New Hydrogen-PEMFC Portable System and Applications

P. Ferreira-Aparicio[a], A. Molinero[b], J.C. Oller[b], J.M. Barcala[b], S. Santamaría[a], J.L. Serrano[a], Antonio M. Chaparro[a]

[a]Low Temperature Fuel Cells Group
[b]Microelectronics Group

CIEMAT
Madrid (Spain)
antonio.mchaparro@ciemat.es

Efficient and LIGht Energy

Hydrogen Portable Fuel Cell

Hidrógeno y Pila de Combustible Portátil

ENE2015-70417-P

236th ECS Meeting

Atlanta, GA

Hilton Atlanta

October 13-17, 2019

CIEMAT: *Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas*

Low Temperature Fuel Cells Group

http://rdgroups.ciemat.es/web/pilascomb/pemfc

The group:

Alba M. Fernández (PhD student)
M.Antonia Folgado (Researcher)
Paloma Ferreira-Aparicio (Researcher)
Antonio M. Chaparro (Researcher)

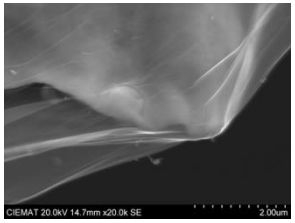
Efficient and LIGht Energy

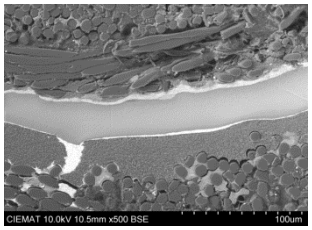
Hydrogen Portable Fuel Cell

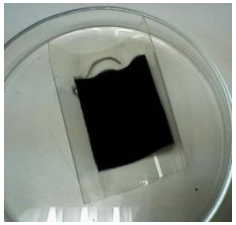
Hidrógeno y Pila de Combustible Portátil

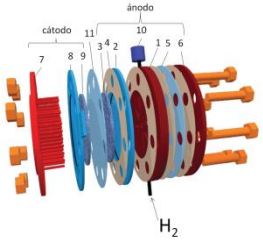
ENE2015-70417-P

http://projects.ciemat.es/web/elige



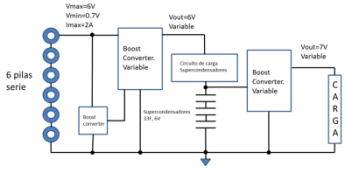






Activities:

1.- Electrochemistry and Materials
2.- PEMFC Components preparation
3.- Fuel cell characterization
4.- Prototypes and demonstrations



Summary

- **1:** **Why** portable power with H_2-PEMFC?

- **2:** **How** a portable H_2-PEMFC?: the *passive feeding* PEMFC
  - Single cell:
    - *Air-breathing* cathode
    - *Dead-end water permeable* anode
  - Stack assembly

- **3:** **What:** portable applications
    - Hydrogen robot
    - Hydrogen airship

Why portable power with H_2-PEMFC?

Battery

Advantages
- Mature technology
- Compact and silent power production
- Can operate in close or open environments with minimal impact to

Ideal power for small personal devices with low power and energy demands (<10W, <30W·h)

- Limited power generation and energy storage capacity of the electrodes
- Leakage currents
- Safety concerns by increasing power and energy

H_2-PEMFC

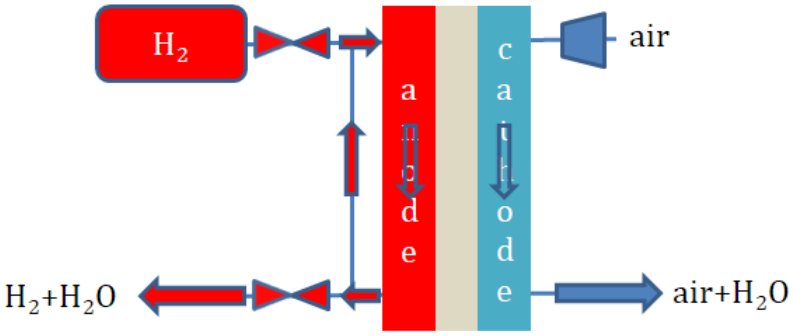
Advantages
- No physical limitation for power production and energy storage (mW-MW)
- No specific safety concerns by

More profitable for higher power and energy demands

Disadvantages
- System compactness is more difficult
- Something noisy (fans and valves)
- Water emission (liquid, vapor)
- Dependent on ambient conditions: temperature, humidity, air convection
- Less reliable technology

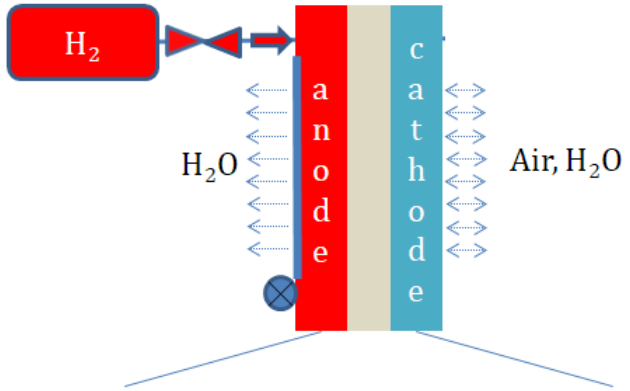
How a portable H_2-PEMFC?: the *passive feeding* cell

Conventional configuration



Electrodes with a flow-field

Passive feeding configuration



Dead-end water permeable anode **air-breathing cathode**

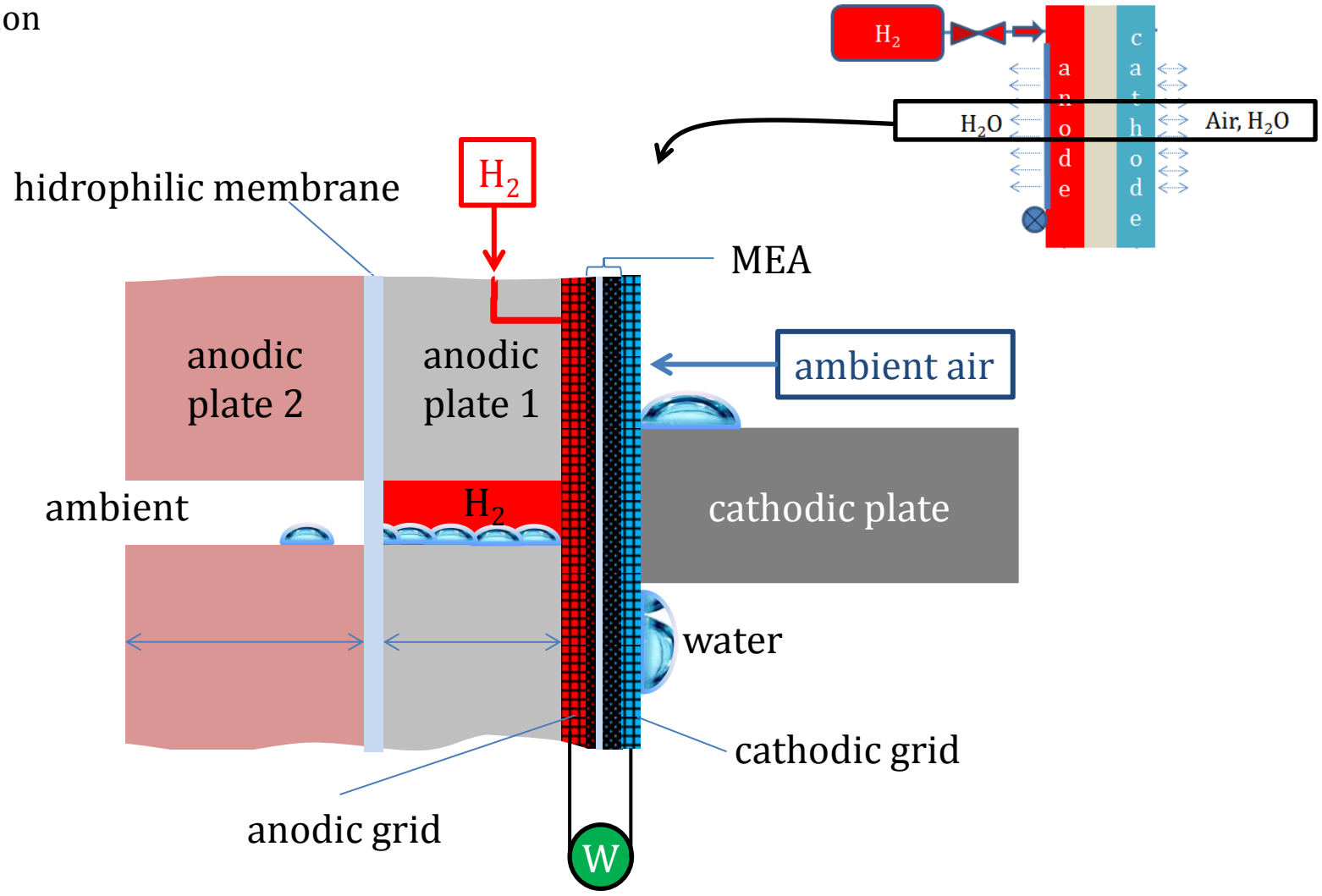
Passive feeding: feeding without a convective flow :

