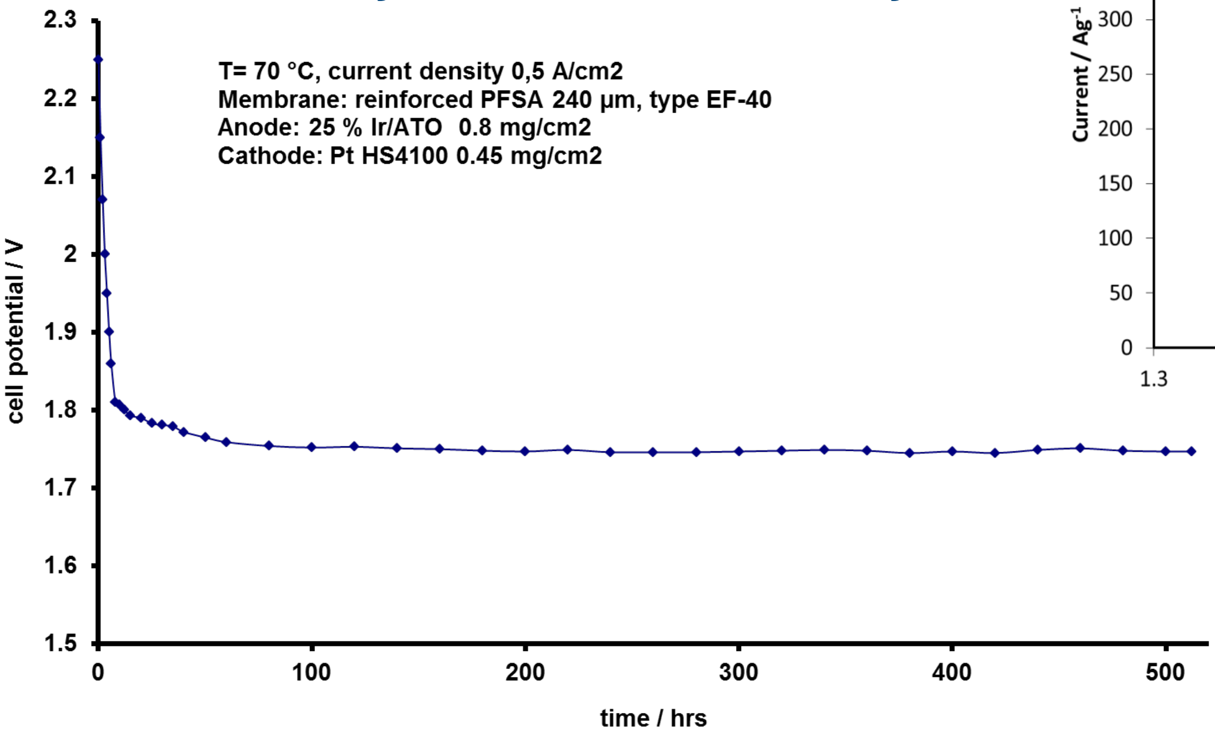




WP 3 New catalyst materials

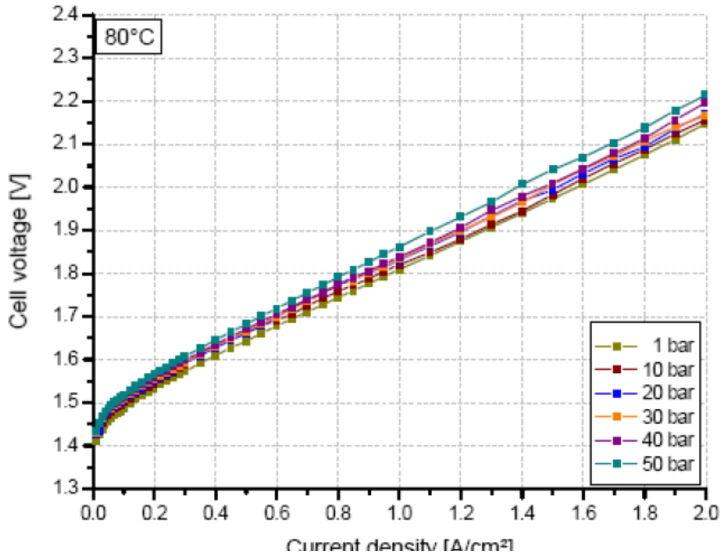
- Ir/ATO stability (ex situ and in situ)
  - 10 000 cycles, 1.35-1.55 V vs. SHE at 300 mVs^{-1}
  - 500h steady state operation (3 μVh^{-1} degradation)

