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ZEOCELL

NANOSTRUCTURED ELECTROLYTE MEMBRANES BASED ON POLYMER-IONIC LIQUIDS-ZEOLITE COMPOSITES FOR HIGH TEMPERATURE PEM FUEL CELL

(Project Nº: 209481)

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1. Project and Partnership Description

- 1st Call Cooperation Programme ENERGY.2007.1.1.1: Basic research for materials and processes for Polymer Electrolyte Membrane Fuel Cells (PEMFC)
- Starting date: 1st January 2008. Duration: 36 months.
- Collaborative project for small or medium scale focused project .
- EU Budget : 1.917 k€, 7 beneficiaries

INA	CIDETEC	UTWENTE	FORTH-ICE/HT	CR FIAT	SOLVIONIC	CEGASA
Zeolite membranes Nanostructured materials	Polymer electrolyte membranes MEAs Fuel Cells	PBI / PEEK Polymeric Membranes	Microporous materials Modelling	Technologies on materials fabrication	Ionic liquids	New Business line activity in Fuel Cells specially for portable and residential applications

1. Project Goals

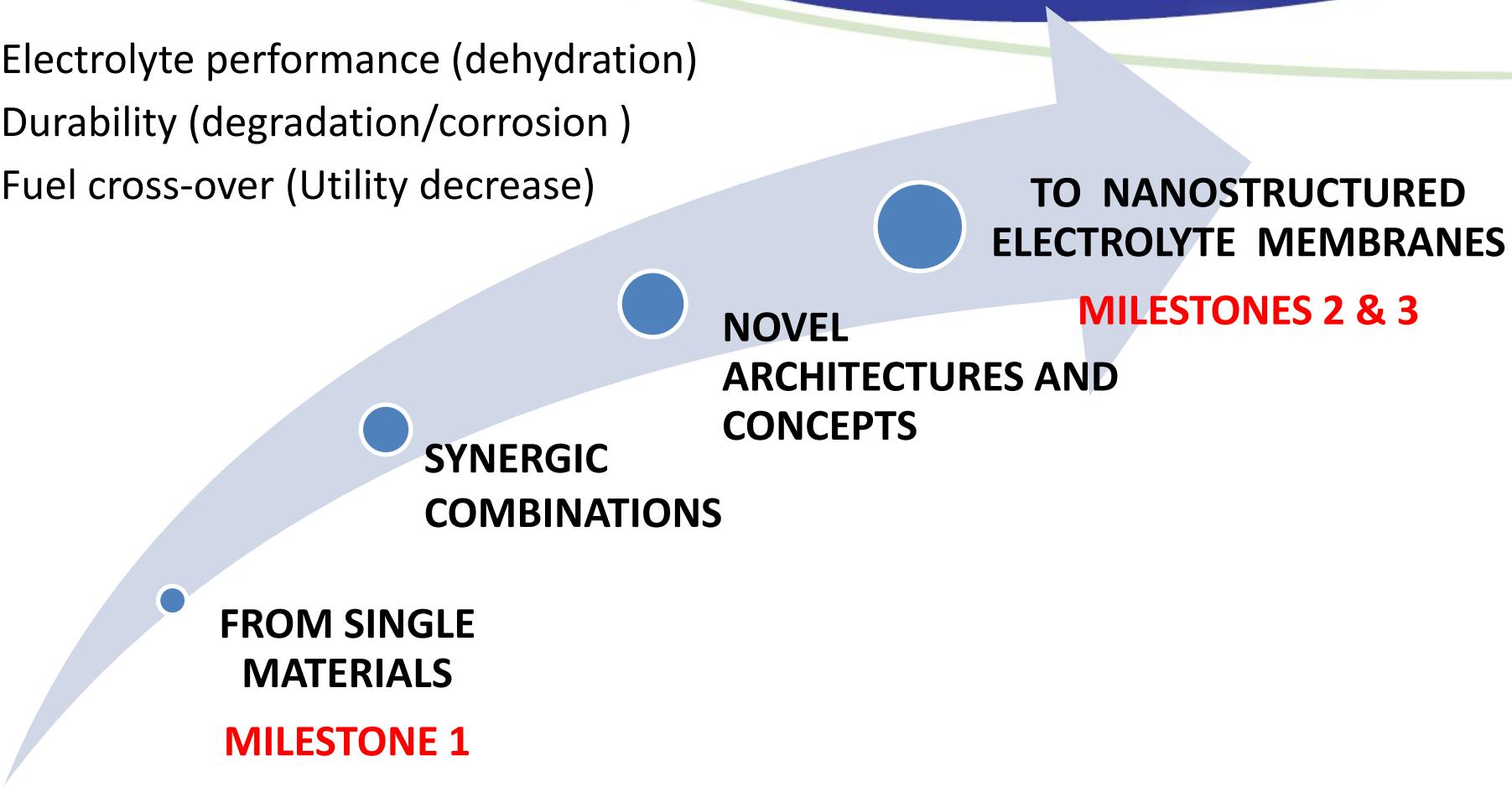
- ZEOCELL GOAL: DEVELOPMENT OF NANOSTRUCTURED ELECTROLYTE MEMBRANES FOR HIGH TEMPERATURE PEMFCs