- Anode: dead-end, water permeable, static H_2 pressure, no purging

- Cathode: air-breathing, static ambient air

How a portable H_2-PEMFC?: the *passive feeding* cell

Cell cross section

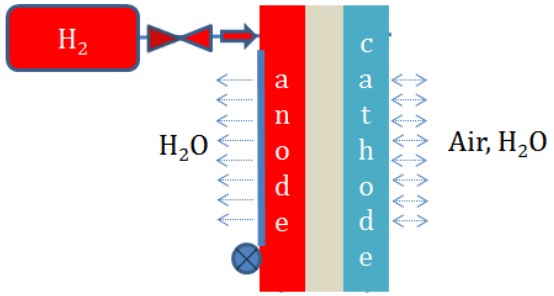


ECS Transactions, 64 (3) 945-950 (2014)

How a portable H_2-PEMFC?: the *passive feeding* cell

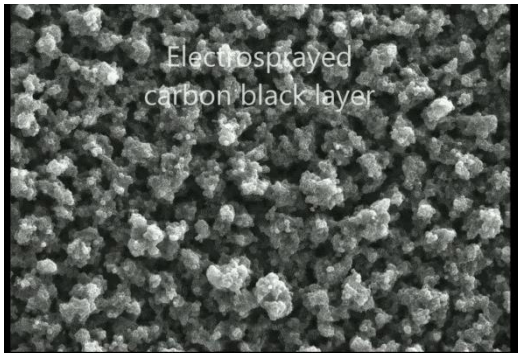
Advantages

- 100% H_2 conversion rate (λ=1.0)
- Simplified FC system
- Minimal auxiliary comsumptions



Some characteristics

- Based on passive transport for hydrogen, air, and water in the electrodes
- Liquid water transport is the main limitation
- Large influence of:
  - Electrodes hydrophobicity
  - Ambient conditions: T, RH, air convection
  - Cell orientation

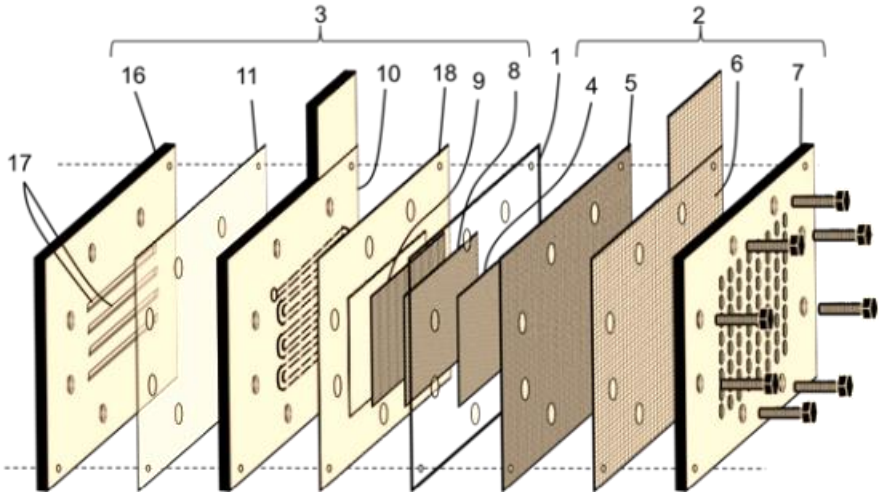


MEA with superhydrophobic electrosprayed electrodes

I01A-1448 - A Comparative Study of Electrospray and Airbrushing Processes for Deposition of Catalyst Layers

Thursday, 17 October 2019
16:20 - 16:40
The Hilton Atlanta - Galleria 2

Patent and utility model



Patent **ES 2466590 A1**, 2015

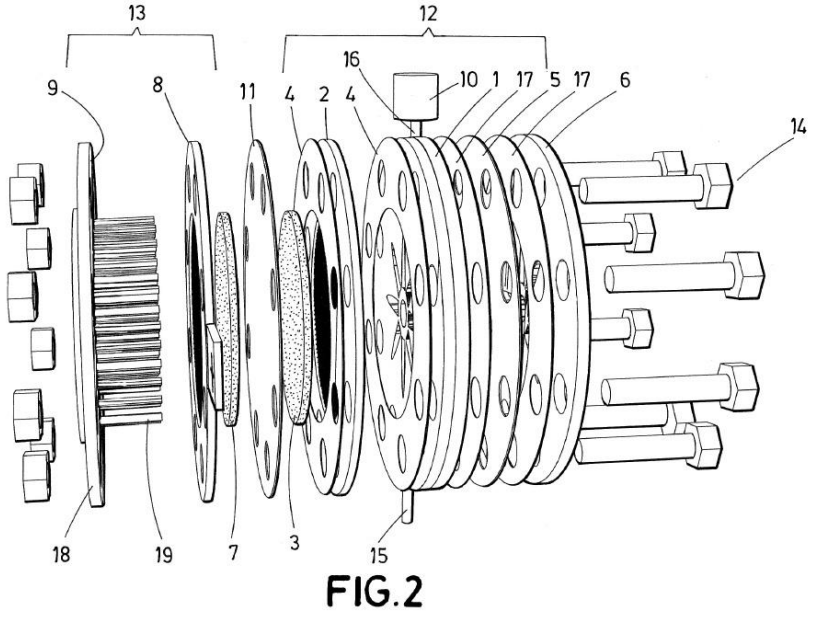
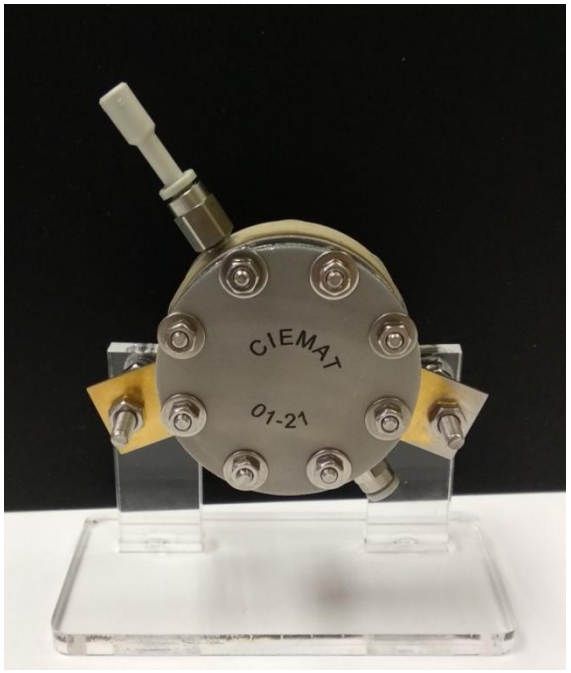
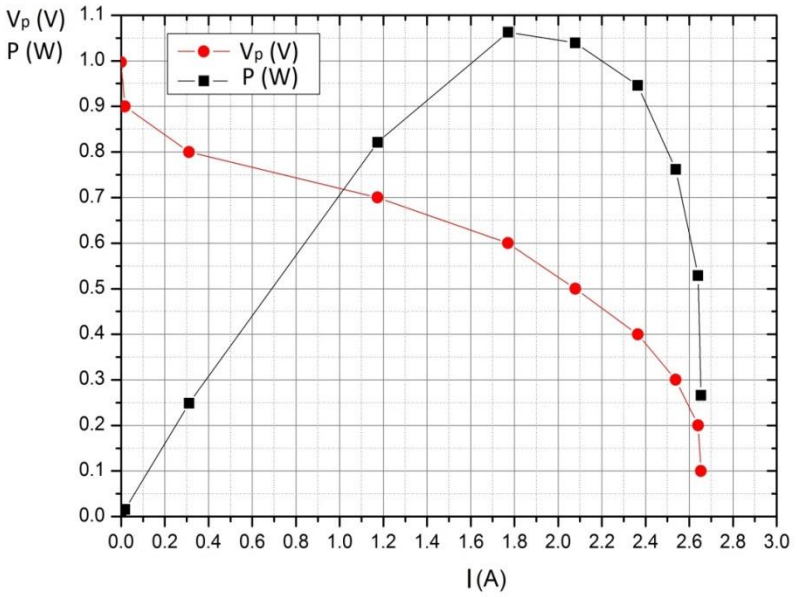


