CERAMIC STACKS FOR URINE ENERGY EXTRACTION

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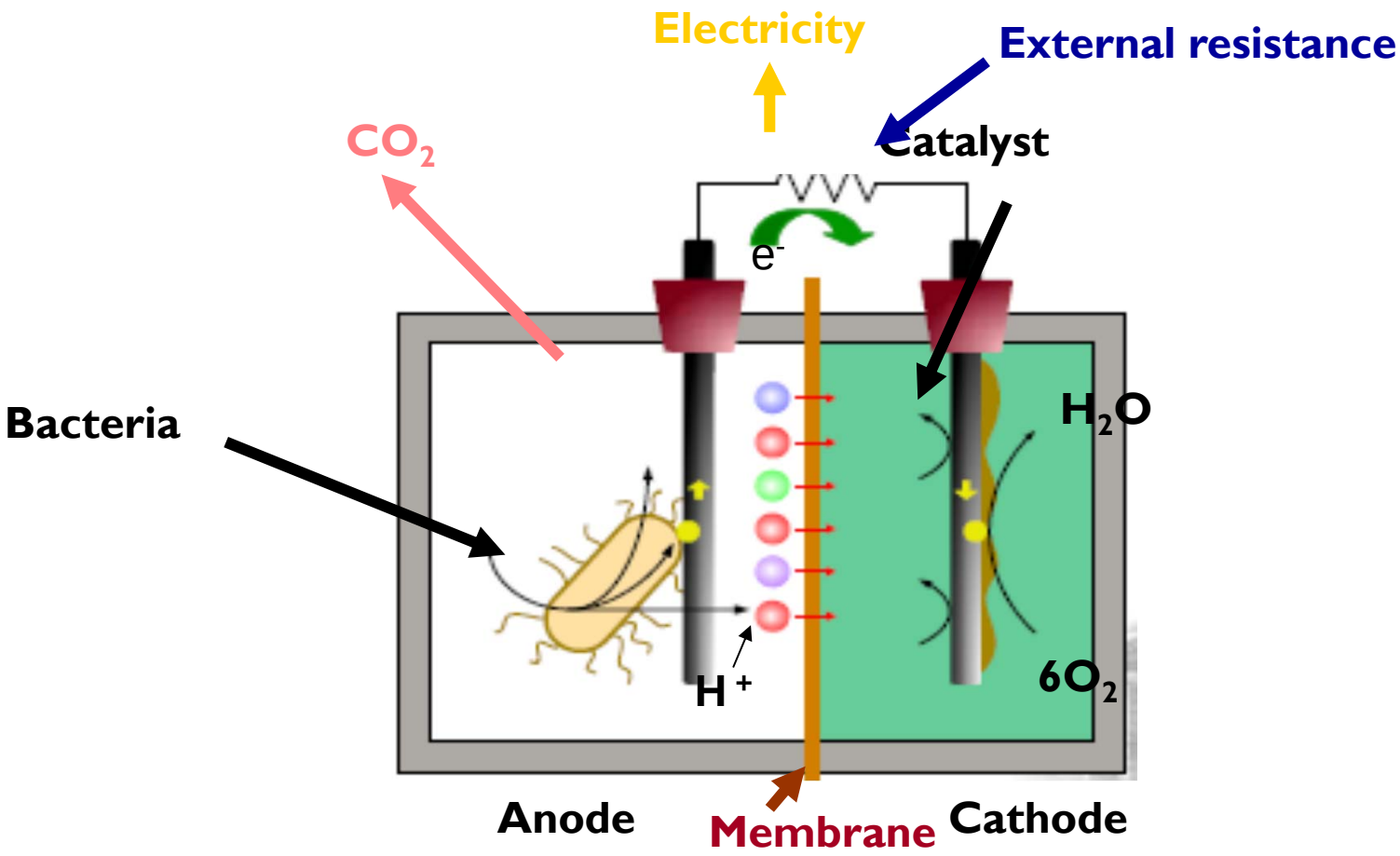
What is a microbial fuel cell?