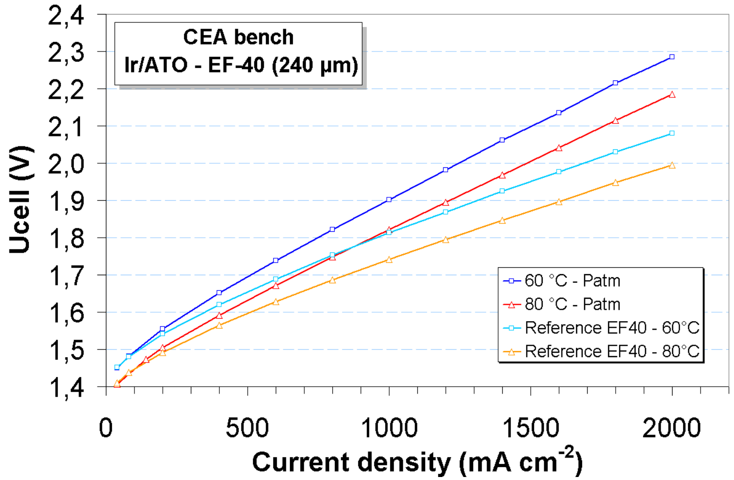




Technical highlights – MEA/CCM development

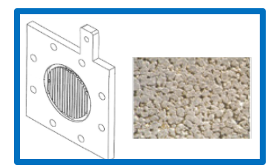
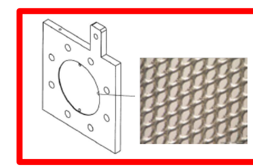
- State of the art CCMs
  - Fumatech reinforced membranes
  - High gas purity (<0.5% H_2 in O_2) and high operating pressure (40 bar)
- New low loading CCMs
  - Utilising Ir/ATO catalysts
  - Optimisation of coating procedures and catalyst loadings
  - Initial results show comparable performance and long term stability
  - Ir loading ~40% of standard CCM



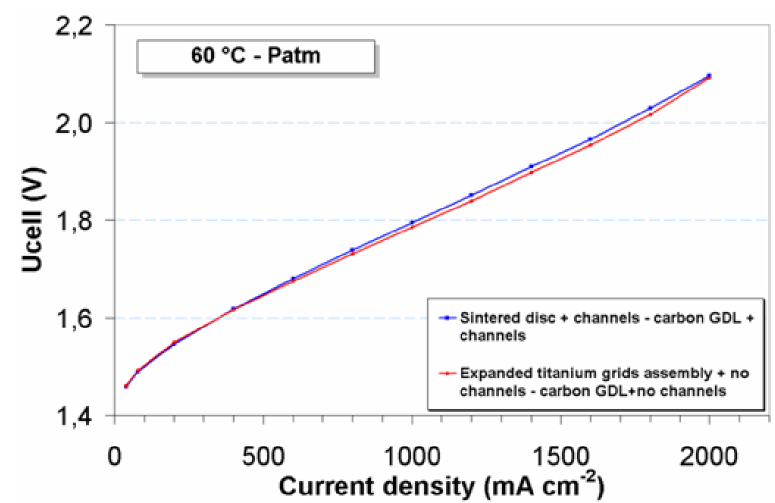


Technical highlights – bipolar plates and current collectors

- Bipolar plates
  - Several Ti grades and stainless steels evaluated in PEMWE representative conditions (several 100h)
- Current collectors
  - Several porous Ti-materials have been tested as current collectors
  - Significant potential for cost reduction identified