FIG.2

Utility Model **201930869**, 2019

Single cell prototype

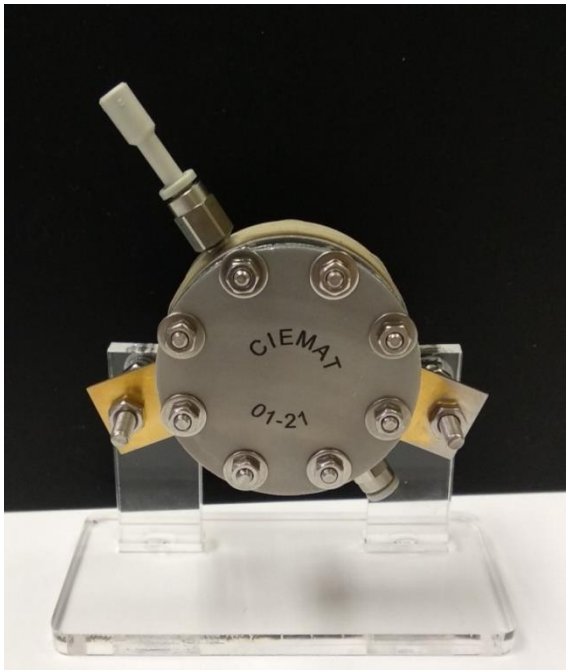




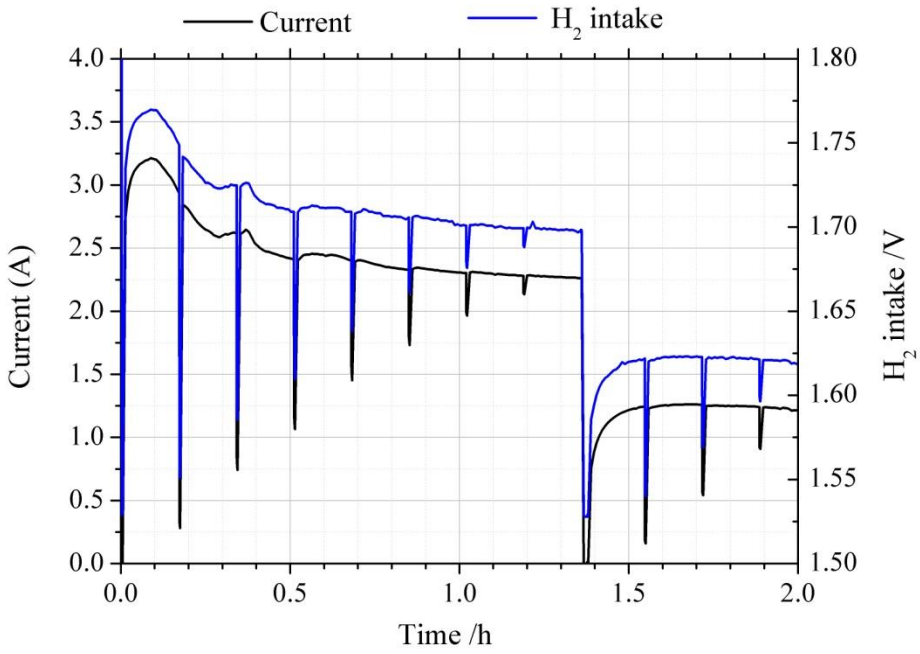
-Power: 1W (0.14 $W \cdot cm^{-2}$)
- MEA: 2x 0.25mg$Pt \cdot cm^{-2}$, Nf212NR
- Active area: 7cm^2 (3 cm diam.)
- Weight: 60 g
- Volume: 60 cm^3

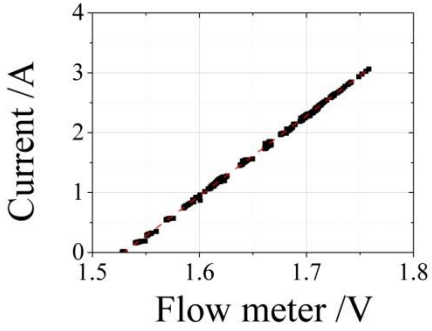
Steady-state response (stabilised cell)
Cell Temp. (auto) 40ºC
Hydrogen intake: H_2, 0.5 bar, static
Ambient air: 23ºC, 30%RH, static

Single cell prototype

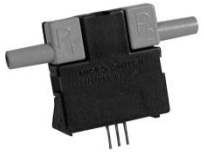


100% faradaic efficiency





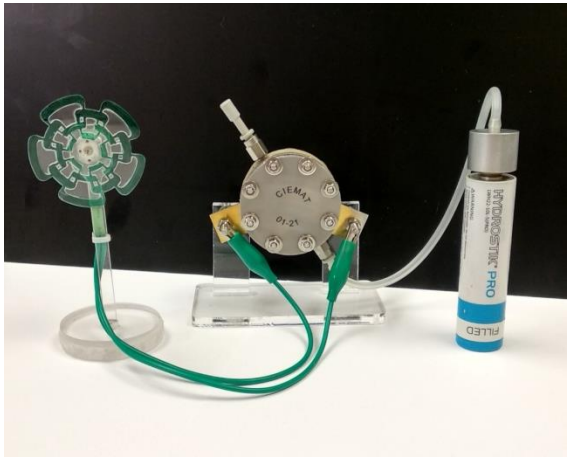
Microbridge mass gasflow meter (Honeywell)



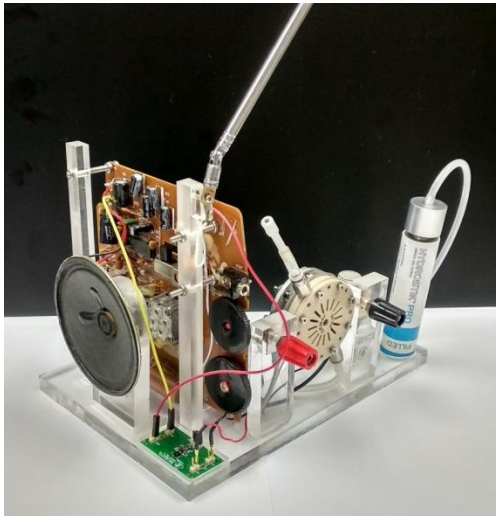
Single cell applications

Lights Propeller (1W)

J. Fernández-Moreno et al., Applied Energy 109 (2013) 60–66



Small wheel (50mW)



Hydrogen radio (0.4W)

Video

http://rdgroups.ciemat.es/web/pilascomb/pemfc

The passive feeding PEMFC stack

6 cells linear stack

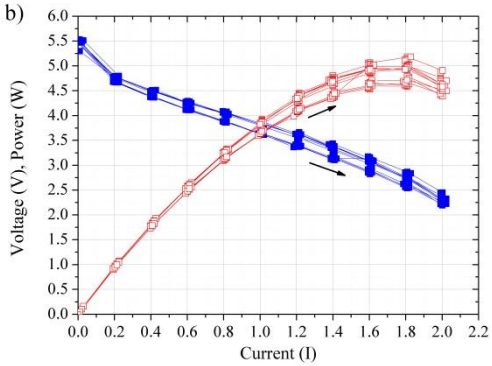
Grid contact inside 3D printed frame

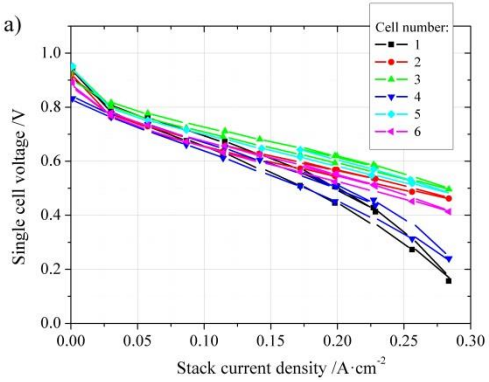
- Power: 6W
- Weight: 420 g
- Volume: 600 cm^3 (40 x 5 x 3)

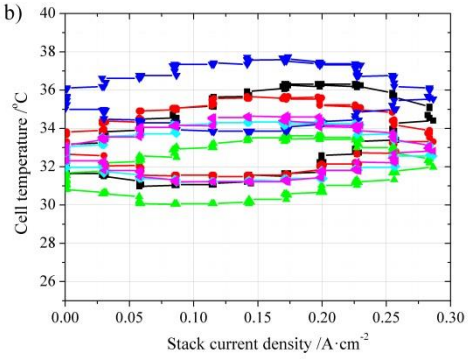
The passive feeding PEMFC stack

6 cells linear stack

Steady-state response
Cells Temp. (auto) 30ºC-38ºC
Hydrogen intake: H_2, 0.5 bar, static
Air intake: ambient, 23ºC, 30%RH, static