Microbial fuel cells (MFCs) are devices that convert biomass directly into electricity through the metabolic activity of microorganisms.

The working principle of an MFC



Chemistry of MFC: As an example, glucose is used as an organic substrate.

Anode : $C_6H_{12}O_6 + 6H_2O \longrightarrow 6CO_2 + 24H^+ + 24e^-$

Cathode : $24H^+ + 24e^- + 6O_2 \longrightarrow 12H_2O$

Advantages of MFC

- **Electricity generation out of biowaste/organic matter:** The treatment process can become a method of producing energy in the form of electricity, when conventional plants are characterized by substantial consumption of electrical energy.

- **Direct conversion of biowaste to electricity.**

- **Cost-effective operation:**

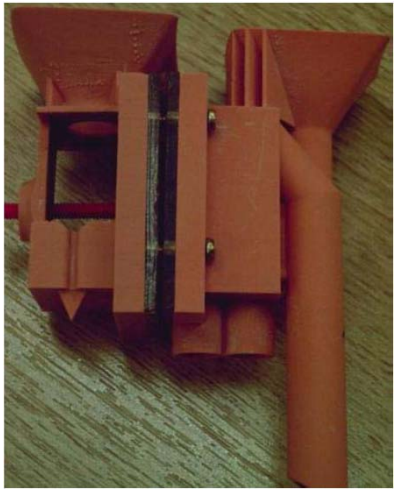
✓They operate under ambient environmental conditions (temperature, pressure).

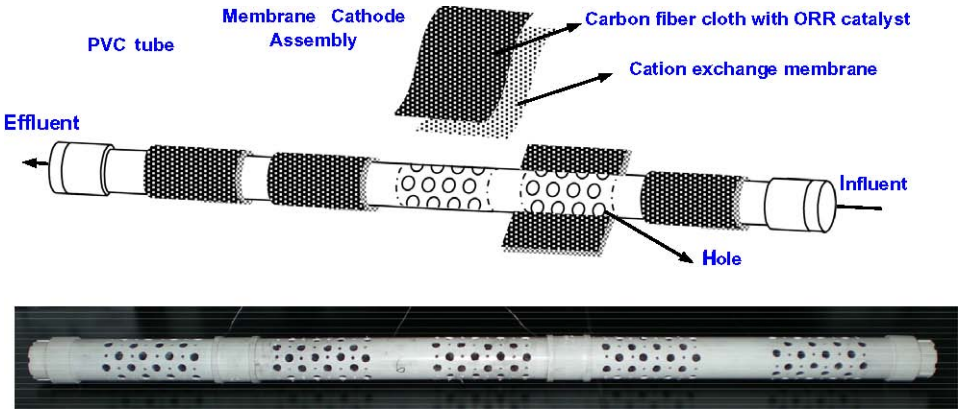
✓No aeration is needed so long as the cathode is passively aerated.

✓There is limited sludge production: Using MFCs could drastically reduce solids production at a wastewater treatment plant, substantially reducing operating costs for solids handling.

- MFCs have the ability to generate energy remotely by using a range of organic feed stocks, and thus be used in areas of poor energy infrastructure.

Different configurations and applications are possible





- **Power generation.**
- **Wastewater treatment.**
- **Bio-sensors.**
- **Bioremediation**

*Ieropoulos, I., Winfield, J., Greenman, J. Melhuish, C., 2010b. Small scale microbial fuell cells and different ways of reporting output. ECS Transactions 28 (9), 1-9.
**Zhuang, L., Zheng, Y., Zhou, S., Yuan, Y., Yuan, H., Chen, Y., 2012 b. Scalable microbial fuel cell (MFC) stack for continuous real wastewater treatment. Bioresource Technology 106, 82-88.
***A. Tremouli, M. Martinos, S. Bebelis, G. Lyberatos. Performance assessment of a four-air cathode single chamber microbial fuel cell under conditions of synthetic and municipal wastewater treatments. *Journal of Applied Electrochemistry*, 2016, 46, 515–525.

Limitations of MFC

- **High initial cost:**

Pt catalysts, Proton Exchange System etc.