150 cm² optimized current collectors for 5 cell stack



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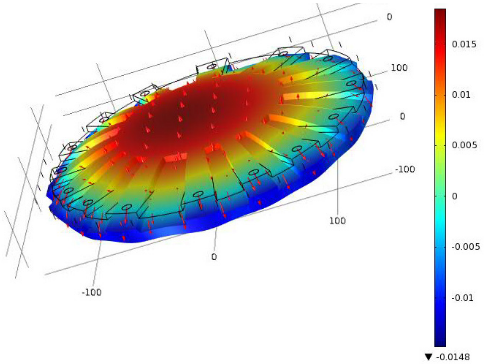
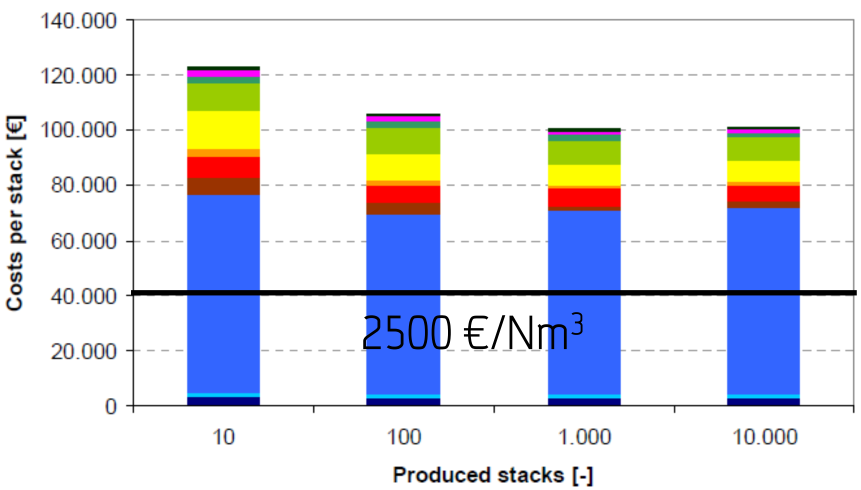
Stack design

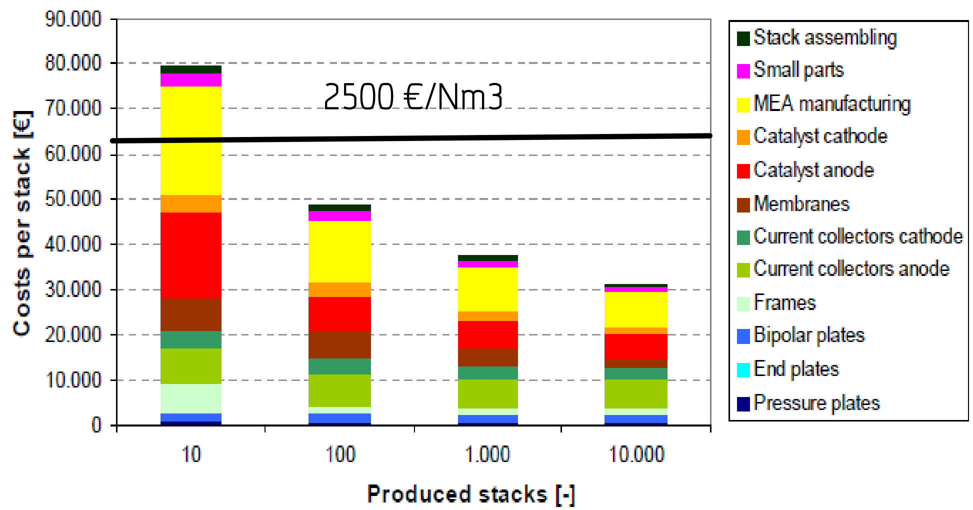
- Stack design for high pressure operation established
  - New sealing concepts
  - Optimisation of pressure drop and thermal management
  - Passed gas/liquid pressure test of 40 bar.
  - Two 10 cell stacks constructed
- End plate optimisation
  - COMSOL Multiphysics model established
  - Endplate thickness and design optimised
  - Elastic and plastic deformation considered.



