IDEAL-Cell
(FET-Energy)
(grant agreement No 213389)

Alain THOREL
ARMINES, France

IDEAL Cell
Innovative Dual mEmbrAne fueL Cell

Innovative dual membrane fuel cell (IDEAL-CELL)

Research area: ENERGY-2007-1.1-03 Innovative concepts for fuel cells

Start Date: 2008-01-01 - **Duration**: 48 months

Project Cost: 4.37 million euro - **Project Funding**: 3.31 million euro

•Consortium:

ARMINES *(**Paris**, France) [**Coordinator**, materials science, shaping, math. morphology]*
Université de Bourgogne *(**Dijon**, France) [reactivity, cathode material, charact.]*
CNR *(**Genova**, Italy) [electroch. testing, wet shaping processes, modeling, interconnect]*
DLR *(**Stuttgart**, Germany) [plasma spraying, kinetic modeling, testing]*
IEES-BAS *(**Sofia**, Bulgaria) [impedance spectroscopy, dissemination]*
AGH *(**Krakow**, Poland) [oxidation of interconnect, hydrothermal analyses]*
Naxagoras *(**Dijon**, France) [SME: microwave sintering of nanopowders]*
Visimbel *(**Stuttgart**, Germany) [SME: CFD calculations]*
Marion Technologies *(**Verniolle**, France) [SME: powders supplier]*