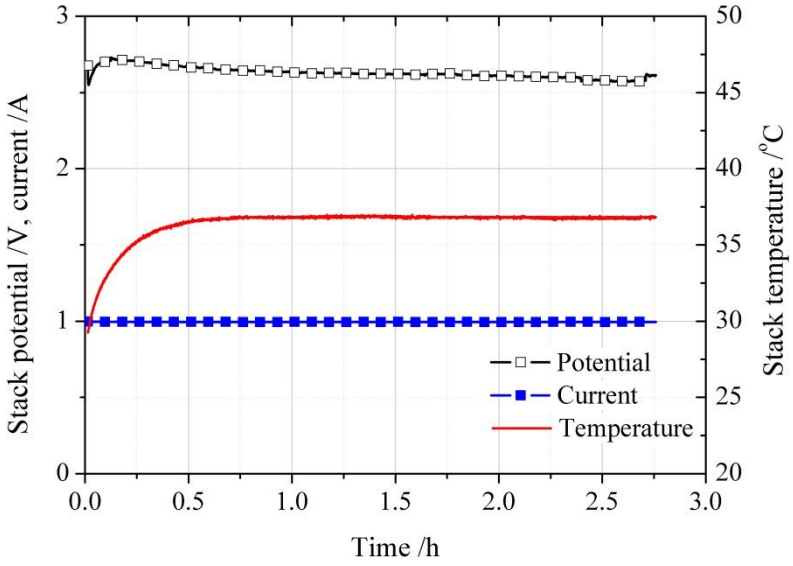


The passive feeding PEMFC stack

6 cells linear stack

Steady-state response
Cells Temp. (auto) 30ºC-38ºC
Hydrogen intake: H_2, 0.5 bar, static
Air intake: ambient, 23ºC, 30%RH, static

Stable power production



The passive feeding PEMFC stack

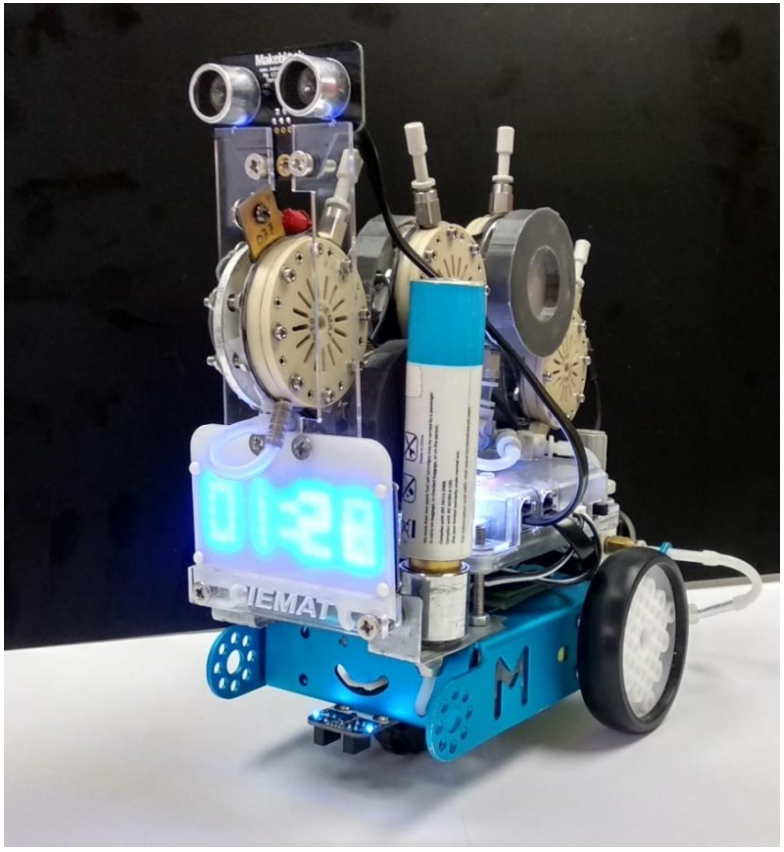
6 cells linear stack

Advantages (vs conventional stack):

- Static air and H_2 feedings
- 100% faradaic efficiency
- No active cooling requirement
- Fully silent
- True modularity
- Individual cells accessibility
- Individual cell on/off
- Flexible connectivity: serial-parallel
- Flexible stacking: linear, planar, volume…
- Easy assembly/disassembly

Stack applications

Hydrogen robot

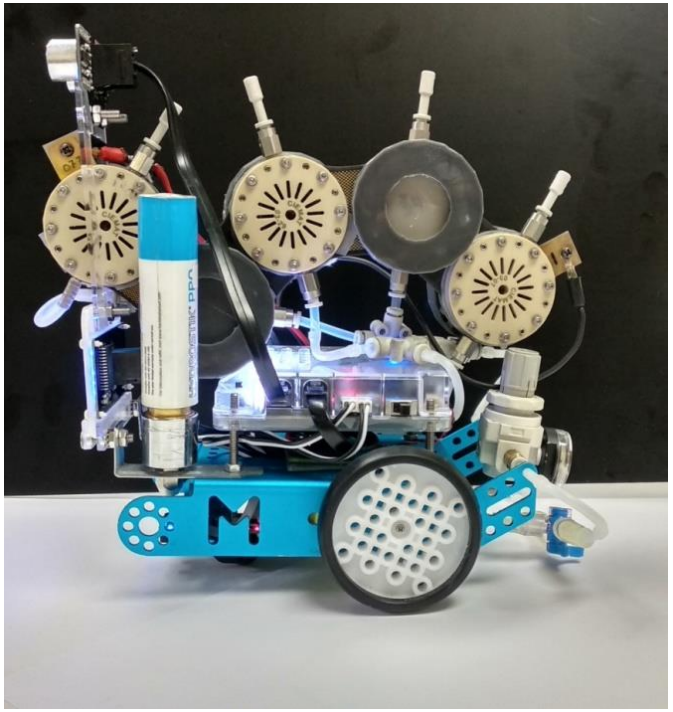


Commercial Mbot (Makeblock):

- 4W power
- Arduino control board
- 2 motors for wheels
- 1 screen with128 leds
- On board leds
- Sensors: Light Sensor, Button, IR Receiver, Ultrasonic Sensor, Line Follower Sensor
- Bluetooth connectivity
- Batteries: 4 LR6 AA, or one 3.7V Li

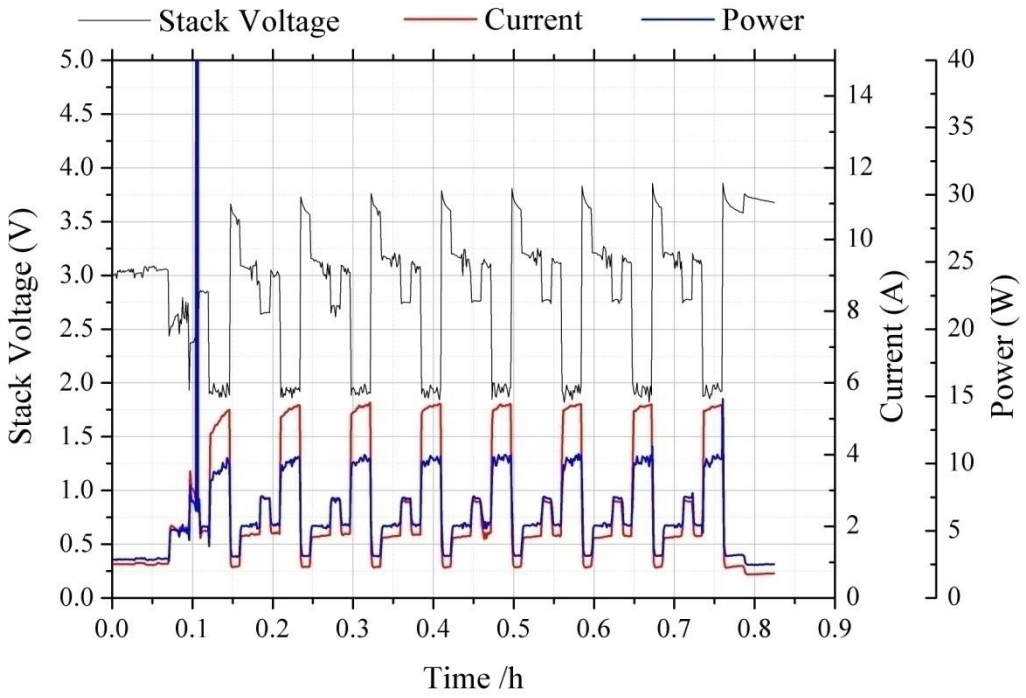
Stack applications

Hydrogen robot



FC system:
5 cells stack
1 metal hydride cartridge
Pressure controller
dc-dc boost board (6V)

	Fuel Cell with Metal hydrides cartridge (0,84g de H_2)	4 batteries LR6 AA
Usefull energy	11.5 Wh	4.3 Wh
Autonomy	5.5 h	2.0 h