Cost break down – conventional vs. NEXPEL design

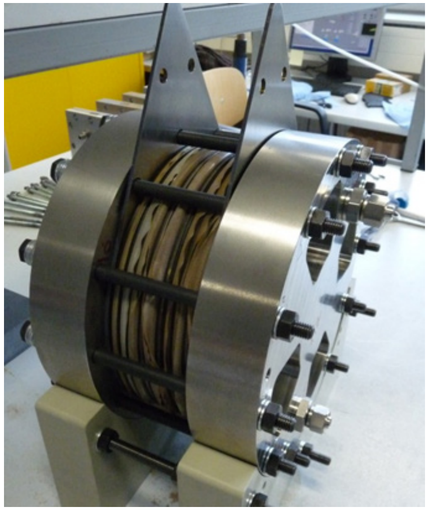
- Cost and market analysis
  - Materials cost based on offers from suppliers / internal cost calculations
  - Production prices based on offers from subcontractors / internal experiences
  - Annual production quantities from 1 – 1000 stacks analysed
  - Stack contributes to 50% of overall system costs
  - <u>NEXPEL stack can reach target costs with production volumes > 100 units.</u>





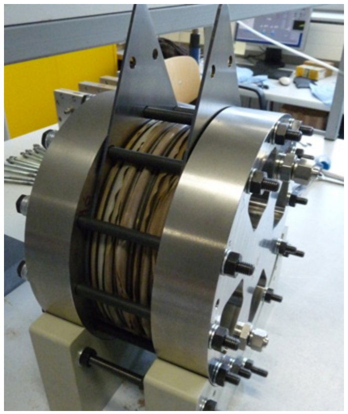
NEXPEL stack demonstration

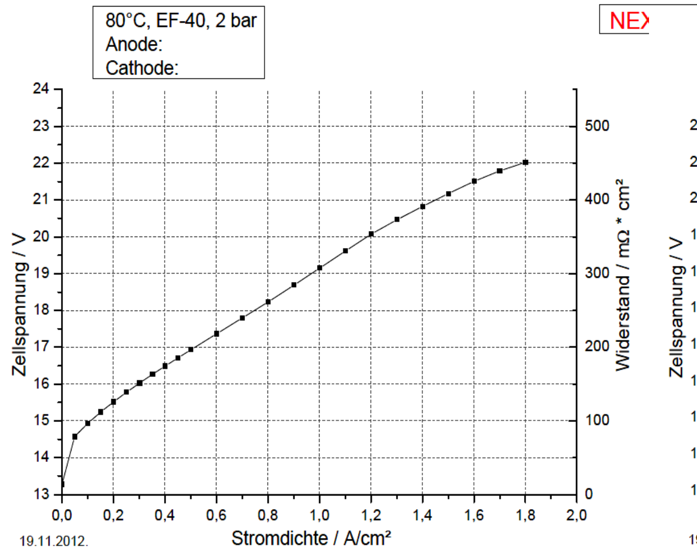
- Two 10 cell stacks built for demonstration
  - Stack 1: Standard EF40 CCMs, Tested at Statoil Energy Park, Norway
  - Stack 2: Ir/ATO CCMs, tested at Fraunhofer ISE, Germany