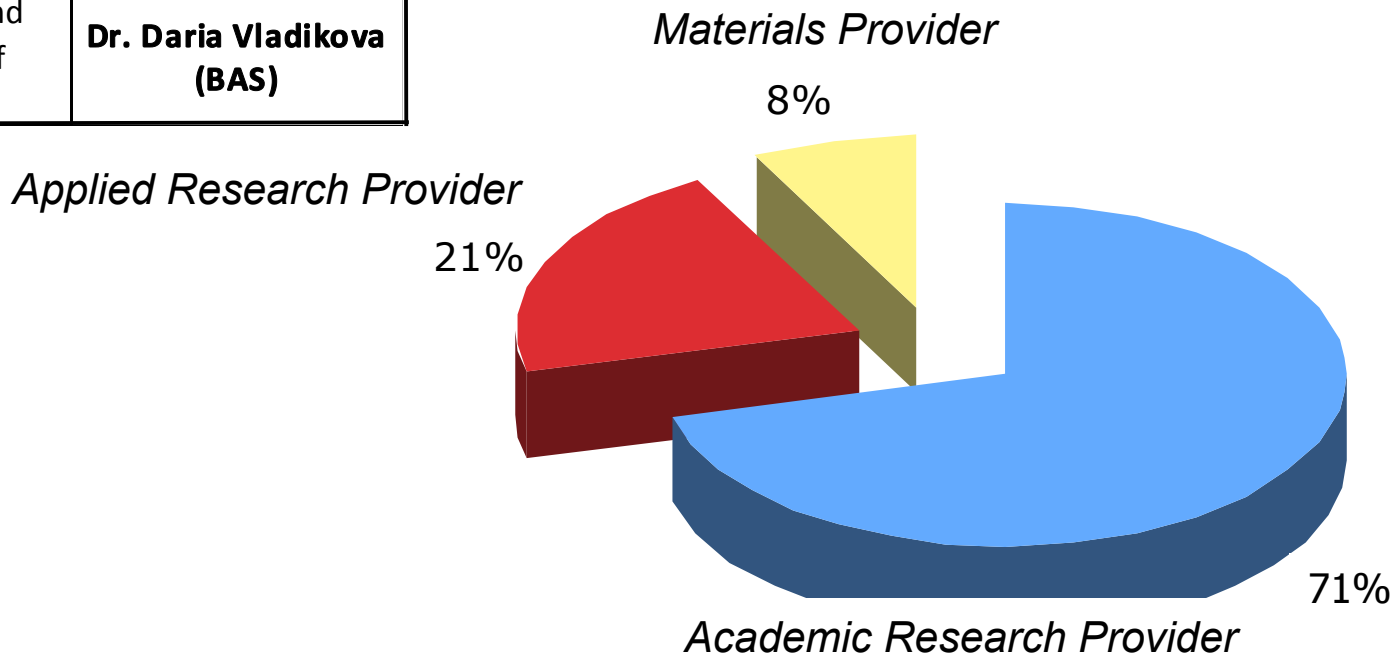
1. Project achievements

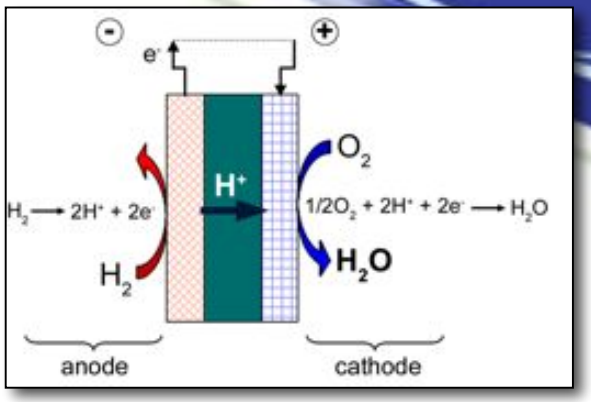
WP n°	WP titles	WP leaders
1	Management	**Dr. Alain Thorel (ARMINES)**
2	Oxygen electrode assembly development	**Dr. Gilles Caboche (UB)**
3	Proton electrode assembly development	**Dr. Alain Thorel (ARMINES)**
4	Dual cell realization	**Dr. Massimo Viviani (CNR)**
5	Dual cell optimization and integration	**Dr. Zeynep Ilhan (DLR)**
6	Dissemination and Management of knowledge	**Dr. Daria Vladikova (BAS)**

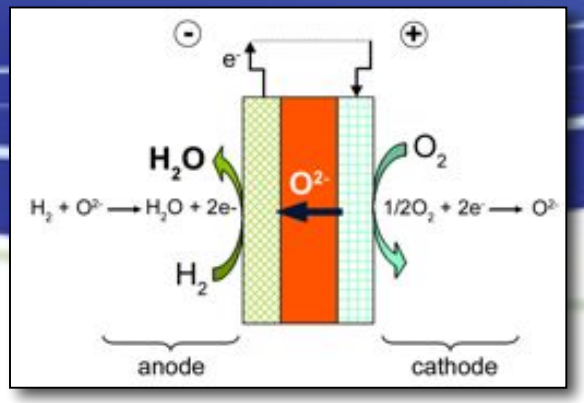
Advisory Board

Dr Nikolaos Bonanos (Risoe, Denmark)
Prof Paolo Spinelli (Politecnico Torino, Italy)

Interconnect Manager	*Dr Paolo Piccardo*
Powder Manager	*Dr Jean-François Hochepied*
Testing Manager	*Dr Antonio Barbucci*
Modelling Manager	*Dr Cristiano Nicolella*