- **Low power output:**

High internal resistances and ohmic losses

Long term goal of the present study :

MFC application in areas of poor energy infrastructure.

Specific objectives

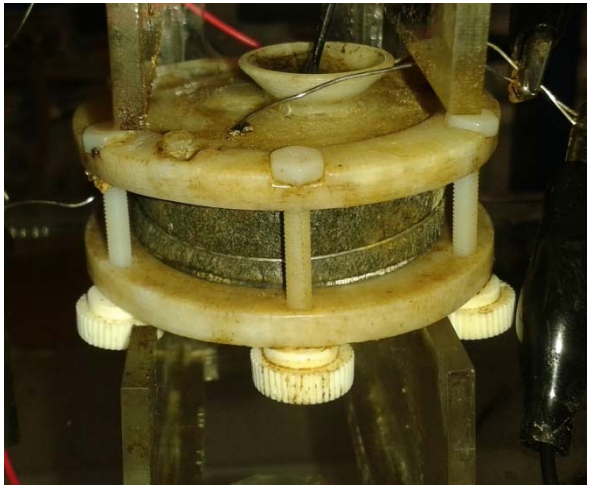
- **Development of an innovative MFC design using low cost materials.**

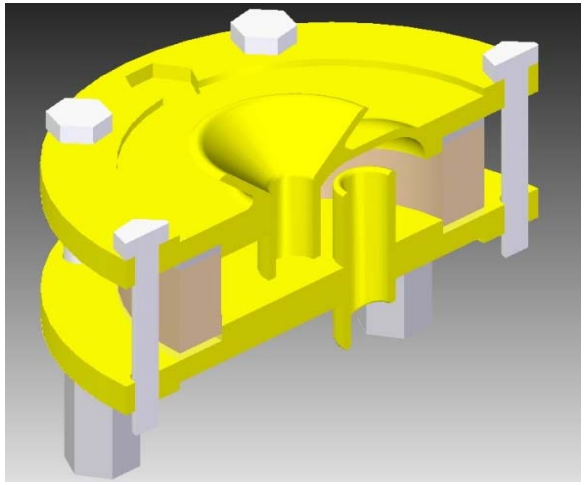
- **Enhance the power output by stacking.**

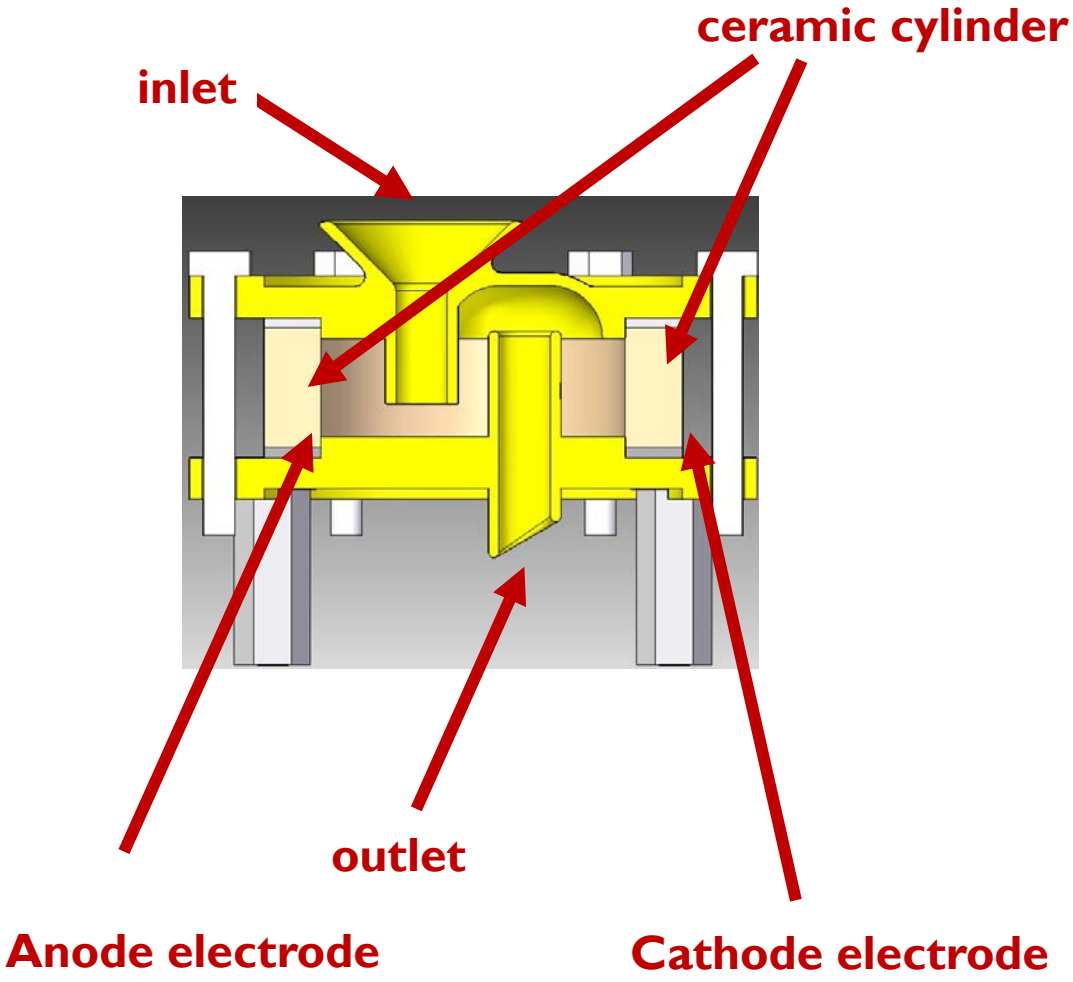
- **Use Urine as a feedstock :** Cost effective and abundant

