FCH JU Review day 2011

Robust Advanced Materials for Metal Suported SOFC

(256768)

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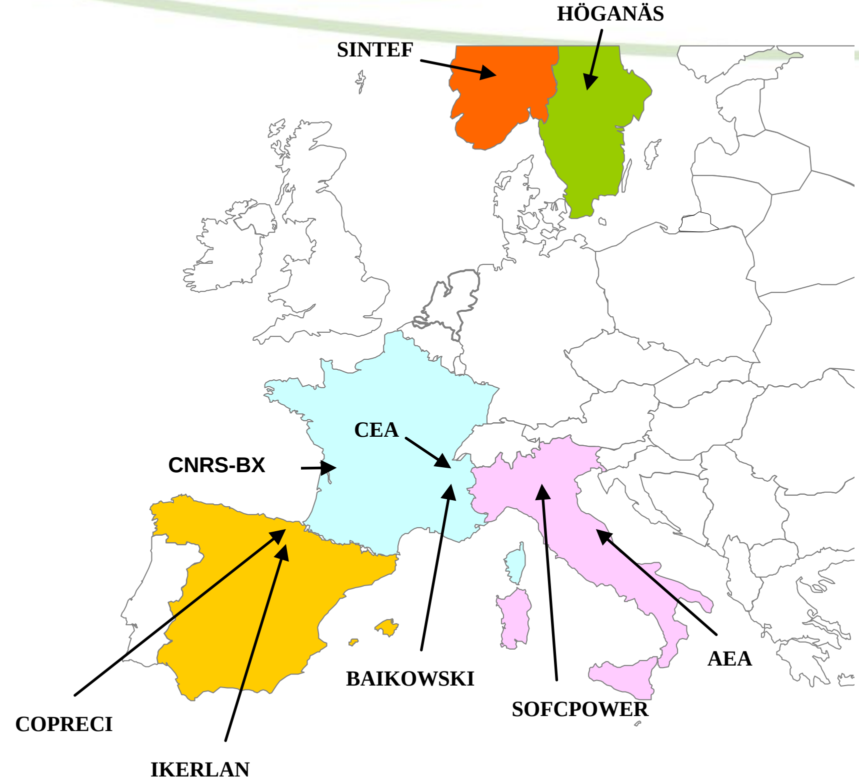
RAMSES Partnership & Budget

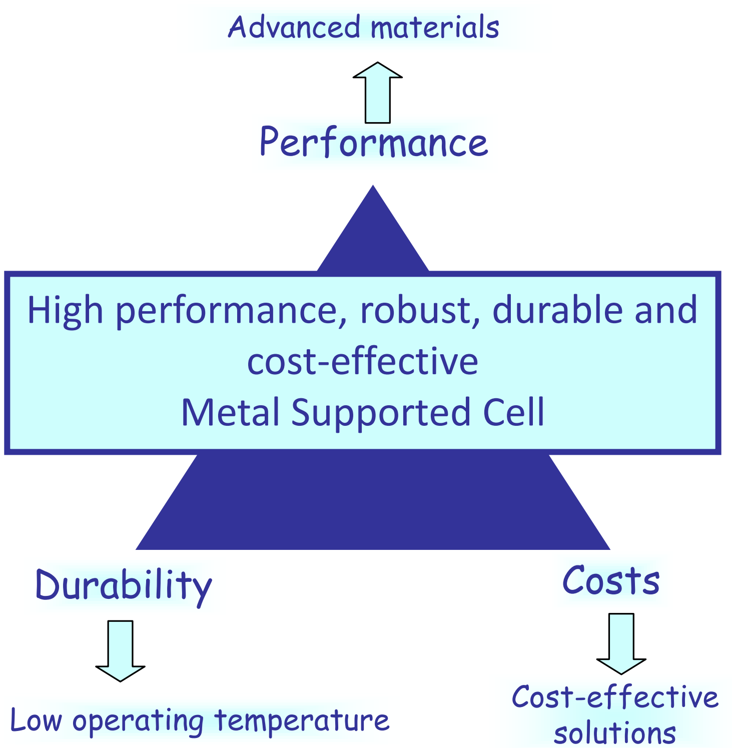
- **3 years** collaboration project:
  01-01-2011 to 31-12-2013
- Total budget: 4’696 k€
- Total funding: 2’140 k€

Partners:	Type
Commissariat à l’Energie Atomique et aux Energies Alternatives	R&D
SOFCpower S.p.a.	SME
Centre National de la Recherche Scientifique	R&D
Höganäs AB	Industry
Baikowski	Industry
AEA S.r.l	Industry
Stiftelsen SINTEF	R&D
Ikerlan S. Coop.	R&D
Copreci S. Coop.	Industry
National Research Council Canada	R&D