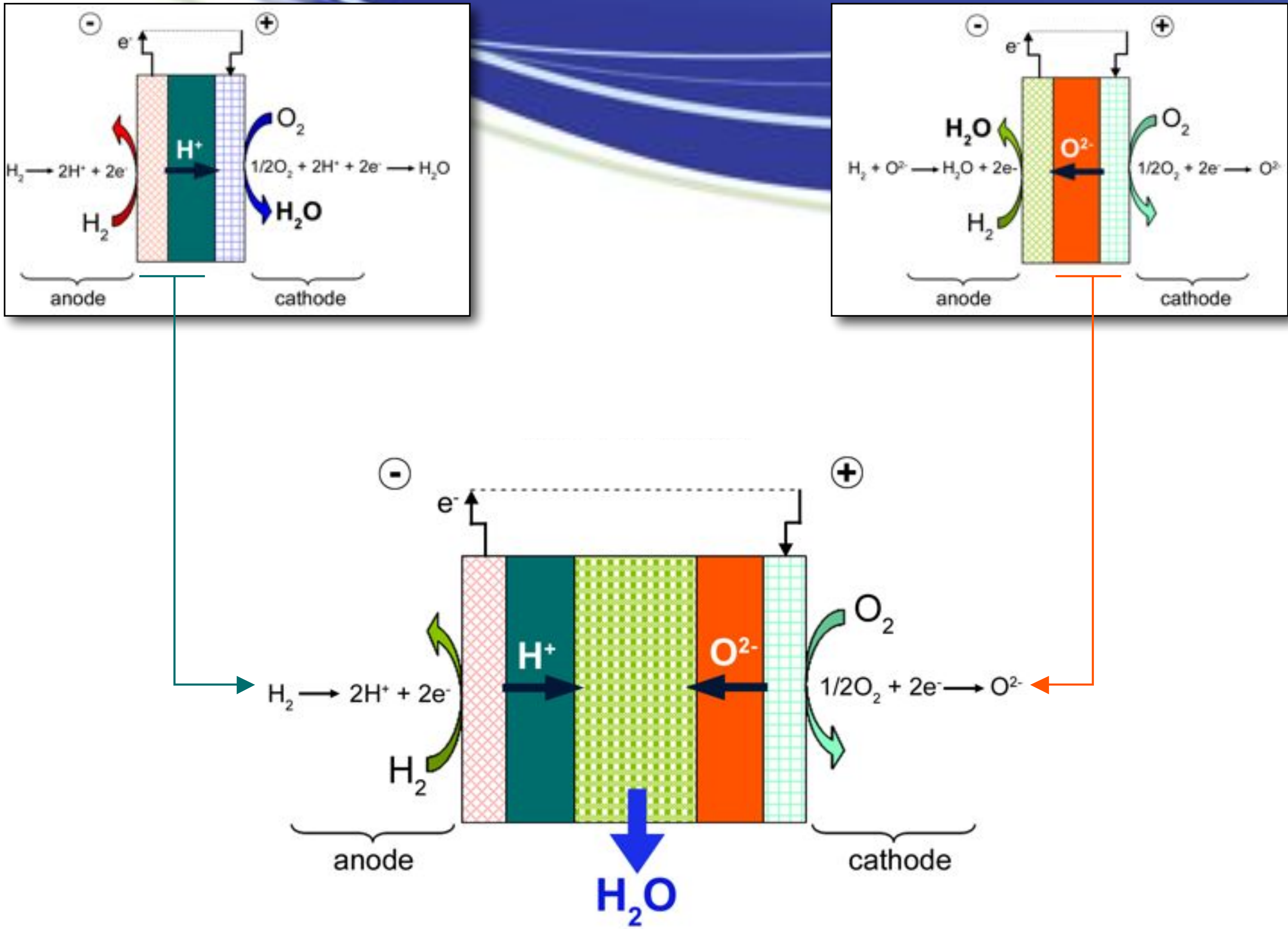


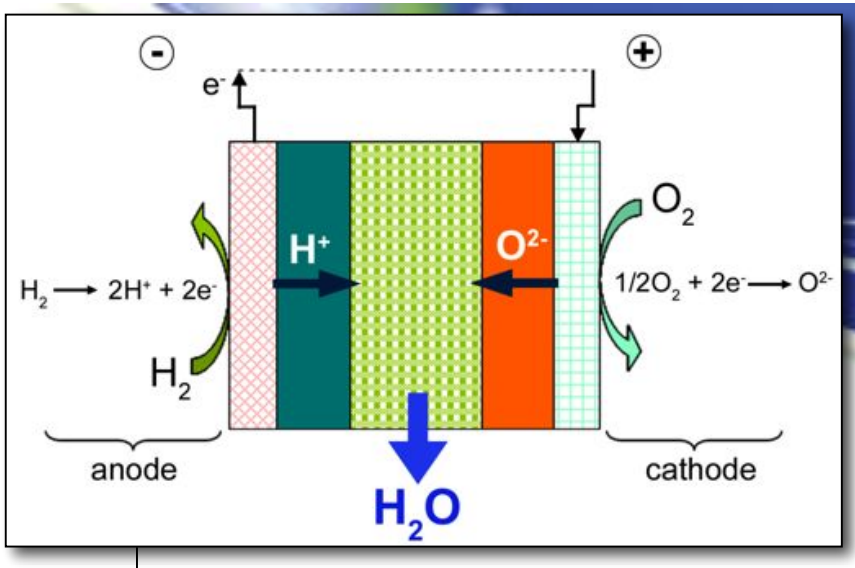
SOFC and PCFC drawbacks: water at anode (SOFC) or cathode (PCFC)

water at electrodes *=>*

- ***dilution of fuel or oxidizer****,*
- ***reduced catalytic activity*** *at the reaction sites,*
- ***counter flow of gas*** *to remove water, which acts against overall efficiency and heat management*
- *severe corrosive environment at the cell-interconnect interface (high temperature water steam + and H_2 or O_2) =>* ***need for sophisticated interconnects and protective layers;***
- *"open system" designs of electrodes for water evacuation =>* ***no easy operation under pressure****;*
- *water and gases* ***carrying heat out of the system****.*