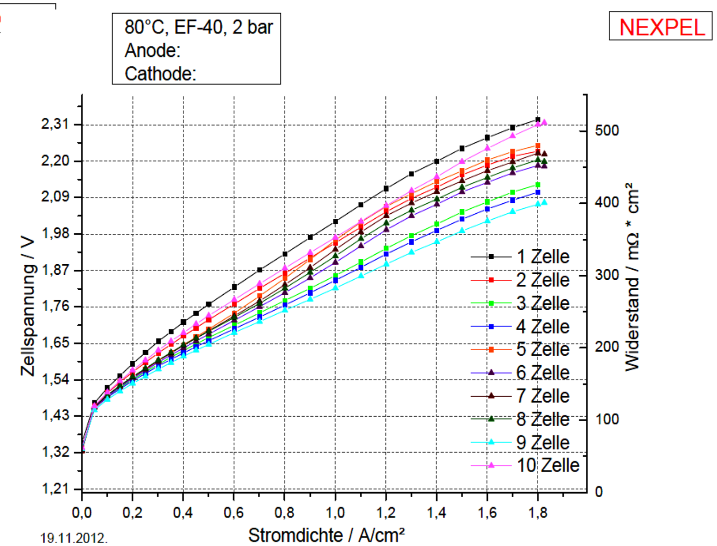


Stack performance results

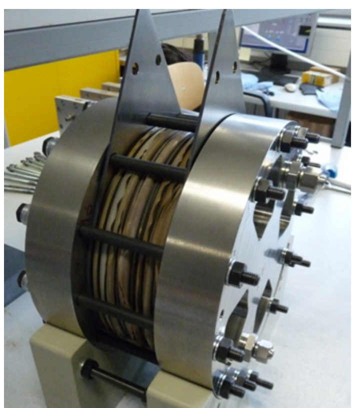
EF40 CCMs

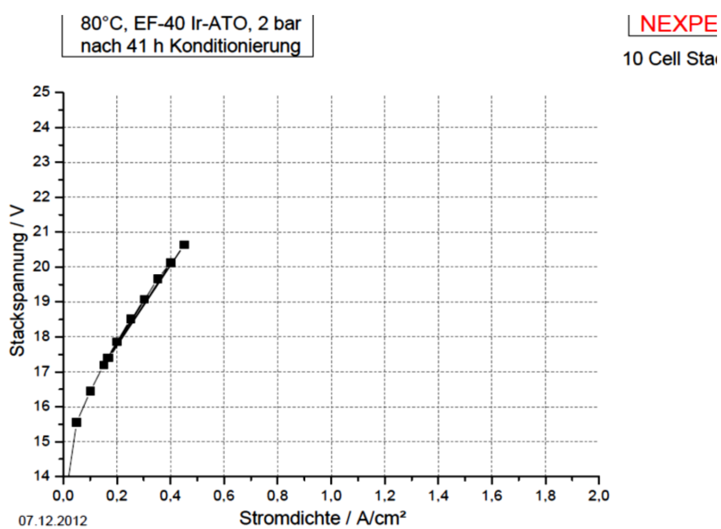


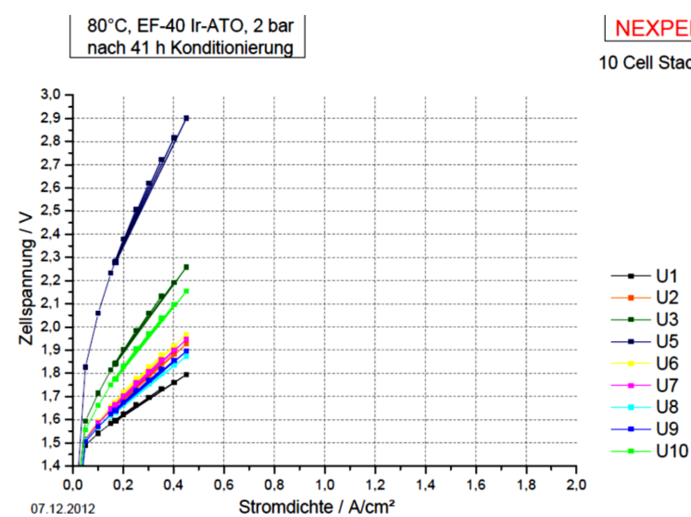




Ir/ATO







NEXPEL - Conclusions

- New low cost membranes
  - Good thermal stability and conductivity (~50% of Nafion)
  - Brittle, needs reinforcement
  - Coating of catalysts is a challenge
- Highly active supported catalysts
  - Ir nanoparticles on oxide supports show higher mass activity,
  - The low conductivity of the catalyst is a challenge (MEA fabrication)
- Stack design
  - Low cost design successful (reaches cost target at 100 units)
  - Gas and water tight at pressures up to 40 bar
  - Can be assembled several times
  - Long term stability not evaluated

The next step; NOVEL

NOVEL

- Continuation of novel materials development
  - New catalysts and catalyst supports
  - Radiation grafted membranes
  - Coatings of bipolar plates and current collectors
- System design and optimization
- Increased understanding of lifetime and degradation issues in PEM electrolysers