- TECHNICAL TARGETS
  - ✓ High ionic conductivity (100 mS/cm at 150ºC vs. 100 mS/cm exhibited by Nafion® at 80ºC),
  - ✓ Low fuel cross over (five times lower than Nafion®)
  - ✓ Suitability for operating at temperatures between 130-200ºC (the membrane materials are conceived to exhibit mechanical, thermal and chemical stability up to 200ºC)
  - ✓ Durable (<1% of performance degradation during first 1000 hours working)
  - ✓ Reduced manufacturing costs (<400 EUR/m2)

A BASIC RESEARCH PROJECT ON MULTIFUNCTIONAL MATERIALS AND PROCESSES

Project Approach

- ❖Electrolyte performance (dehydration)
- ❖Durability (degradation/corrosion)
- ❖Fuel cross-over (Utility decrease)

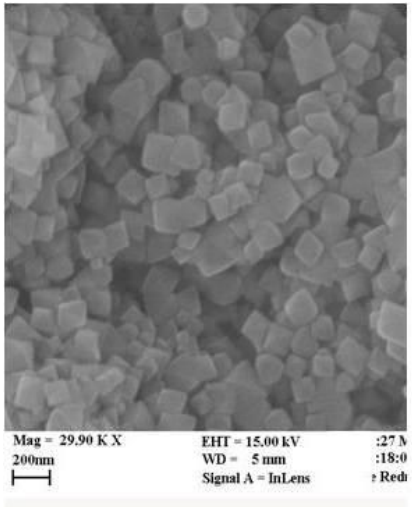


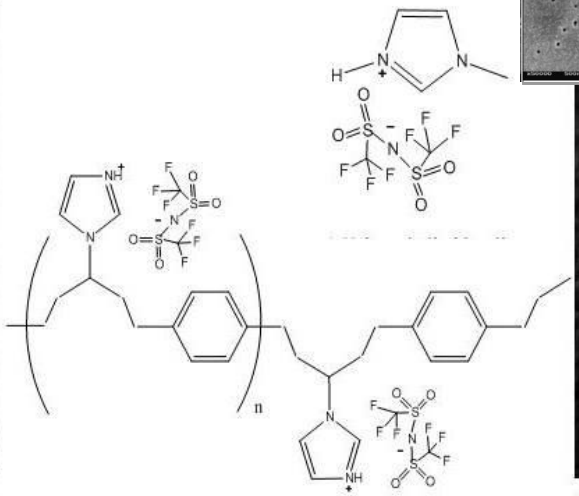
1. Project Achievements: Milestones

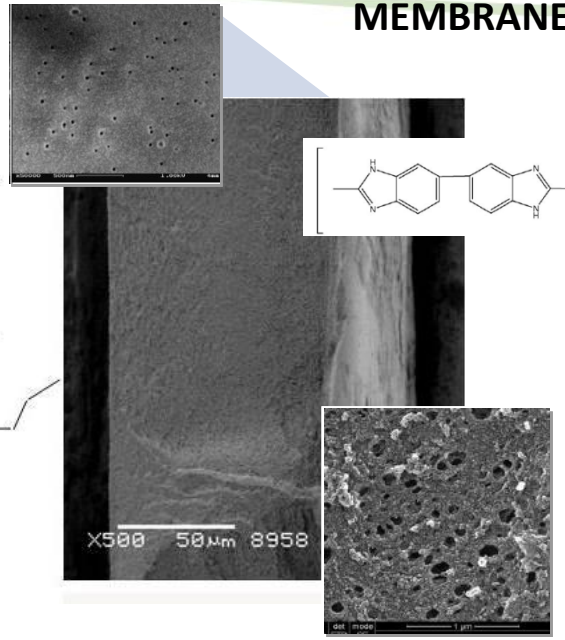
MICROPOROUS ZEOLITES AND RELATED

PROTIC IONIC LIQUIDS

POROUS PBI BASED MEMBRANES

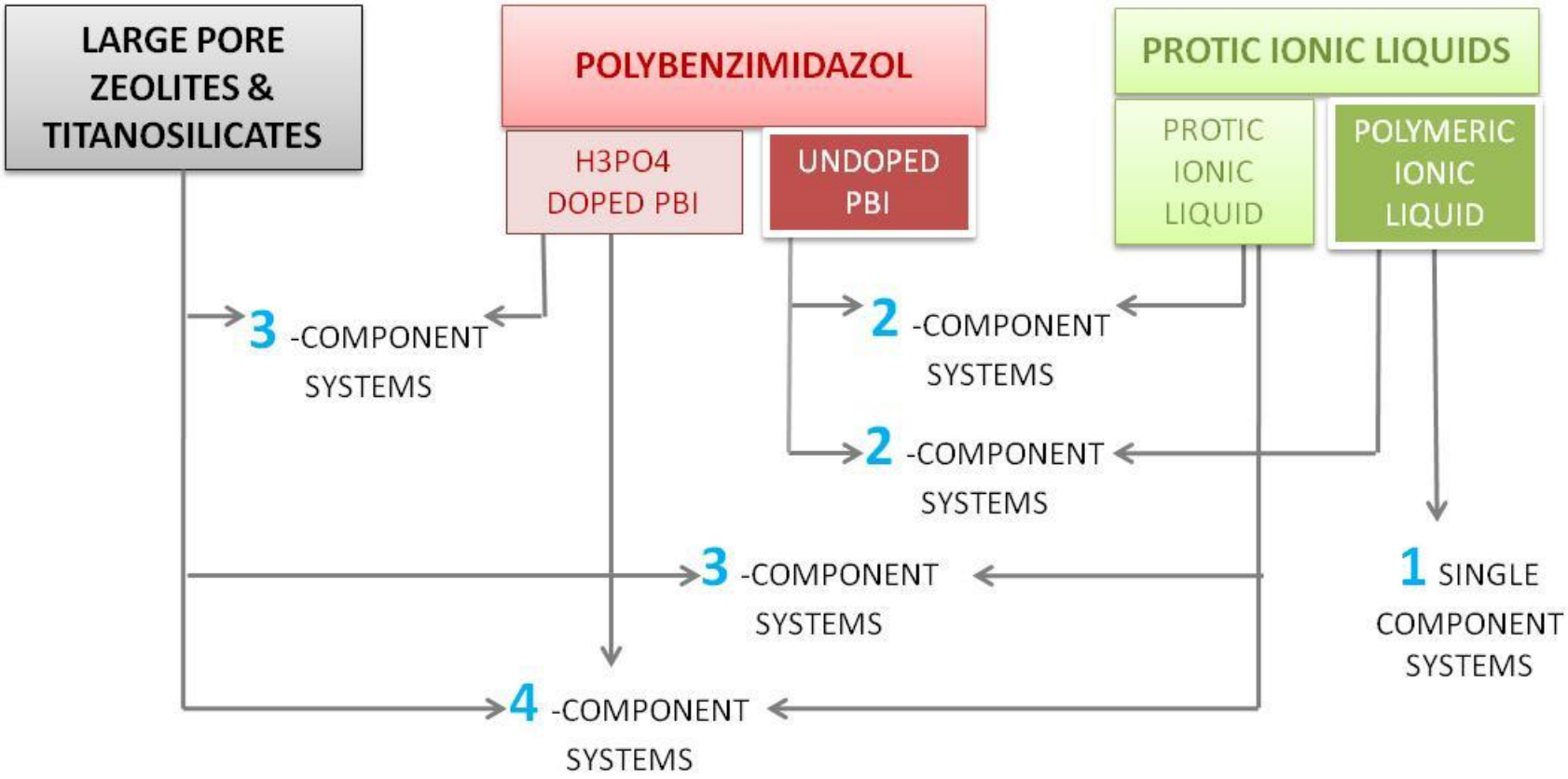






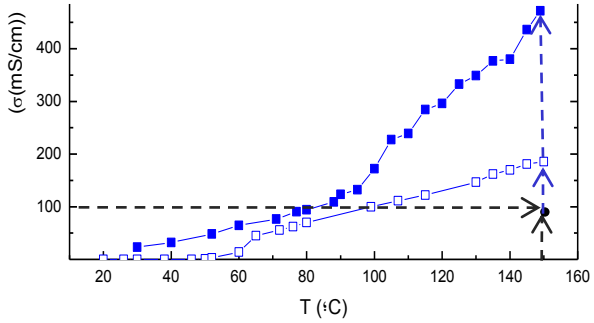
- **FROM SINGLE MATERIALS : MILESTONE 1**
  - ❖Proton Conductivity
  - ❖Textural and surface properties
  - ❖ Chemical and Thermal Resistance
  - ❖Manufacturing Costs

1. Project Approach



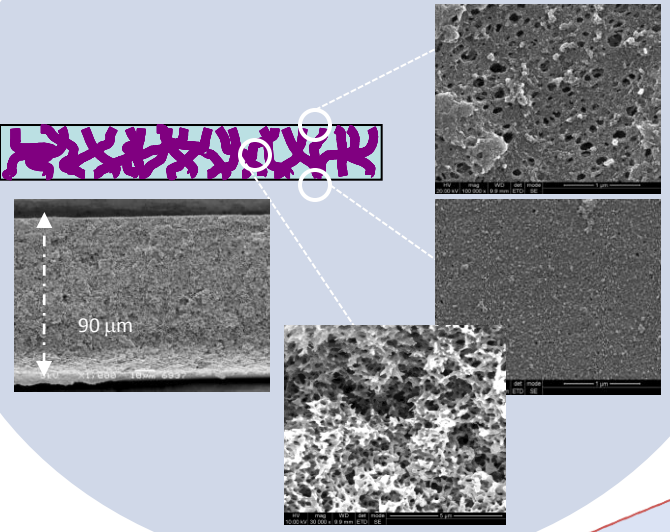
- **SYNERGIC COMBINATIONS**

❖Conduction Performance (T, RH)