1. Project achievements

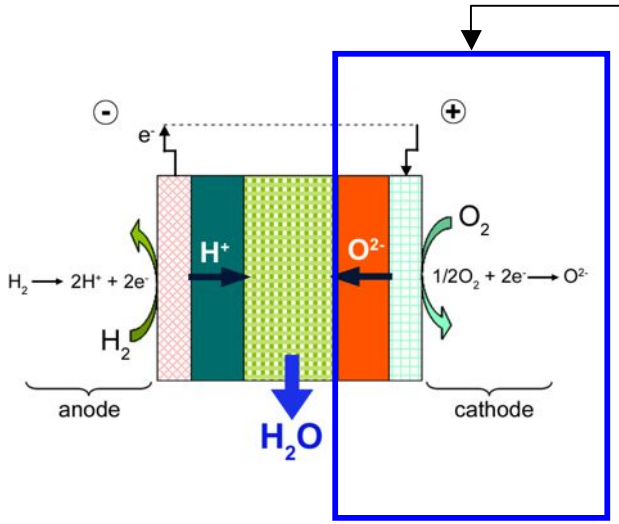




Objectives:

- ✓ *proof the concept,*
- ✓ *fabricate and optimize single dual cells,*
- ✓ *make a short stack*

- *no dilution of fuel*
- *no corrosion of electrodes*
- *no condensation of water on catalytic sites*
- *no counter-flow of gas needed*
- *each compartment has a single role to play and can be fully optimized*
- *electrode polarization expected to strongly diminish*
- *no "open" system, then pressure can be easily applied*
- *pure water and heat can be recovered easily*
- *can work as an HTE (pure H_2 and O_2 produced in separate chambers)*
- *…*



