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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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$^3$h$^{-1}$, 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

Partners:
- University of Reading
- Fumatech
- Fraunhofer ISE
- SINTEF
- CEA
- Helion
NEXPEL – Main results and achievements

WP2 New membrane materials

WP3 New catalysts

WP4 Improved MEAs

WP5&6 Novel stack design and new construction materials

WP7 Improved DC-DC converter

WP7 Integration with RES

NEXPEL - Next-Generation PEM Electrolyser for Sustainable Hydrogen Production
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 m² 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)

![Graph showing Log I vs. E (V)](image_url)
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 (3µVh\(^{-1}\) degradation)

T= 70 °C, current density 0.5 A/cm\(^2\)
Membrane: reinforced PFSA 240 µm, type EF-40
Anode: 25% Ir/ATO 0.8 mg/cm\(^2\)
Cathode: Pt HS4100 0.45 mg/cm\(^2\)
Technical highlights – MEA/CCM development

• State of the art CCMs
  – Fumatech reinforced membranes
  – High gas purity (<0.5% H₂ in O₂) 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
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
  - NEXPEL stack can reach target costs with production volumes > 100 units.

[Graph showing cost per stack vs. produced stacks]

2500 €/Nm³

2500 €/Nm³
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 - Next-Generation PEM Electrolyser for Sustainable Hydrogen Production
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

- 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 electrolyzers
NOVEL, Preliminary results

- New oxygen evolution catalyst developed with 75% higher electronic conductivity
  - 20wt% Ir/NbxTi_{(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®: \(5.8 \pm 1.3\)  
Grafted membranes: \(9.5 \pm 1.9\)
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

The research leading to these results has received funding from the Fuel Cells and Hydrogen Joint Undertaking under grant agreements n°245262 - NEXPEL & n° 303484 - NOVEL
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