Video: http://rdgroups.ciemat.es/web/pilascomb/pemfc

Stack applications

Hydrogen airship

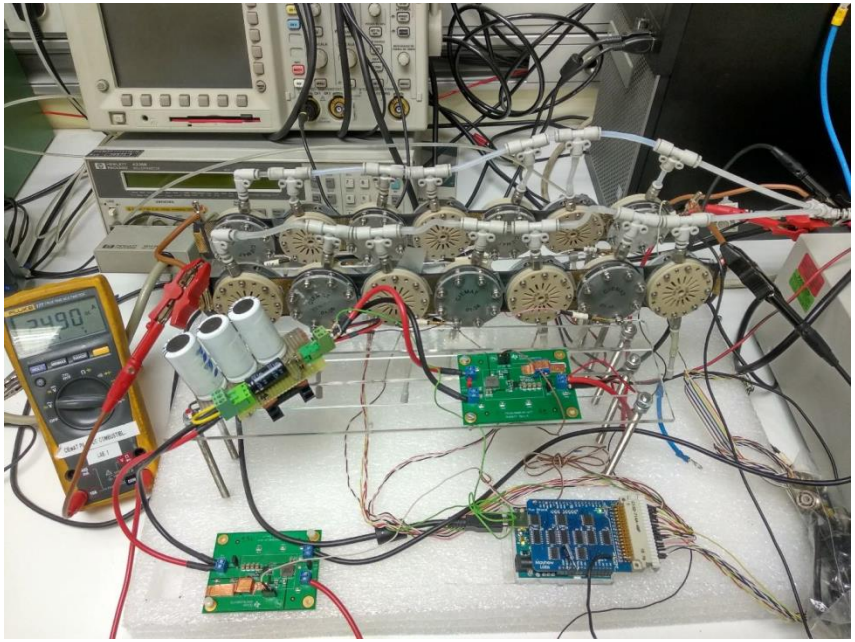
- 3.5m long (3 m^3 He)
- Cabine: 3 propellers, 40 W maximum power
- Power:1 battery (40W, 7V, 47W·h)