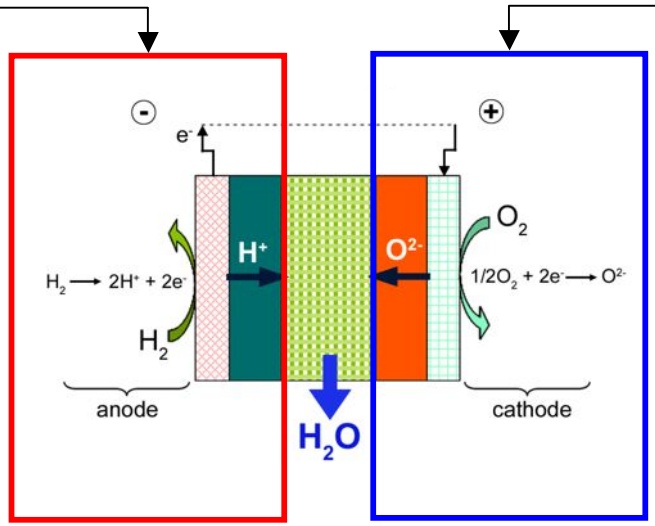
WP2: cathode compartment

- Powders, reactivity
- Shaping
- Testing

Month 0 | Month 12 | Month 24 | Month 36 | Month 48

WP2: cathode compartment

WP3: anode compartment
- Modelling
- Powders, reactivity
- Shaping
- Testing



WP2: cathode compartment
- Powders, reactivity
- Shaping
- Testing

Month 0 | Month 12 | Month 24 | Month 36 | Month 48

WP2: cathode compartment

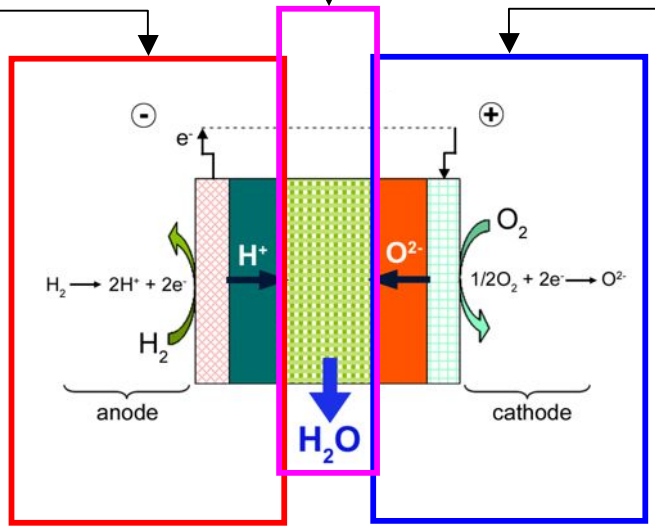
WP3: anode compartment

Milestone M14: dual cell forming process

- *Sequence of wet processes*
- *Fully plasma sprayed*
- *HP, SPS, sequence of processes for PoC samples*

WP4: central membrane
- Modelling
- Powders, reactivity
- Shaping
- Testing , proof of concept

WP3: anode compartment
- Modelling
- Powders, reactivity
- Shaping
- Testing



WP2: cathode compartment
- Powders, reactivity
- Shaping
- Testing

Month 0 | Month 12 | Month 24 | Month 36 | Month 48

WP2: cathode compartment

WP3: anode compartment

WP4: central membrane

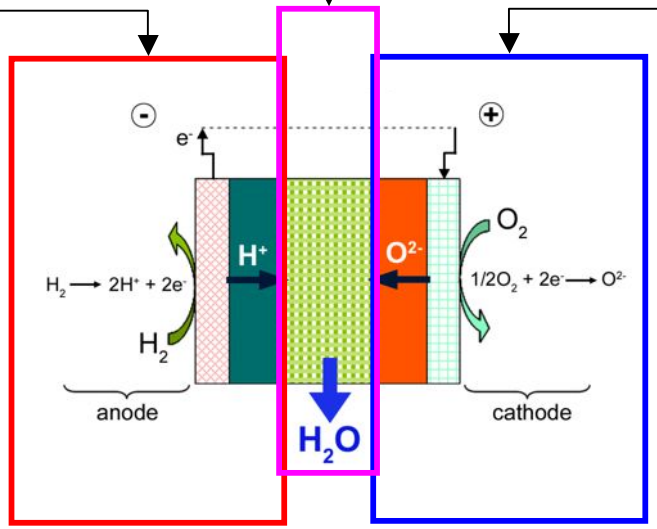
Milestone M18: choice of the assemblies forming process

- *Sequence of wet processes*
- *Fully plasma sprayed, DLR metal cassette supported design*
- *HP, SPS, sequence of processes for PoC samples*

WP4: central membrane
- Modelling
- Powders, reactivity
- Shaping
- Testing , proof of concept

GO/NO GO at month 24

WP3: anode compartment
- Modelling
- Powders, reactivity
- Shaping
- Testing



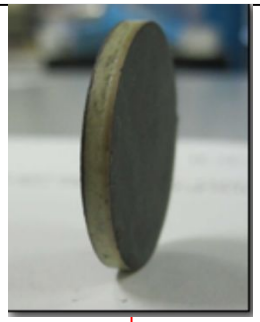
WP2: cathode compartment
- Powders, reactivity
- Shaping
- Testing

Month 0 | Month 12 | Month 24 | Month 36 | Month 48

WP2: cathode compartment

WP3: anode compartment

WP4: central membrane



EC

GO/NO GO

Focus on Understanding, Performances, Modelling
Use tools developed specifically for the project
Do not focus on Interconnect, Stack, Economy

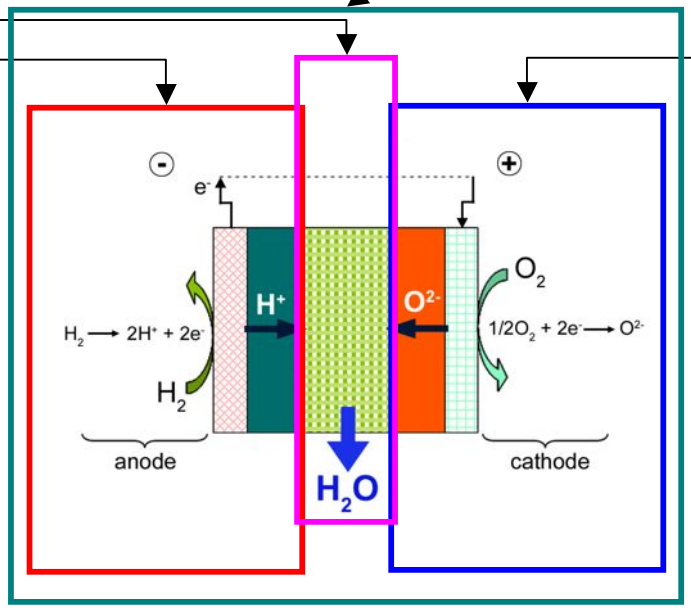
Concept proven on HP, SPS, TC samples

WP4: central membrane
- Modelling
- Powders, reactivity
- Shaping
- Testing : proof of concept