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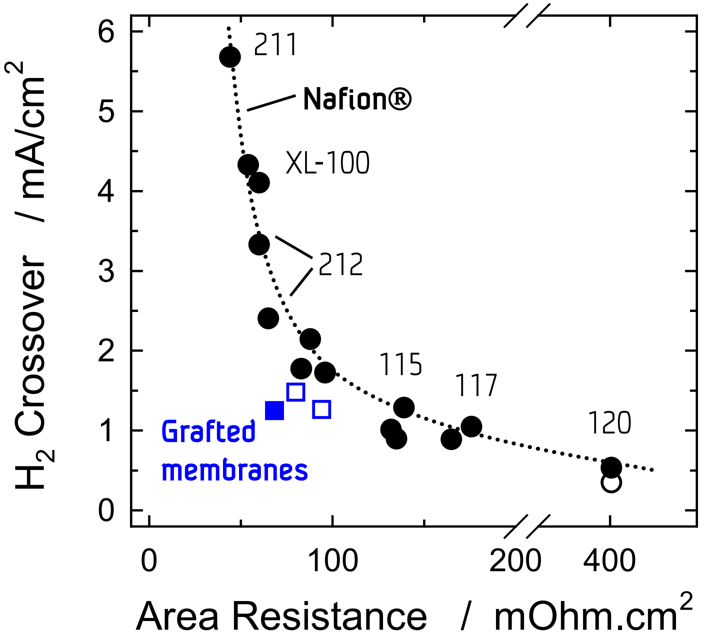
NOVEL, Preliminary results

- New oxygen evolution catalyst developed with 75% higher electronic conductivity
  - 20wt% $Ir/Nb_xTi_{(1-x)}O_2$
  - Similar activity to Ir/ATO
- Irradiation grafted membranes with higher "figure of merit"
  - ETFE Base polymer with Acrylonitrile as Co-monomer

Figure of merit:

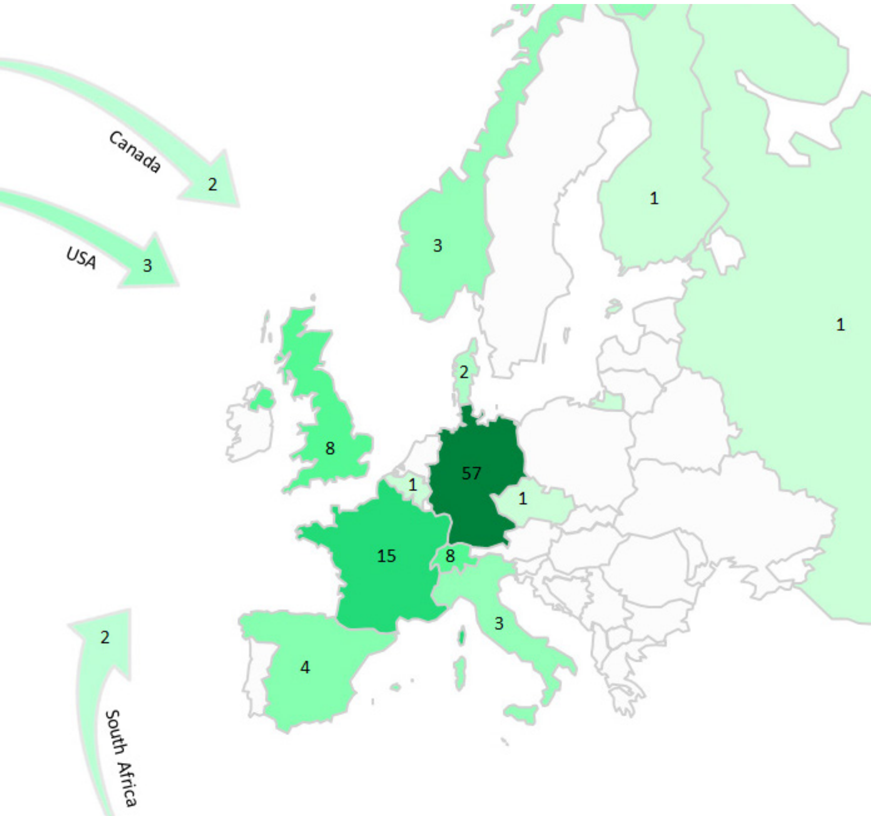
Nafion®: 5.8 ± 1.3
Grafted membranes: 9.5 ± 1.9

$30cm^2$ cell, 80°C, H_2/O_2 stoich. 1.5/1.5, full humidification, 2.5 bar_a



NOVEL Preliminary results

- 1st international Workshop on Durability and Degradation Issues in PEM Electrolysis Cells
  - Hosted by Fraunhofer ISE
  - 111 Participants from 15 countries
  - Presentations available on NOVEL web site.



Thank you for your attention

NEXPEL

www.nexpel.eu

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