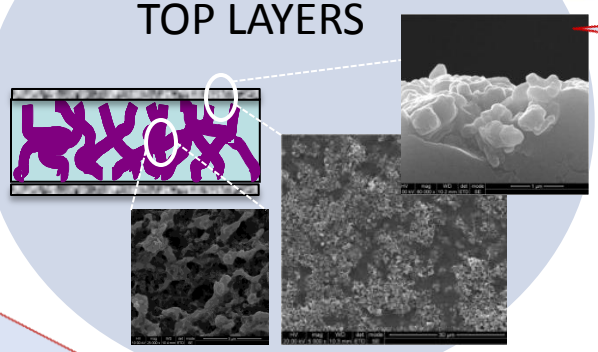
1. Project Approach

RANDOMLY <u>POROUS</u> PBI



<u>MICROPOROUS</u>

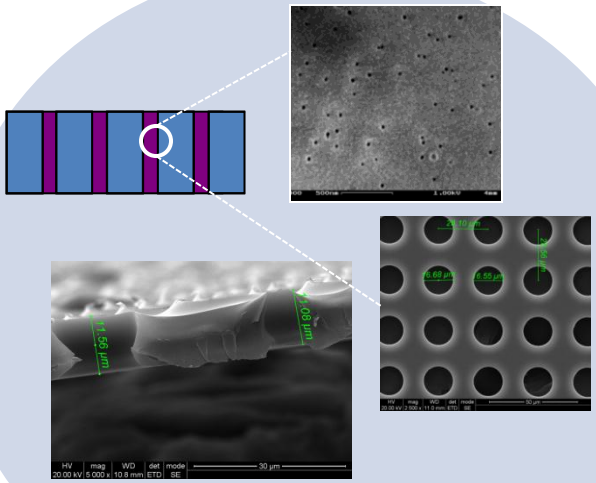
TOP LAYERS



2. MEAs FROM CCM APPROACH

NOVEL ARCHITECTURES AND MEMBRANE CONCEPTS:

1. SUPPORTED PROTIC IONIC LIQUID MEMBRANES ON POROUS PBI MATRIXES



STRAIGHT <u>POROUS</u> PBI

1. Project Achievements: Milestones 2 &·3

LARGE PORE ZEOLITES & TITANOSILICATES

POLYBENZIMIDAZOL

H3PO4 DOPED PBI

UNDOPED PBI

PROTIC IONIC LIQUIDS

PROTIC IONIC LIQUID

POLYMERIC IONIC LIQUID

3 COMPONENT SYSTEMS

PBI+H_3PO_4+ETS-10

2 COMPONENT SYSTEMS

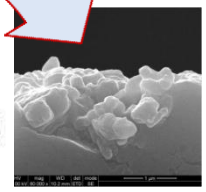
PBI+ImSF2808c

1 SINGLE COMPONENT SYSTEMS

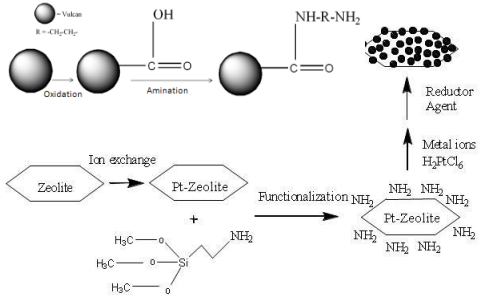
ImSF2808c

4 COMPONENT SYSTEMS

PBI+H_3PO_4+Im008b+ETS-10

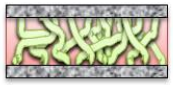


3-LAYER INTEGRATED MEAs



NANOSTRUCTURED ELECTROLYTE MEMBRANE DEVELOPMENT, MEA ASSEMBLY AND VALIDATION IN SINGLE CELL (H_2/CH_3OH)

1. Technical Accomplishements

Formulation	Membrane Architecture	Perfomance at 150ºC		Transport Selectivity		Durability Cost
		Conductivity (cross/*surface)	Fuel Cross Over (H_2/methanol Permeability)	H^+/H_2 transport	% Improv.	
1 SINGLE COMPONENT SYSTEMS ImSF2808c		350 mS/cm //y_{H20}= 0 400 mS/cm // y_{H20}= 0.05	Methanol ☹ H_2 1.4 10^{-7} mol/cm.s.bar	2.9 10^3 kS.s.bar/mol	10^2 baseline	1000h //200ºC 325 mS/cm 184 €/m^2 //10^4 m^2/year 13 €/m^2 //2 10^6 m^2/year
2 COMPONENT SYSTEMS PBI+ImSF2808c		260 mS/cm // y_{H20}= 0.05	Methanol 1.6 10^{-9} mol/cm.s.bar H_2 1.1 10^{-7} mol/cm.s.bar	2.4 10^3 kS.s.bar/mol	10^2 baseline	1000h //200ºC 260 mS/cm 253 €/m^2 //10^4 m^2/year 18 €/m^2 //2 10^6 m^2/year
3 COMPONENT SYSTEMS PBI+H_3PO_4+filler		73* mS/cm // y_{H20}= 0 (ETS-10) 223* mS/cm // y_{H20}= 0 (NaY-Im008b)	Methanol 7.2 10^{-10} mol/cm.s.bar	n.a.	n.a.	n.a. 296 €/m^2 //10^4 m^2/year 22 €/m^2 //2 10^6 m^2/year
4 COMPONENT SYSTEMS PBI+H_3PO_4+Im008b+ETS-10		49 mS/cm //y_{H20}= 0 55 mS/cm // y_{H20}= 0.05 100* mS/cm // y_{H20}= 0	Methanol 6.8 10^{-10} mol/cm.s.bar H_2 8.5 10^{-10} mol/cm.s.bar	6.5 10^4 kS.s.bar/mol	10^3 baseline	500h //150ºC 15 mS/cm 322 €/m^2 //10^4 m^2/year 23 €/m^2 //2 10^6 m^2/year
REFERENCE Dense PBI		1.3mS/cm //y_{H20}= 0.05 64.8*mS/cm // y_{H20}= 0	Methanol 9.2 10^{-11} mol/cm.s.bar H_2 6.2 10^{-8} mol/cm.s.bar	21 kS.s.bar/mol	Baseline	150h //150ºC 4.3 mS/cm 280 €/m^2 //10^4 m^2/year 60 €/m^2 //2 10^6 m^2/year