GO/NO GO at month 24

WP5: dual cell fabrication
- Modelling
- Optimization, advanced mat.
- Shaping, stacking, architecture
- Testing, operating conditions
- Benchmarking

WP3: anode compartment
- Modelling
- Powders, reactivity
- Shaping
- Testing



WP2: cathode compartment
- Powders, reactivity
- Shaping
- Testing

Month 0 | Month 12 | Month 24 | Month 36 | Month 48

WP2: cathode compartment

WP3: anode compartment

WP4: central membrane

WP5: dual cell fabrication

EC

GO/NO GO

Focus on Understanding, Performances, Modelling
Use tools developed specifically for the project
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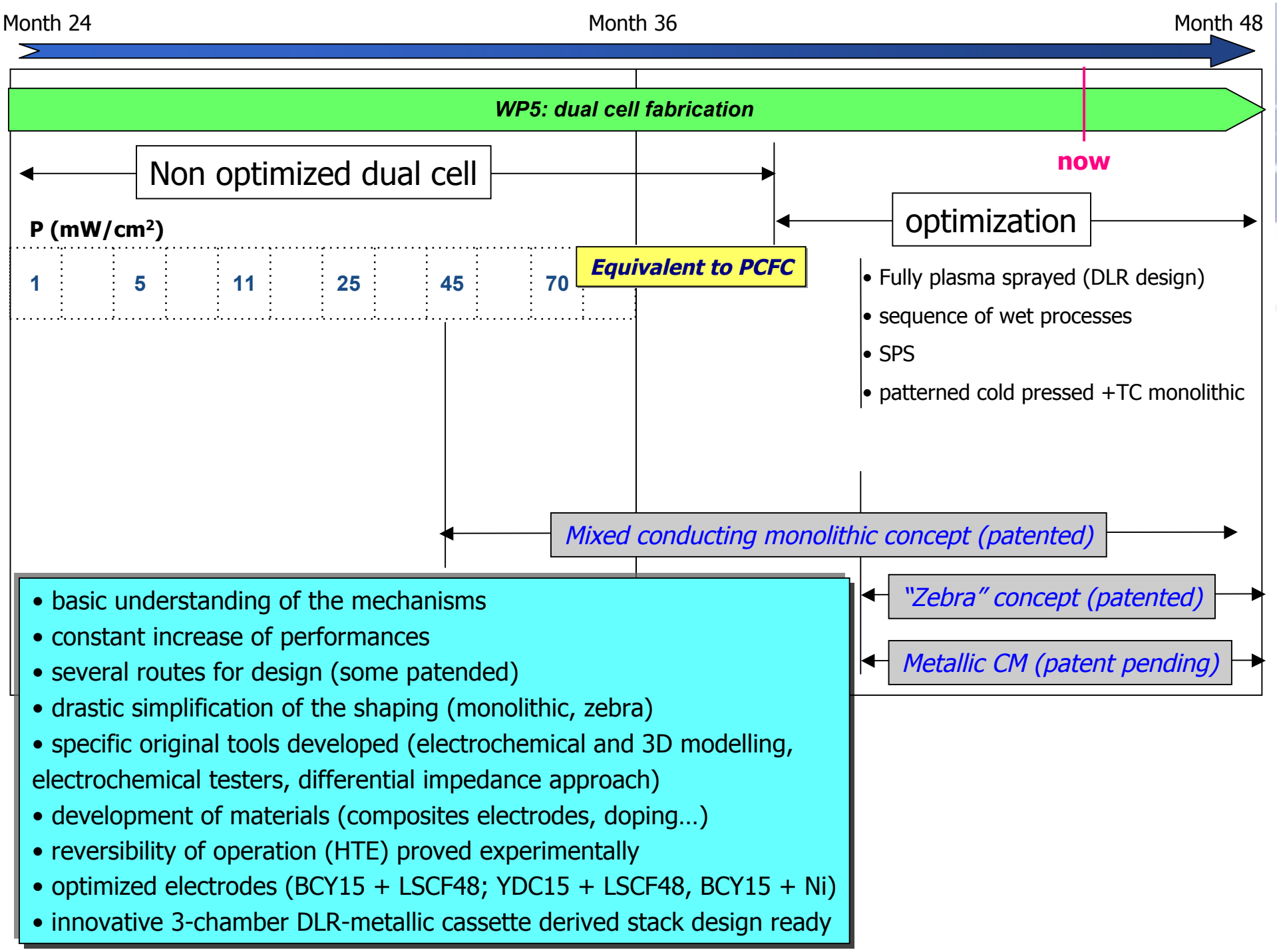
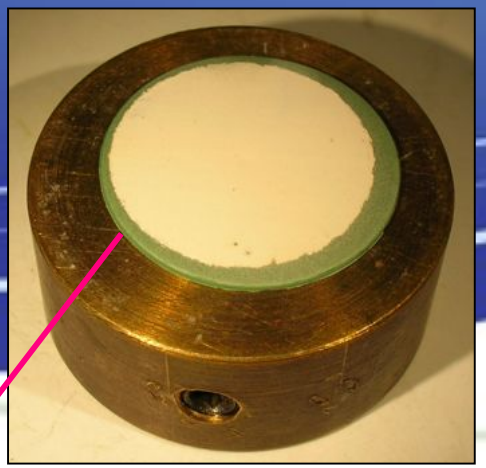
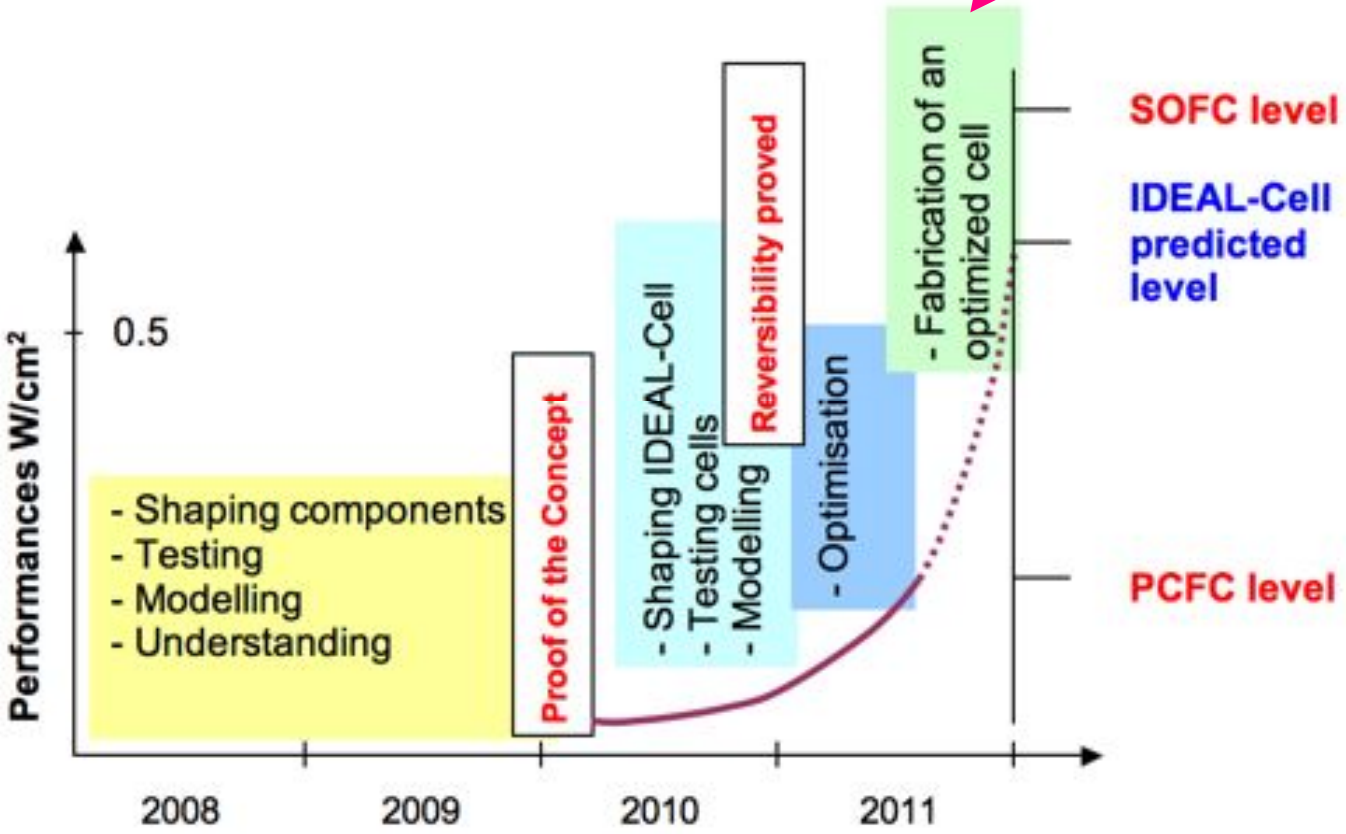
Milestone M35: choice of the materials architecture for the CM