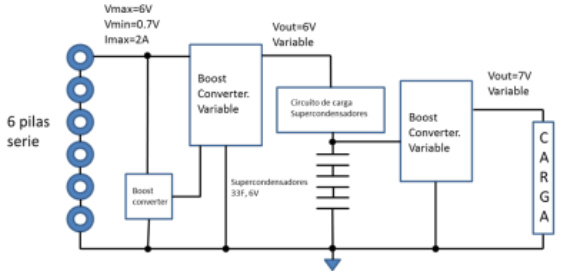
Li-polymer battery

Stack applications

Hydrogen airship

Components power system





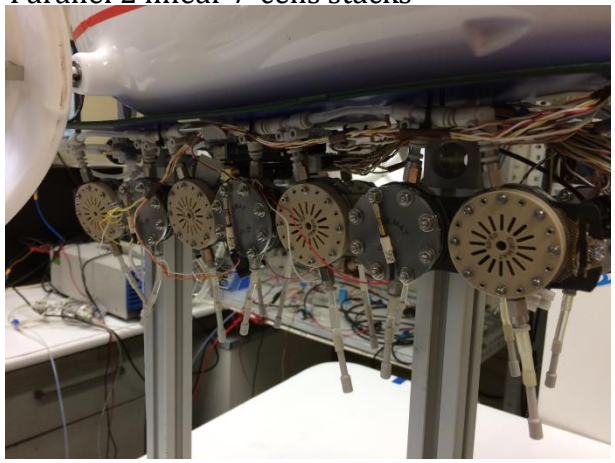
Stack applications

Hydrogen airship integration

Gondola with stack

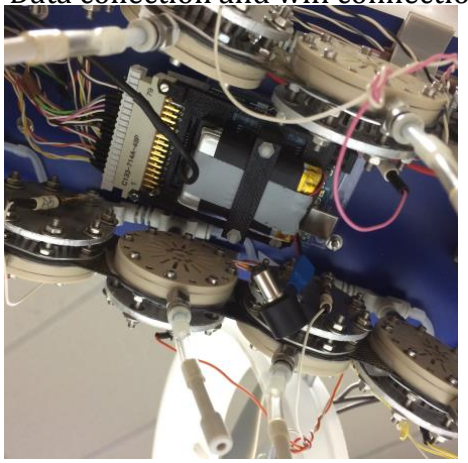
dc-dc conversion and 3 supercaps

Parallel 2 linear 7-cells stacks



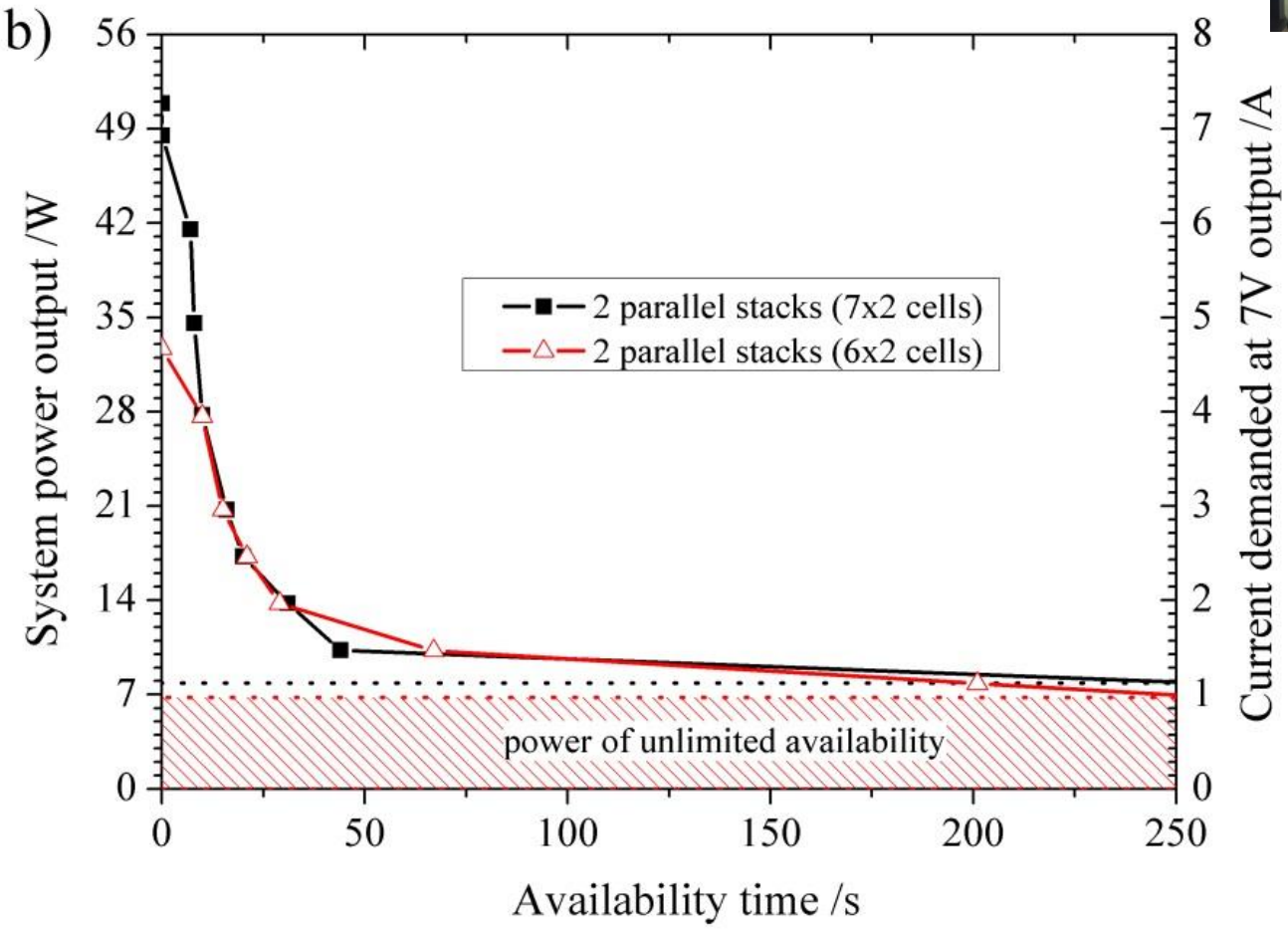
H2 storage in metal-hydrides

Data collection and wifi connection



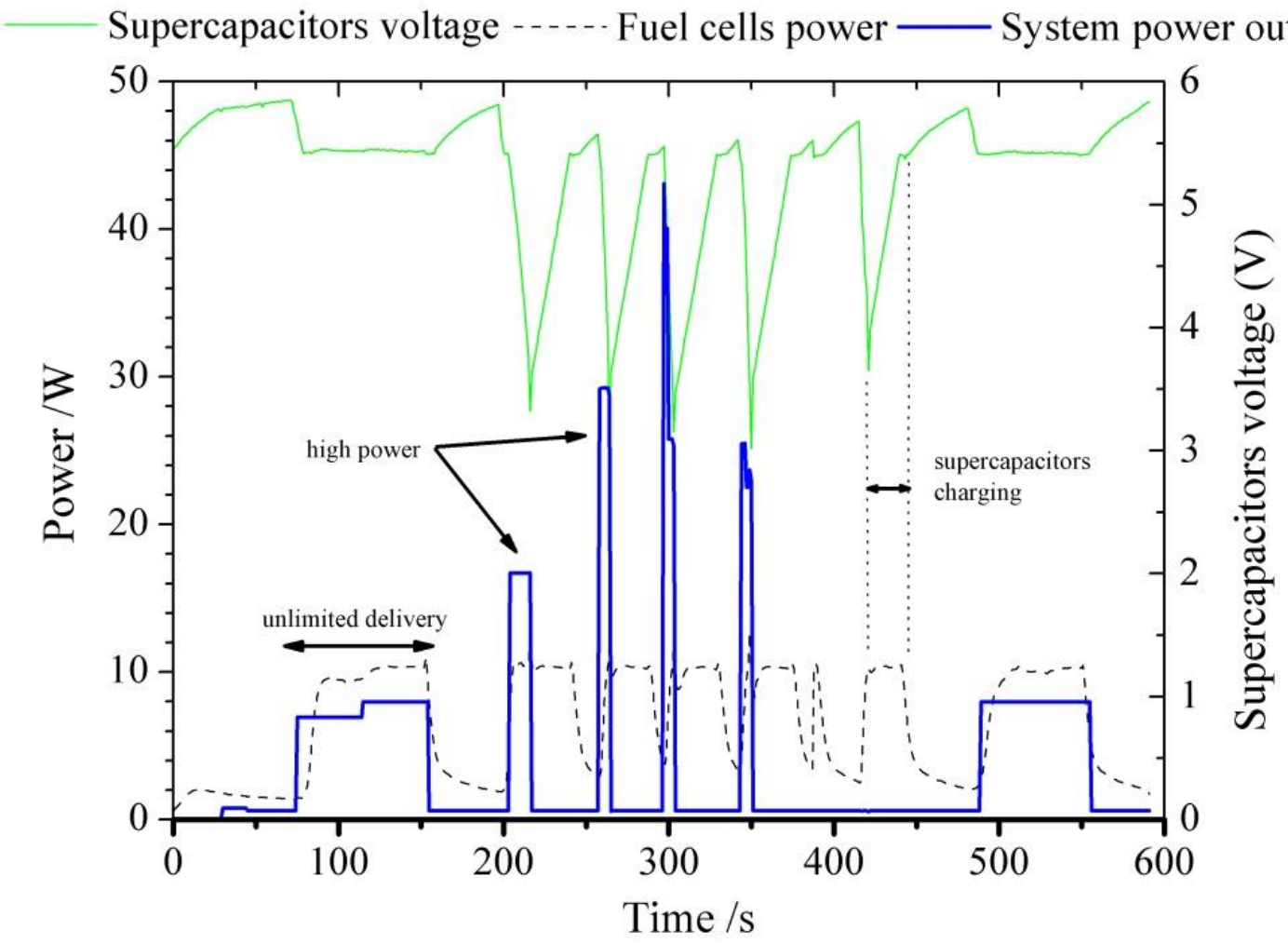
Stack applications

Power output characteristic



Stack applications

Output power profile



Summary

- Passive feeding PEMFC stack with continuous power production developed
- Patent and utility model availables
- MEA: electrodes with enhanced passive water transport
- Symplified fuel cell system for portable applications
- 100% H_2 consumption
- Modularity, flexibility, no active cooling.
- Future work: improve power density:
    - Optimisation of liquid water transport
    - Remove metallic components (bolts, nuts…)

New Hydrogen-PEMFC Portable System and Applications

P. Ferreira-Aparicio, M.A. Folgado, J.J. Conde, S. Santamaría, J.C. Oller, J.M. Barcala, A. Molinero, A.M. Chaparro

CIEMAT
Madrid (Spain)
antonio.mchaparro@ciemat.es

Efficient and LIGht Energy

Hydrogen Portable Fuel Cell

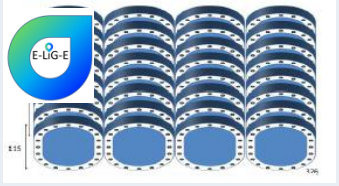
Hidrógeno y Pila de Combustible Portátil

ENE2015-70417-P

Thank you for your attention

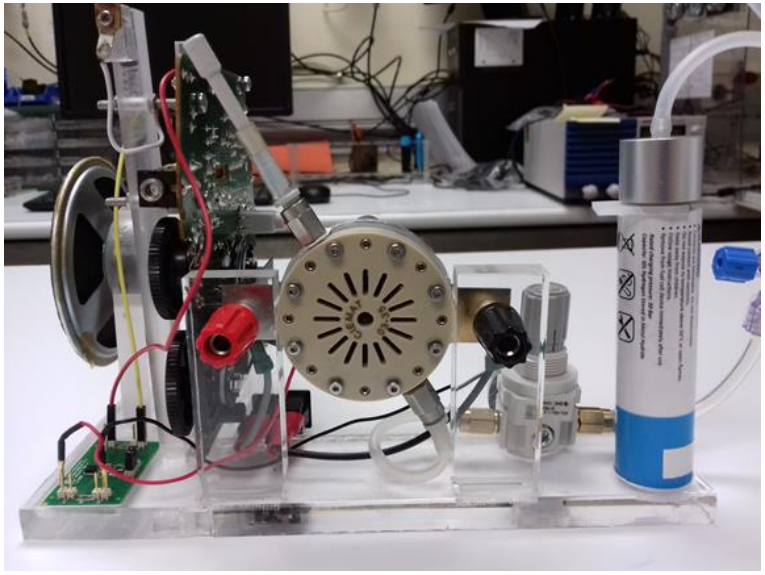
The passive feeding PEMFC for portable power generation

Comparing the passive feeding fuel cell stack with commercial units

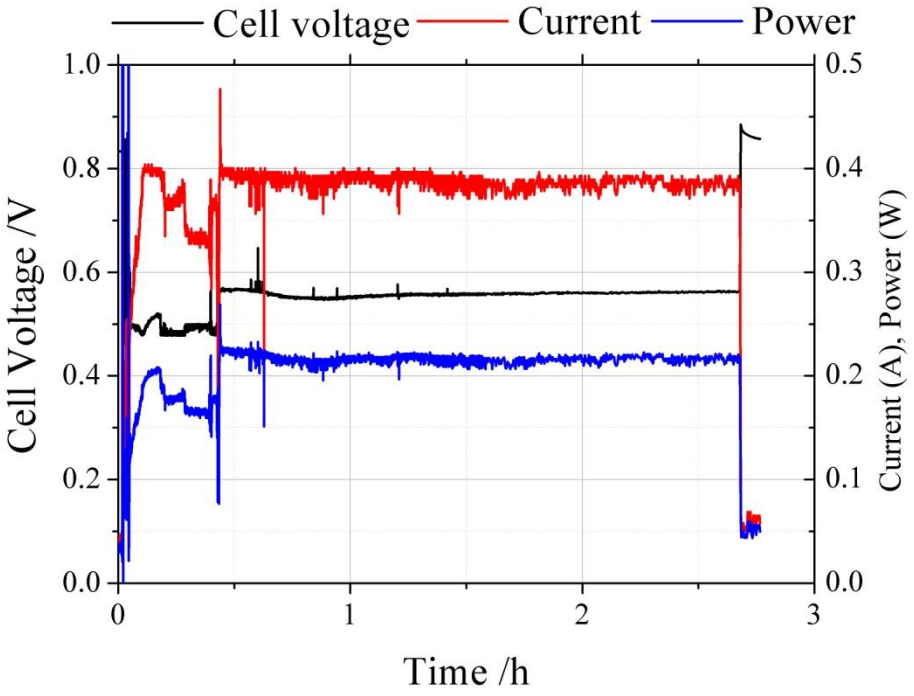
Company		Stack	Rated Power W	Dimensions mmxmmxmm	Weight g
Inteligent Energy		UAV Fuel Cell	650	196x88x140 (2.4l)	810 (only stack?)
HES Energy Systems		Aerostak A-250	250	110x120x124 (1.6l)	730 (dry, full system)
Laboratory stack present status					
E-LIG-E Project and H2DRONEnergy		Passive anode-airbreathing	114	289x240x105 (7.2l)	3000 (full system)

The passive feeding PEMFC for portable power generation

Single cell application with DC-DC boost conversion



Portable hydrogen radio

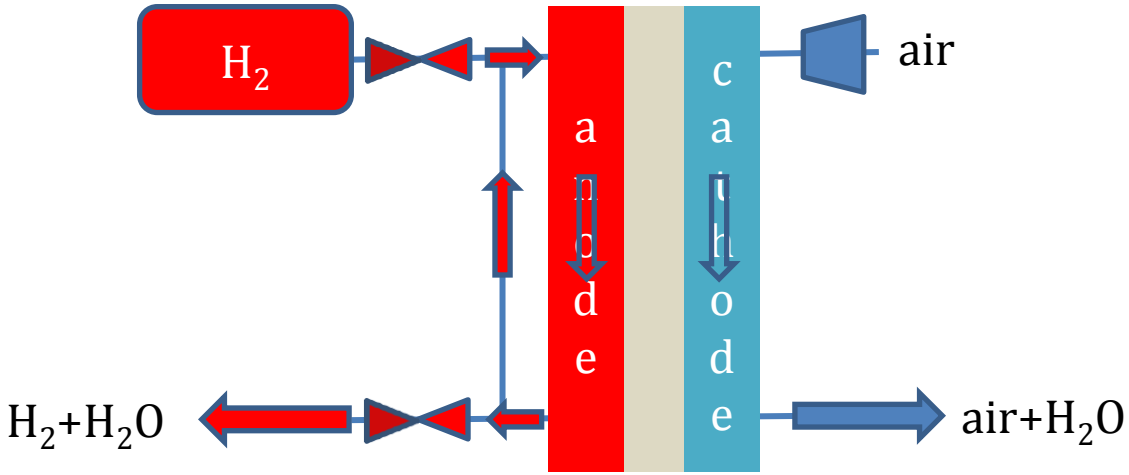


Original:
Sanyo RP 6165 F
Batt.: 3x R20/D (4.5V)
Auton.: 48 W·h
Power: 400mW

Hydrogen-FC system
Fuel Cell: 1x PEMFC 7 cm^2
H_2 cartridge: 1g Metal Hydrides
H_2 pressure control 0.5bar: 2 steps
Boost dc dc conversion
Auton.: 15 W·h
Power: 400mW