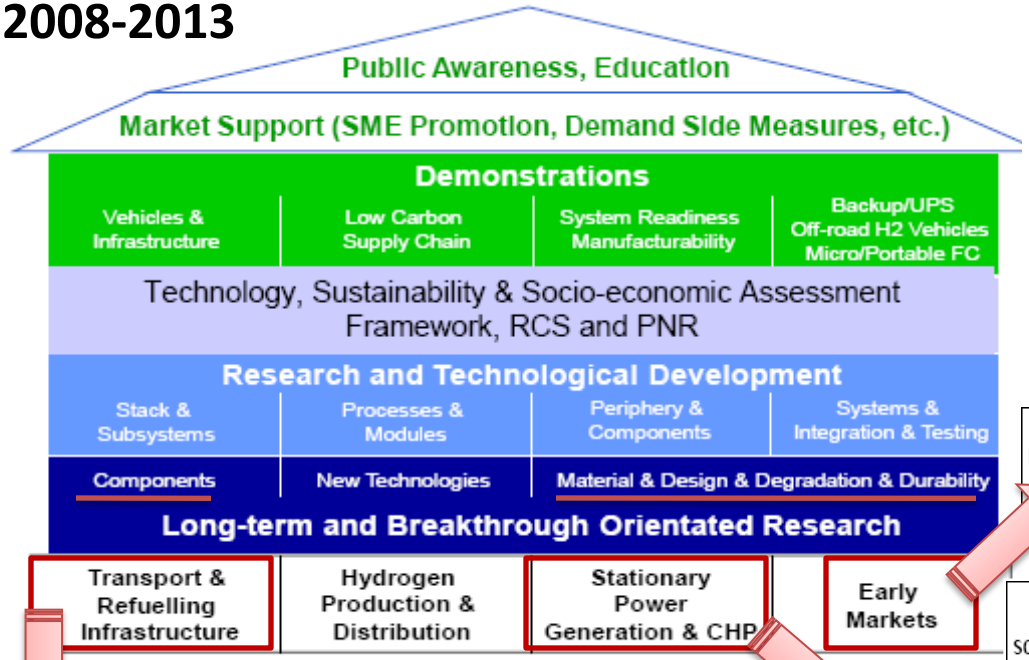
2. Correlation of Zeocell with MAIP

Priority Research Areas

Technological Development

Demonstration Topics

2008-2013



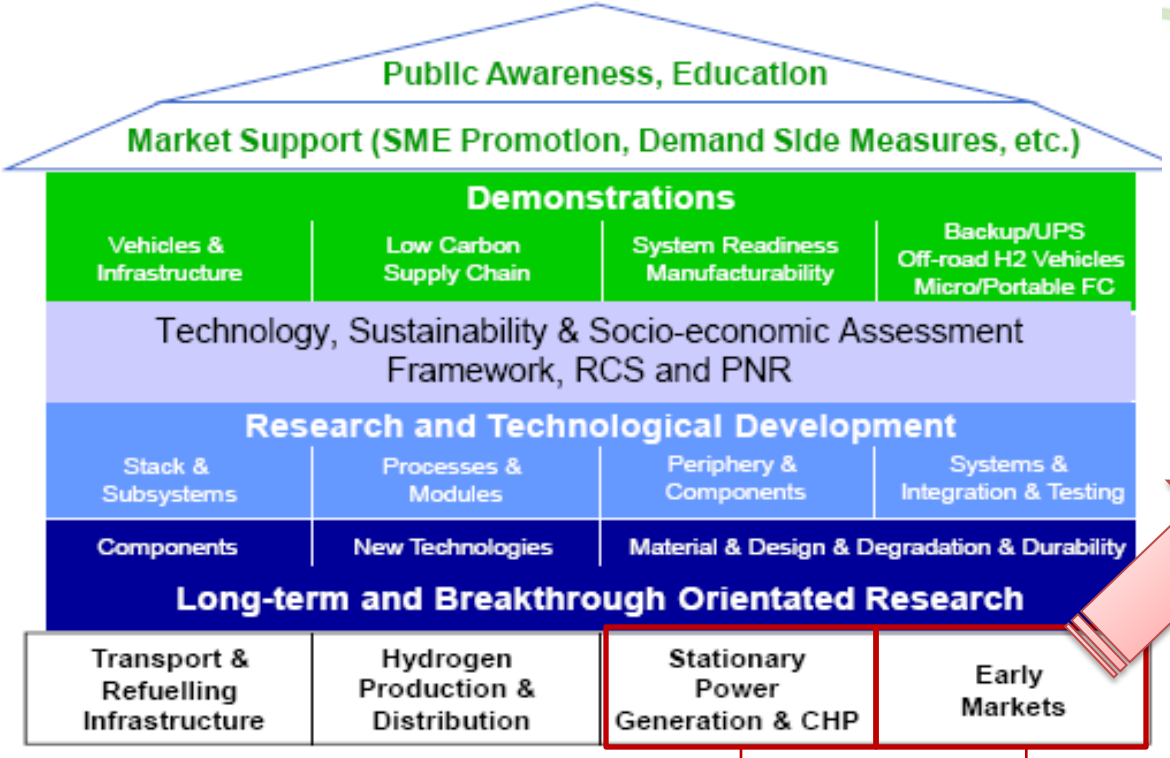
T05	New catalysts and membrane electrode assemblies (MEA)	BR RT	electrolyte membrane fuel cells- to further reduce the use of platinum in MEAs, increase performance and electro-chemical stability of the catalyst, identify potential, alternative low-cost catalysts observing suitable high quality manufacturing processes. Coordination with T02 required.
T06	New membranes including for higher temperatures	BR RT	Research and development of membranes for polymer electrolyte membrane fuel cells to reduce humidification requirements, improve mechanical stability and increase operating temperature under observation of suitable high quality manufacturing processes, thereby enhancing robustness and life time to allow for further simplification of system architectures. Coordination with T02 required.