A European dimension with a good balance between academics, R&D centres and industries

1. Project achievements
Goals and Targets



- **Increase durability through operating at low T:**
  - decreased rate of thermally activated degradation mechanisms
    - cell components
    - interconnects
  - reduced problems due to CTE mismatch
    - within the cell
    - between cell and interconnect
  - simplify BoP components
- **Increase performance:**
  - selection of advanced materials (cell/interconnects/coatings)
  - selection of adapted cell design
- **Reduce costs:**
  - low T = use of cheaper materials, mainly metallic materials
  - cost-effective materials and processing routes

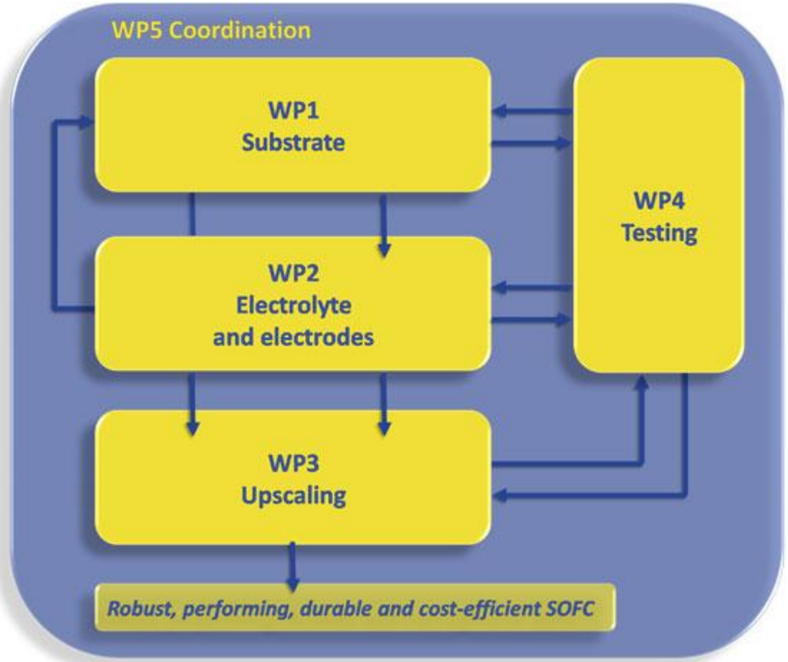
Targets and milestones

Milestones :

M0	
M3	
M6	
M9	MS material selection
M12	
M15	Optimised MS Gastight electrolyte
M18	**Proof of concept at button cell level**
M24	Selection of the best solution for upscaling
M27	
M30	Full-scale cells delivery
M33	Stack delivery, adapted to MSC
M36	Proof of concept of short stack operation

- **Technical objectives:**
- Operating at **600° C** with **H_2** or **internal methane steam reforming (ISR)**
- **Planar** and **tubular** MSCs
- **Performances:**
  - planar cells: ASR=0.6 $\Omega.cm^2$ with H_2, 0.8 $\Omega.cm^2$ with ISR
  - tubular cells: ASR=0.8 $\Omega.cm^2$ with H_2, 1 $\Omega.cm^2$ with ISR
- **Durability:**
  - H_2: ASR increase < 15 $m\Omega.cm^2$/kh
  - ISR: ASR increase < 30 $m\Omega.cm^2$/kh
- **Combines thermal and redox cycles**

1. Project achievements
Ramses approach



Approach in performing the activities :

1. materials optimisations
2. development of the manufacturing processes
3. proof of concept at cell → short stack level
4. investigation of the performance, degradation and some specific failure mechanisms

Performance & Durability CRITERIA to follow project achievements

(progressive targets at component and cell levels)

CONTINGENCY PLAN

after Go No Go decision for upscaling in M18

Technical Accomplishments

- Metal support development:
  - Several metal powders have been manufactured
  - 1 grade for perforated sheet has been selected
  - all ferritic stainless steels
  - Porosity target achieved ✓
  - Pre-selection of 1 grade from shrinkage, porosity and oxidation behaviour. Further evaluations in progress
  - Pre-sintering atmosphere selection ✓
  - Sintering atmosphere recommendations (low oxidising/reducing)
  - Protective coatings in progress

➡ Milestone 1: MS material selection (M9) close to be achieved

Technical Accomplishments

- Electrodes development:
  - Anode
    - 1st target of ASR can be reached with material optimisation and specific sintering conditions
  - Cathode
    - Materials selected in the project are already better than targets (in reference sintering conditions)
    - Stability of the structure of these materials is shown under MSC sintering conditions