Conventional fuel cell vs passive feeding fuel cell

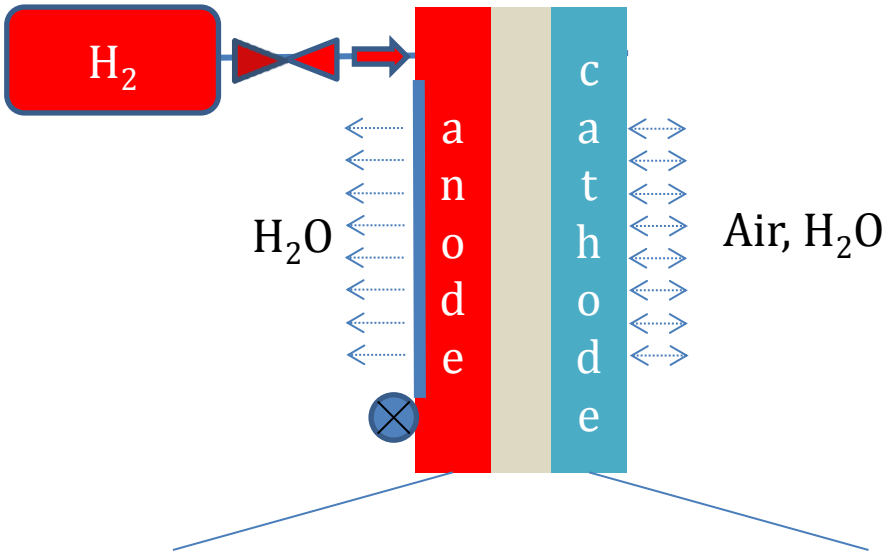
Conventional configuration



Electrodes with a flow-field

Conventional fuel cell vs passive feeding fuel cell

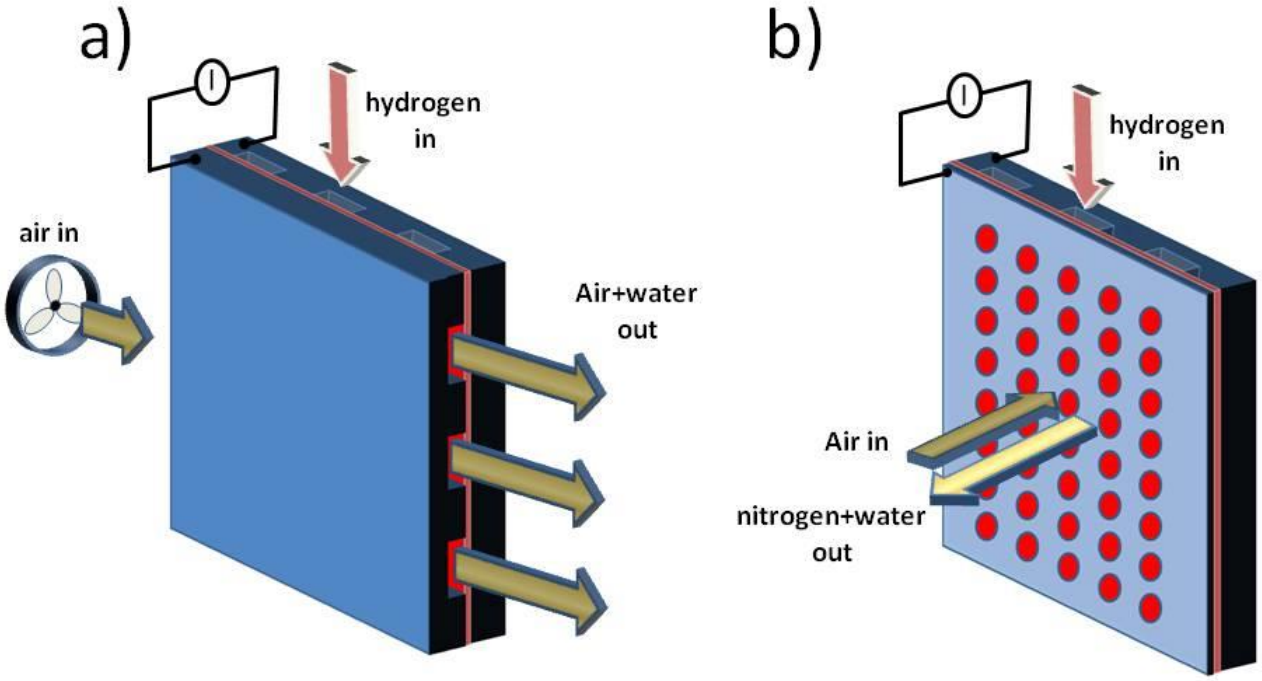
Passive feeding configuration



Dead-end water permeable anode **air-breathing cathode**

Conventional fuel cell vs passive feeding fuel cell

Cathode configuration



Flow-field

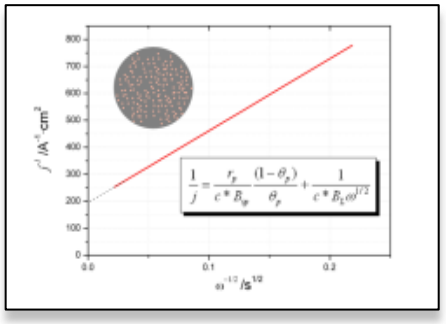
Air-breathing

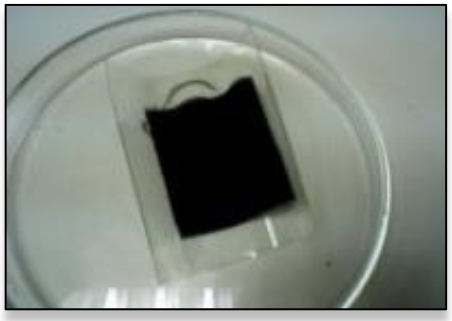
Low Temperature Fuel Cells Group of CIEMAT

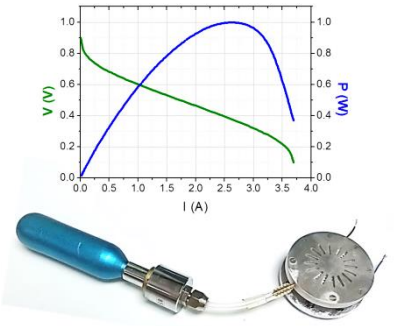
http://rdgroups.ciemat.es/web/pilascomb/pemfc

The group:

Alba M. Fernández (PhD student)
M.Antonia Folgado (Researcher)
Paloma Ferreira-Aparicio (Researcher)
Antonio M. Chaparro (Researcher)





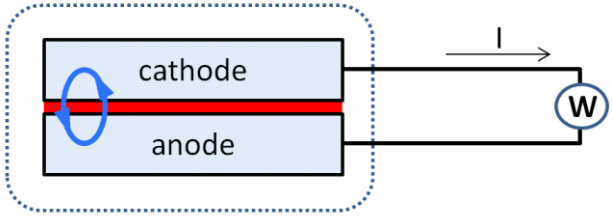


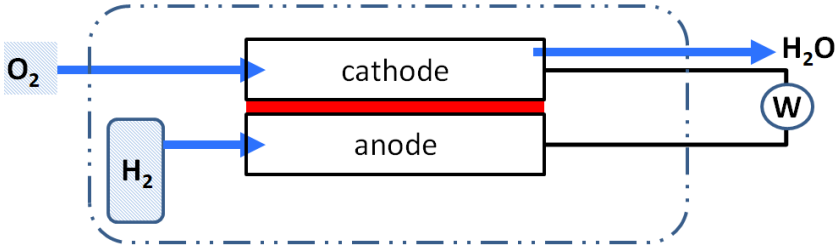
Activities:

1.- Electrochemistry and Materials
2.- PEMFC Components preparation
3.- Fuel cell characterization
4.- Prototypes and demonstrations