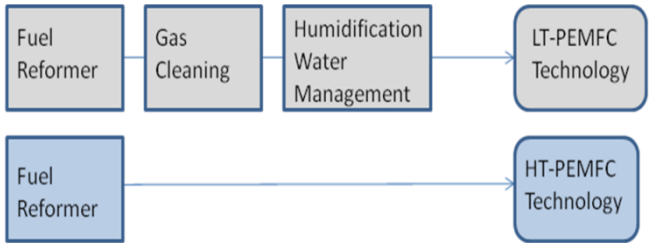
E08	Manufacturing, assembly and testing for micro FCs	RT	Research and development on high quality production methods and processes for micro fuel cells in order to develop and implement reliable production methods and appropriate quality standards.

S02	Materials development for cells, stacks and balance of plant (BoP)	BR RT	Development of materials to improve performance in terms of higher lifetime and lower degradation as well as mechanical, thermal and electro-chemical stability of single cells stacks and BoP components including consideration of high quality manufacturability. Coordination with S01 required.
S03	Next generation stack and cell designs	BR RT	Long-term and break-through oriented research on novel architectures for cell and stack design to provide step change improvements over existing technology in terms of performance, endurance, robustness and cost targets for relevant applications.
S05	Improvement of components and their interaction	RT	Research and development to improve a.) The performance of all individual components of the fuel cell system including FC-unit, reformer, heat exchangers, fuel management and power electronics and b.) The understanding and optimization of interaction between components and mature stacks to meet application relevant functional performance criteria, including durability, target cost and developing the supply chain.

2. Exploitation Plan for Zeocell HT-PEMFCs

MAIP Structure





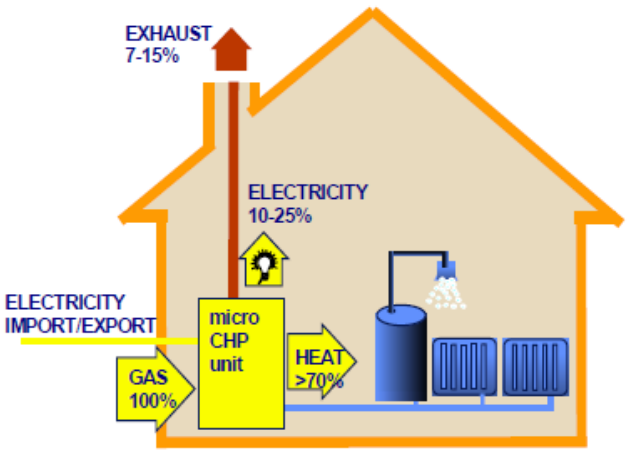
Potential Stationary Markets

- **Back up Power (UPS)**
  - **Servers**
  - **Hospitals,**
  - **Telecommunications**
- **Combined Heat & Power (CHP)**
- **Auxiliary Power Units (APU)**

Targets 2015

- **Volume**
  - **1000 UPS/back-up power**
- **Cost & Technology**
  - **4000 - 5000 € /kW for micro CHP**
  - **1500-2500 € /kW for industrial/commercial units**

2. Case Study for Zeocell HT-PEMFCs: Micro-scale Residential CHP market



CHP Market Assesment; 10% Share of the Market

Application Micro-CHP	Units accumulated (2015)	Units accumulated (2020)	Units accumulated (2025)
Total Units	3.600.000	7.200.000	24.000.000
HT-PEMFC Units	360.000	720.000	2.400.000

2 kW Stack 3-Component Zeocell Membranes

Annual Production rate	1 (Manual)	1000	80000	130000	500000
Total stack cost €/kW)	3530	637	230	191	134
BOP	2765	495	215	195	160
Total system cost (€)	9825	1769	674	578	429
Total system cost (€/kW)	4912	884	337	289	214

