Advanced Multi-Fuel Reform for Fuel CELL CHP Systems

ReforCELL

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Summary

REforCELL aims at developing a high efficient heat and power cogeneration system based on:

i) design, construction and testing of an advanced reformer for pure hydrogen production with optimization of all the components of the reformer (catalyst, membranes, heat management etc) and

ii) the design and optimization of all the components for the connection of the membrane reformer to the fuel cell stack.

The main idea of REforCELL is to develop a novel more efficient and cheaper multi-fuel membrane reformer for pure hydrogen production in order to intensify the process of hydrogen production through the integration of reforming and purification in one single unit.
Layout of PEM m-CHP unit using traditional reforming (TR) for fuel processing

Layout of PEM m-CHP unit using membrane reformer (MR) for fuel processing
This research is carried out by a multidisciplinary and complementary team consisting of 11 top level European organisations from 6 countries: 6 Research Institutes and Universities working together with representative 5 top industries in different sectors (from hydrogen production to catalyst developments to boilers etc.).

Partnership

- TECNALIA, Spain
- TU/e, Netherlands
- CEA, France
- POLIMI, Italy
- SINTEF, Norway
- ICI, Italy
- HYGEAR, Netherlands
- SOPRANO, France
- HYBRID, Netherlands
- QUANTIS, Switzerland
- JRC, Netherlands

Consortium
Project objectives

- Development of novel catalysts
- Development of high performance Pd-based membranes
- Novel catalytic membrane reactors
- Prototype reactor testing and validation
- BoP optimization
- Novel micro-CHP system
- Modelling and simulation of both reactors and complete system
- Life Cycle Analysis, industrial risk assessment study

Work Structure

WP2. Industrial specifications of FC micro-CHP [ICI]

WP3. Catalysts development [HYBRID]
- Catalyst preparation
- Catalyst characterisation
- Activity test

WP4. Membrane development [SINTEF]
- Material for membranes
- Membranes development and characterization

WP5. Lab scale reactors [TU/e]
- Integration in micro-structured membrane reactors
- Testing and model validation

WP6. Novel ATR prototype [HYGEAR]
- Design of Pilot
- Set up and testing
- Process design & Simulation

WP7. Integration and validation of micro-CHP system [ICI]
- Fuel Cell stack selection
- FC - CHP system optimization
- Integration and testing

WP1. Management [TECNALIA]

WP8. LCA and Safety analysis [QUANTIS]

WP9. Dissemination and exploitation [HYGEAR]
Partnership Synergies

LCA and risk assessment
- QUANTIS
- HYGEAR
- ICI

Modelling and simulation
- TU/e
- POLIMI
- HYGEAR

Catalyst Development
- HYGEAR
- ICI
- SOPRANO
- TECNALIA
- CEA

Membrane Development
- HYGEAR
- ICI
- SOPRANO
- TECNALIA
- CEA

Industrial Specifications
- HYGEAR
- ICI
- SOPRANO
- TECNALIA
- CEA

Lab scale Reactors
- TU/e
- POLIMI
- HYGEAR
- ICI
- SOPRANO
- TECNALIA
- CEA
- JRC

Prototype Reactor
- Proof of principle
- Proof of concept

Integration and testing
- CEA
- POLIMI
- ICI
- SOPRANO
- TECNALIA
- CEA
- JRC

Catalytic Materials

- Selection of commercially available catalyst as benchmark
- Development of novel catalysts for ATR
- Characterization of catalysts

Carbon formation on commercial and new catalyst

Experimental results and modeling (only valid above 600 °C)
Membranes Development

- Selection of ceramic and metallic porous material for membrane supports
- Development of ceramic interdiffusion layer for metallic support
- Development and optimization of Pd-based membranes for H₂ separation
- Development and optimization of non-Pd based for hydrogen separation
- Membrane characterization under realistic reforming conditions in lab-scale units prior to application of the optimal membranes in the pilot prototypes
- Manufacturing of dense-metal membranes for integration into prototype unit
- Analysis of production costs and scale up of the membrane production technology unit

TECNALIA is developing two types of Pd-Ag supported membranes:

A) Ceramic supported thin Pd-Ag membranes (14-15 cm long):
   - Support: Asymmetric alumina tubular support (10.3 mm OD) with 110 nm pore size ZrO₂ top layer provided by Rauschert Kloster Veilsdorf.
   - Deposition of ~4 microns thick Pd-Ag layer by Electroless plating.
   - Sealing by graphite gaskets carried out by TU/e

B) Metallic supported thin Pd-Ag membranes (13-14 cm long):
   - Support: Hastelloy X tubular support (9.5 mm OD) provided by Mott Corp.
   - Development of interdiffusion barrier layers (YSZ-Al₂O₃) using different techniques (atmospheric plasma spraying, wet deposition techniques…). Work still ongoing.
   - Deposition of ~4 microns thick Pd-Ag layer by Electroless plating.

Up-scaling of the membranes (25-30 cm long) is ongoing.
Membranes Development

- SINTEF has improved the pressure and temperature stability of Pd-membranes integrated into micro-channel reactors.
  - Porous stainless steel permeate support increases the temperature stability to 15 bars at 450°C using a 10 micron thick Pd-alloy.
  - Two different intermetal diffusion barrier layers, YSZ and TiN, have been deposited using reactive magnetron sputtering and an increase in operating temperature have been obtained. Work is ongoing.

- Up-scaling of the micro-channel reactor is ongoing

Lab Scale ATR-CMR fuel reforming

- Selection of ATR-CMR components: catalysts, membranes and supports, and sealing based.
- Integration of these elements in lab scale reactors specifically designed for ATR.
- Validation of the lab scale reactors performances and identification of the best design for prototype pilot in WP6
Lab Scale ATR-CMR fuel reforming

Figure 1 Lab scale FBMR, developed by TU/e

Typical results of ATR at 600°C

Lab Scale ATR-CMR fuel reforming

Membrane bundle ready for tests

CO effect at 600°C and 2.0 bar

Hydrogen separation tests
Pilot Scale ATR reactor

- Design of the pilot scale ATR reactor
- Setup of ATR including controls
- Factory Acceptance Test of ATR
- Test and validation of ATR pilot scale prototype.
- Process design and simulation
- Assessment of potentials & markets

Integration & Validation in CHP-System

- Selection and test of fuel cell stack: definition of a PEMFC stack adapted to the micro-CHP system,
- Optimization of the fuel cell CHP focusing both on technical and economic point of view (example of optimization parameters: feed pressure, permeate side configuration, S/C ratio, etc.)
- Manufacturing and testing of a PEMFC micro-CHP system
Life Cycle Assessment and Safety Issues

Global environmental assessment of the new technologies:

- Environmental Life Cycle Assessment analysis of the CMR-CHP system.
- Identification and evaluation of key safety parameters and risk analysis.
- Proposal of recommendations for the safe operation of the CMR-CHP technology.

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Thank you for your attention

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