➡ Developments on the way to meet the criteria

Technical Accomplishments

- Electrolyte powder development
  - 1st development can lead to a reduction sintering T of MSC compared to commercial powder
- Tubular cell development
  - Tubular MSC with RAMSES metal powders have been manufactured and tested
  - Cell performance is similar to SoA tubular cell at 700° C but unstable

Developments on the way to meet the criteria

2. Alignment to MAIP- AA3
Stationnary Power Generation & Combined Heat and Power

"The aim will be to achieve the principal technical and economic specifications necessary for stationary fuel cell systems to compete with existing and future energy conversion technologies"

This project will participate to increase fuel cell competitiveness by:

→ Increasing SOFC durability: achieved thanks to lower operating temperature and Metal Support which allows decreasing mechanical failure

→ Cost reductions: cost reductions for BoP components thanks to lower operating temperature, and MS allows decreasing the amount of expensive ceramic materials

"This aim includes the use of multiple fuels"

→ Targets to be reached in the project have been fixed both for H_2 and ISR.

"This aim includes a lifetime increase up to 40,000h "

→ Lower operating temperature and the use of a Metal Support will allow increasing SOFC lifetime by decreasing constraints on materials and mechanical failure; degradation target in agreement with such lifetime target.

"Novel architecture for cell and stacks leading to step change improvements of performance, endurance, robustness, durability and cost"

→ The innovative Metal Supported Cell architecture is developed in the RAMSES project to achieve these goals as explained above.

2. Alignment to AIP 2009 – Topic 3.2
Materials development for cells, stacks and balance of plant

1. Novel and improved materials can increase performance, reduce statistically based failures, increase lifetime and reduce cost

→ Innovation = porous metal as cell support, selected advanced materials, performing at low T, and advanced processes which contribute to the robustness and cost-effectiveness of the concept

✓ Improved performances have been obtained for anode and electrolyte materials

2. Projects are expected to cover development and design of materials to improve performance of both cells and stack and BoP components. Mechanical, thermal and electro-chemical stability should be considered and lifetime and degradation issues relevant to production cost for single cells and stacks.

→ Improvement in performance by material and manufacturing development will be investigated at the cell and stack level: WP3 dedicated to up-scaling and stack manufacturing

→ MSC concept, selected materials and low operating temperature to increase mechanical and thermal resistance and to reduce degradation: WP4 dedicated to test these points

2. Alignment to AIP 2009 – Topic 3.2

Materials development for cells, stacks and balance of plant

3. Investigation on failure mechanisms (such as Cr poisoning, redox resistance in SOFCs)

→ In the MSC concept, the use of a thin anode layer makes such a cell less sensitive to re-oxidation ; anode material and microstructure are also developed with this aim: 1 task dedicated to redox resistance investigation

→ Selected cathode materials are considered as good candidates regarding the chromium poisoning: 1 task dedicated to chromium poisoning investigation

4. New and improved material production techniques to reduce cost, emissions and improve yields, quality and performance in industry relevant cells, or BoP materials in FC-units

→ Low cost processes are considered for the metallic support and electrodes

→ Non conventional techniques are selected for the electrolyte to allow densification at lower sintering temperature or without any additional sintering step ; they will assist also by this way the cost reduction in the whole manufacturing route

5. Development of inspection techniques that can be used in manufacturing of materials and cells to identify known defects or anomalies related to materials

→ Efforts to develop inspection techniques that are transferrable to manufacturing lines, in particular to evaluate the electrolyte gastightness in MSCs by direct or indirect methods: development of inspection technique for electrolyte gastightness will be assessed in 1 task.