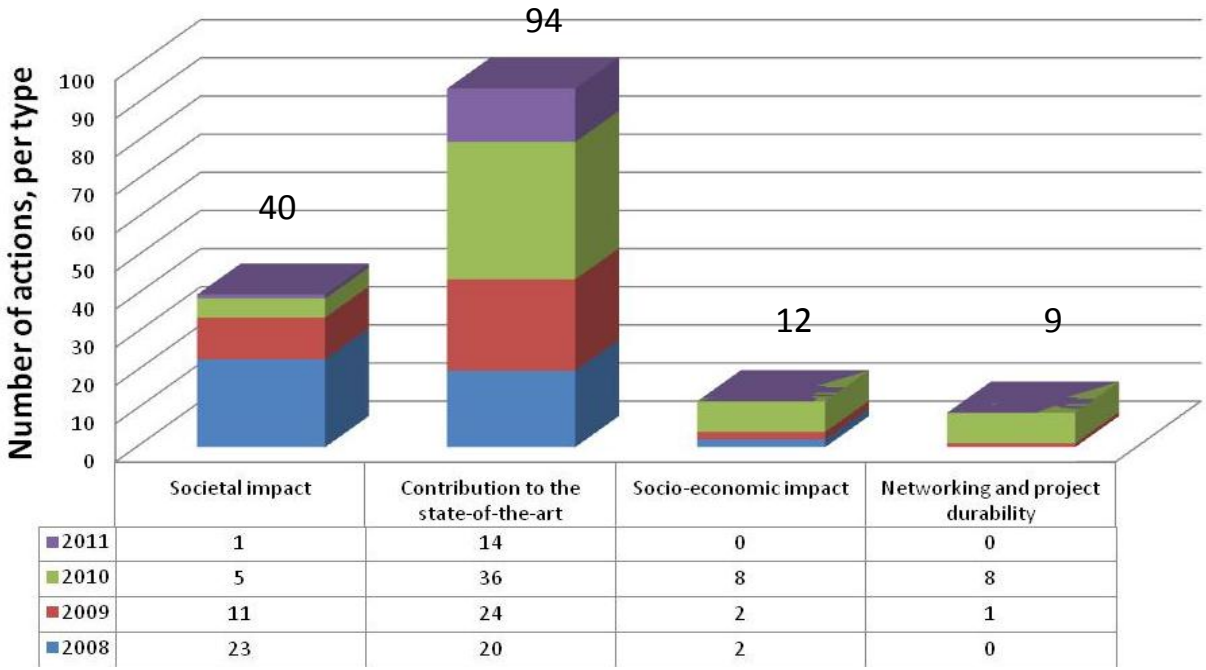
2020 EU Target: 500 €/kW

3. ZEOCELL Impact

ZEOCELL

Nanostructured electrolyte membranes based on polymer/ionic liquids/zeolite composites for high temperature PEMFCs

- INTRODUCTION
  - Project summary
  - Project scope
  - Project objectives
  - List of beneficiaries
- PROJECT MANAGEMENT
  - Contacts
  - Time-sheets
  - Amortisation of equipment
  - Participant Portal - SESAM - FORCE
- RESTRICTED AREA
  - Restricted area
- DISSEMINATION ACTIONS
  - Brochure
  - Poster
  - Publicity actions
  - Attendance to conferences, etc.
  - Publications and meeting commun.
  - Patent



	Societal impact	Contribution to the state-of-the-art	Socio-economic impact	Networking and project durability
2011	1	14	0	0
2010	5	36	8	8
2009	11	24	2	1
2008	23	20	2	0

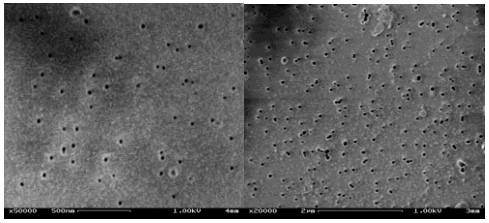
TYPE OF ACTION — TYPE OF IMPACT

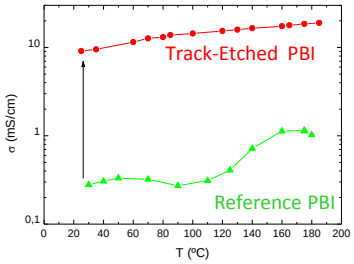
TYPE OF ACTION	TYPE OF IMPACT
Round tables, forums, workshops,publicity, education, etc.	Societal impact
Scientific conferences, direct dissemination, publications, meeting communications, presentations	Contribution to the state-of-the-art
Patents, stakeholders, contacts	Socio-economic impact
Project ideas, proposals submitted, new research lines, training	Networking and project durability

4. Technology Transfer / Collaborations: International level

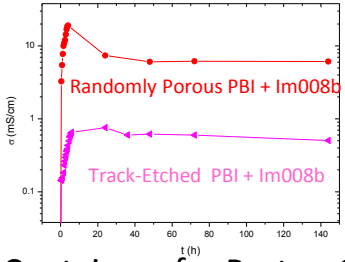
CRF-it4ip-INA

- Ion-track technology on PBI





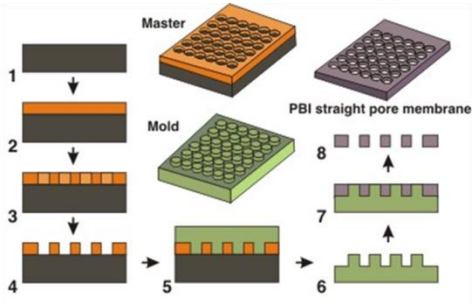
• Doped PBI for PEMFCs

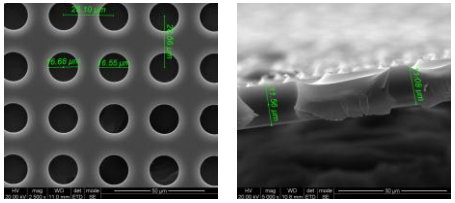


• Inert Containers for Proton Conductors

INA-I3A-CNM

- Micro-structured PBI films by Microtransfer Moulding Techniques





- Inert Containers for Proton Conductors
- Microstructured PBI for Lab on chip, Micro Total Analytical Systems, Flexible Structured Micro Reactors, Micro fuel cells.