now


Month 24
Month 36
Month 48
WP5: dual cell fabrication
now
Non optimized dual cell
optimization
P (mW/cm²)
1
5
11
25
45
70
Equivalent to PCFC
• Fully plasma sprayed (DLR design)
• sequence of wet processes
• SPS
• patterned cold pressed +TC monolithic
Mixed conducting monolithic concept (patented)
"Zebra" concept (patented)
Metallic CM (patent pending)
• basic understanding of the mechanisms
• constant increase of performances
• several routes for design (some patended)
• drastic simplification of the shaping (monolithic, zebra)
• specific original tools developed (electrochemical and 3D modelling, electrochemical testers, differential impedance approach)
• development of materials (composites electrodes, doping…)
• reversibility of operation (HTE) proved experimentally
• optimized electrodes (BCY15 + LSCF48; YDC15 + LSCF48, BCY15 + Ni)
• innovative 3-chamber DLR-metallic cassette derived stack design ready




Performances W/cm²
0.5
- Shaping components
- Testing
- Modelling
- Understanding
Proof of the Concept
- Shaping IDEAL-Cell
- Testing cells
- Modelling
Reversibility proved
- Optimisation
- Fabrication of an optimized cell
SOFC level
IDEAL-Cell predicted level
PCFC level
2008
2009
2010
2011

- **<u>Dissemination of IDEAL-Cell</u>**
  - 2 international workshops with 6 training courses
  - website, animation, domain names, 4 patents
  - about 60 papers, 15 conferences talks (*+ workshops*)
  - 2 editorials, book chapters
  - internal and external training on FC and H_2
  - exchanges of students, PhD jurys…
  - 3-chamber testing set-up (Real Life Tester™)*
  - …

** Contact CNR, our stand*

- **Technology Transfer / Collaborations**
  - ✓ *academic collaborations easy*
  - ✓ *IDEAL-Cell not mature enough to raise interest within industrials (however with a level of performances that is equivalent to that of a PCFC, without its drawbacks)*
  - ✓ *Technology transfer is therefore not relevant at this stage (except for some innovations i.e. new 3-atmosphere testers, algorithms for microtomography 3D reconstruction or differential impedance, can be transferred quickly)*

- **Project Future Perspectives**

near

  - ✓ *Optimized IDEAL-Cells (wet shaping process) are under testing*
  - ✓ *Full plasma sprayed metal support cells are being fabricated at DLR*
  - ✓ *Gap between today's performances of IDEAL-Cell (lab samples, ≈ PCFC, ≈ 1/5 SOFC) and those that can be of interest for industrials (very new concept, to be compared to 40-50 years of research for SOFCs, 25 years for PCFCs!)*
  - ✓ *Need to fill this gap by:*

mid-term

1. *more scientific and technological research (already established consortium)*
2. *industrial development (industries-JTI)*

  - ✓ *A FET project on a HTE version of IDEAL-Cell is being proposed (project H_2GO)*

you are most welcome

to come and see us

at our Ideal-Cell stand

today and tomorrow

Charlemagne Bldg.
First Floor, Stand J (ARMINES)