3. Cross-cutting issues

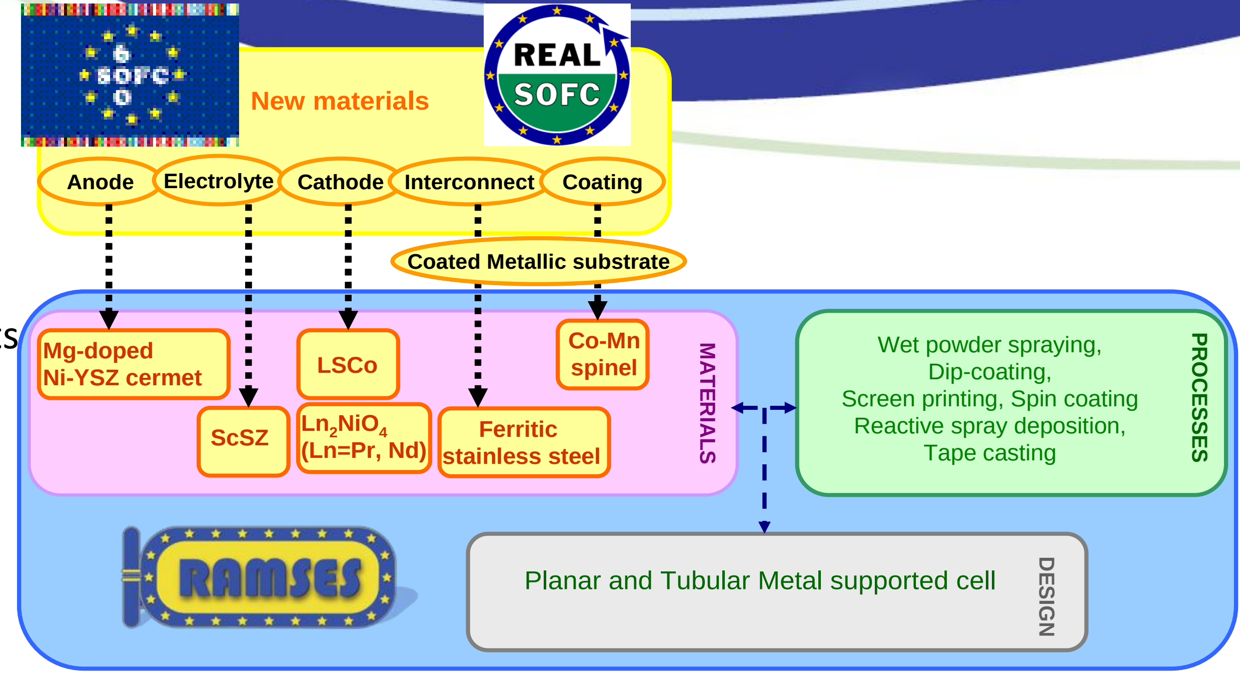
- Training and Education
  - post-doctorates and training engineers are contributing to the RAMSES project at several partners
  - exchange of students during the project possible upon request by partners
- Safety, Regulations, Codes and Standards
  - water-based processes, reduction of hazardous materials are considered preferentially for manufacturing for safety/environmental issues, in addition to costs reduction
- Dissemination & public awareness
  - Public website available since M4: www.ramses-project.org
  - Promotion of publications and conference papers, with preliminary validation of the PCC
    - Peer review journals: J. of Power Sources, Fuel Cells, J. of the Electroch. Society, …
    - Conferences: EFCF, SOFC-x series, Fuel Cell Seminar,…
  - Organization of one Workshop on MSCs in M36
  - Membership in associations/technical committees (International Energy Agency Advanced Fuel Cells technical Annex XXIV, …)

Technology transfer and collaboration

- Main outputs taken from former FP6 projects:

SOFC600 (FP6-SUSTDEV IP, 2006-2010, ref. 20089, Coordinator: ECN, Common Partners: CEA, CNRS-BX, HTc/SP, NRC): materials developments

RealSOFC (FP6-SUSTDEV IP, 2004-2008, ref. 502612, Coordinator: Forschungszentrum Jülich, Common Partners: HTc/SP, CEA, SINTEF): materials development



- RAMSES will also capitalize on previous EU-funded projects:

CEXICELL (FP5, ref. ENK5-CT-2002-00642, 2002-2005, Coordinator: INASMET): cost effective SOFC

FCTESTNET (FP5 ref. ENK5-CT-2002-20657, 2003-2005): testing procedures

FLAME-SOFC (FP6-SUSTDEV IP, 2005-2009, ref. 19875), Coordinator VDI, start-up time requirements and thermal cycle tolerance.

Technology transfer and collaboration

- RAMSES will also capitalize on previous national-funded projects:
  - French ANR Fuel Cells and Hydrogen program (program Ceramet, Icare, Ciel, Oxygene) or ADEME program (Armanasol)
  - Italian, Norvegian, Spanish programs
- Complementarities with ongoing projects
  - other architectures and other concept considered compared to METSOFC project
- Participation in the consortium of a Canadian partner (NRC)
- Industrial partners involved in the project

- RAMSES coordinator (CEA) is chairing the N.ERGHY association

(50 European universities and research centres working in the field of hydrogen and fuel cells)

Project Future Perspectives

In the future, RAMSES could interact with national, European or international projects on MSCs and/or SOFC/SOEC at reduced temperature :

- RAMSES-METSOFC joint workshop (both dealing with MSC)
- ADEL, dealing with 600° C operation in SOEC
- SOFC-Life for generic evaluation of the degradation mechanisms
- DESIGN for diagnostic tools development
- …