4. Technology Transfer / Collaborations: National Level

CIDETEC-INA

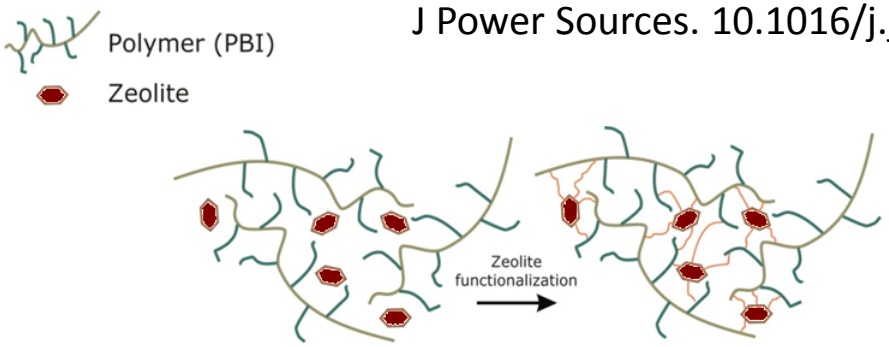
- MEAs Optimization for Zeocell Membranes:
  - Polymeric Ionic Liquid Based Membranes

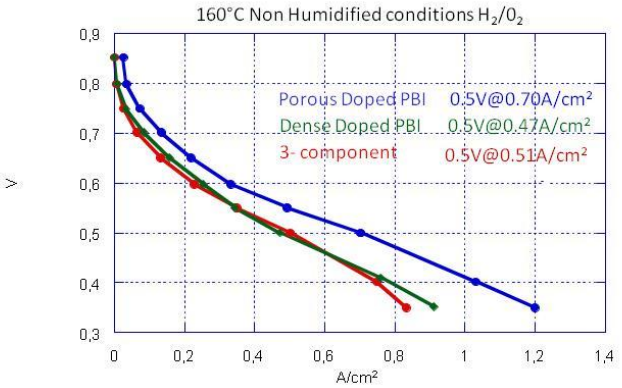
ImSF2808c

PBI+ImSF2808c

  - 3 component systems: Patent PCT/EP2010/064857; Priority date 05/10/2010

J Power Sources. 10.1016/j.jpowsour.2011.03.006

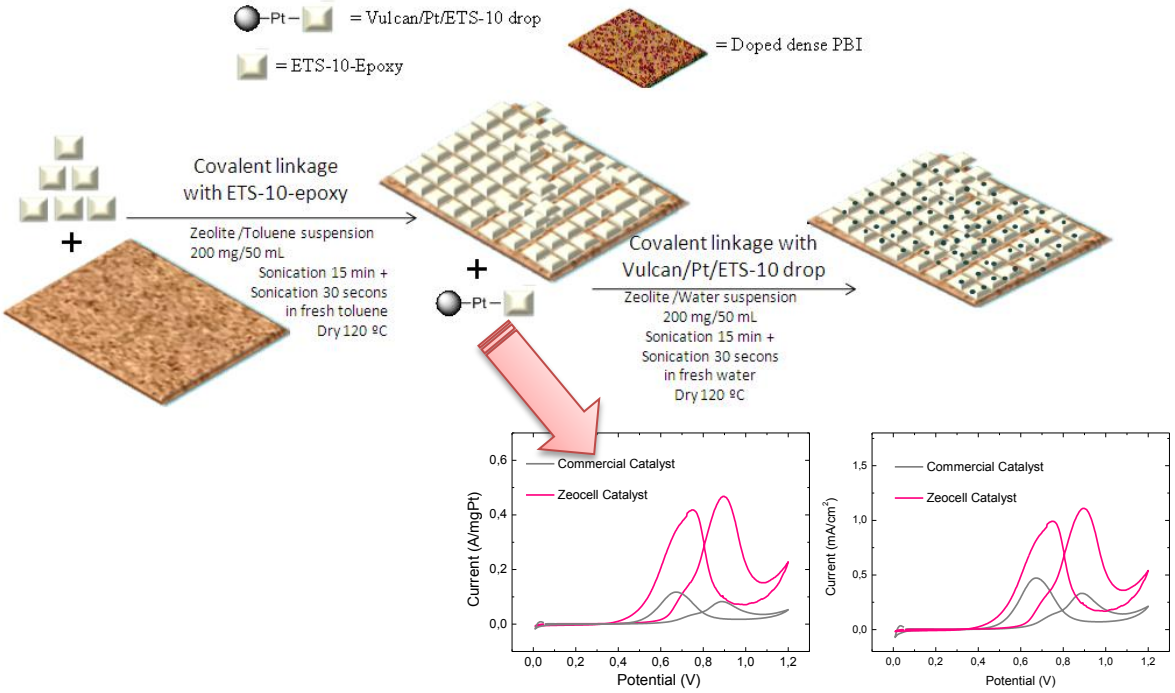




4. Technology Transfer / Collaborations: Regional Level

INA-I3A-LITEC

• Development of flexible SU8 and PBI microstructures with advanced functionalities for Separation and Reaction Applications



• Patterned MEA Prepared by Catalyst Coated Membranes for high temperature PEMFCs

• Flexible Supports for Catalytic MicroReactors able to operate up to 400ºC, extreme pH or oxidant-reducing conditions.

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