Portable power generation

Batteries and Hydrogen fuel cells

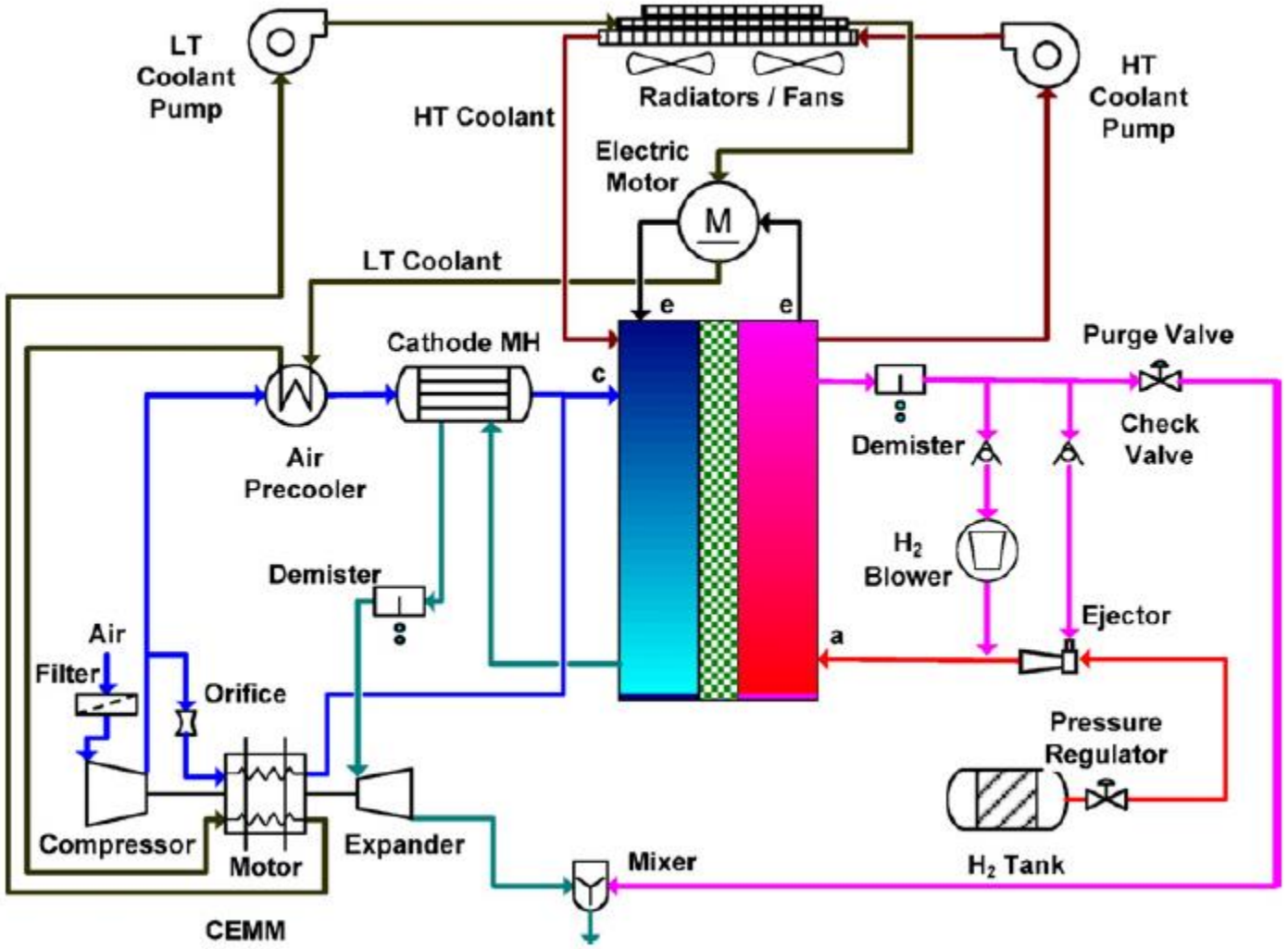




4 AA batteries
6V DC
4 W·h

1 fuel cell + H_2 cartridge (1g)
0.6V DC
15 W·h

Fuel cell power system

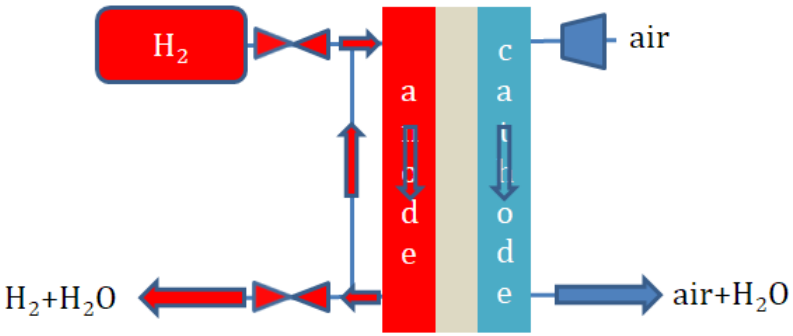


R.K. Ahluwalia et al. / Journal of Power Sources *196 (2011) 4619–4630*

The passive feeding PEMFC for portable power generation

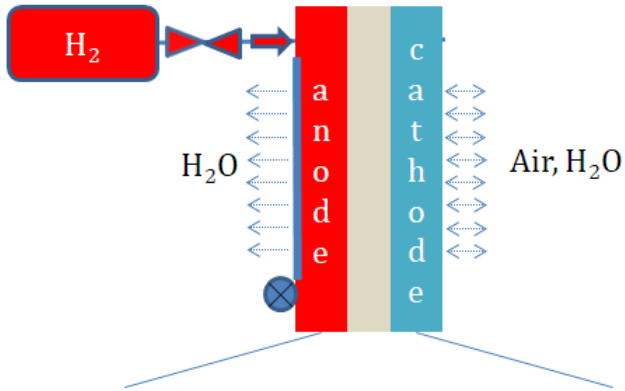
Conventional fuel cell vs passive feeding fuel cell

Conventional configuration



Electrodes with a flow-field

Passive feeding configuration

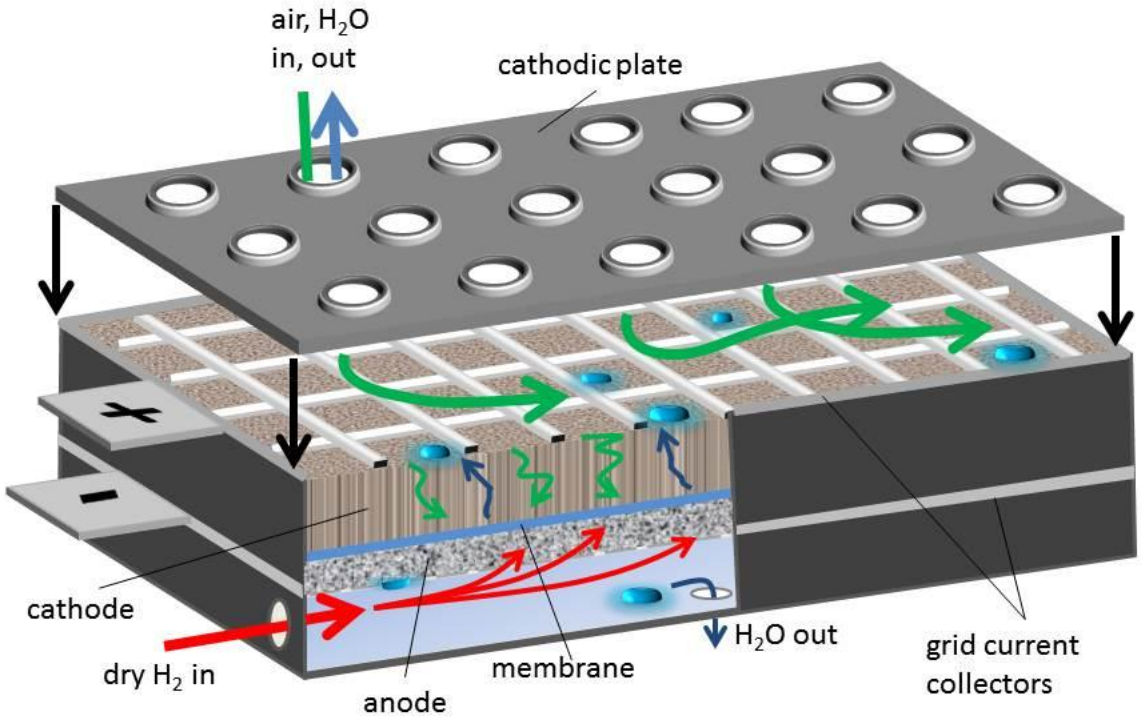


Dead-end water permeable anode **air-breathing cathode**

Poster A1008: *Analysis of passive water removal from the anode chamber under dead-ended conditions in an innovative design of air-breathing PEM fuel cell.*
P. Ferreira-Aparicio, A. Fernández-Sotillo, A.M. Chaparro

The passive feeding PEMFC for portable power generation

The passive feeding fuel cell



"Portable Hydrogen Energy Systems", Elsevier 2018
P. Ferreira-Aparicio, A.M. Chaparro (Editors)