Urea is enzymatically hydrolysed to ammonia and carbon dioxide.
Ammonia is then oxidised at the anode of the MFC to generate mainly nitrite and in smaller amounts nitrate.

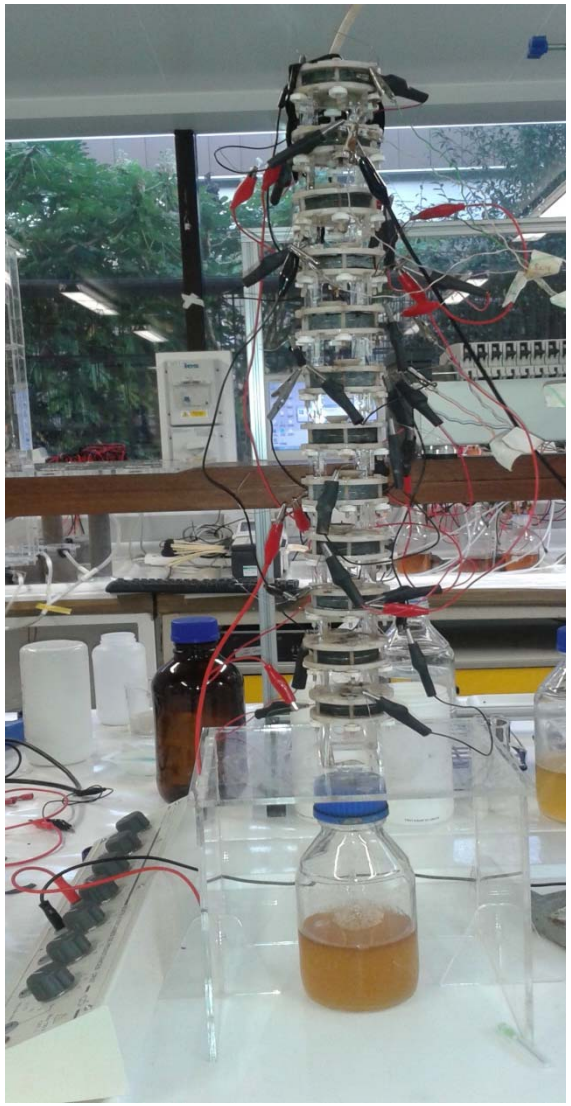
The Ceramic MFC Architecture

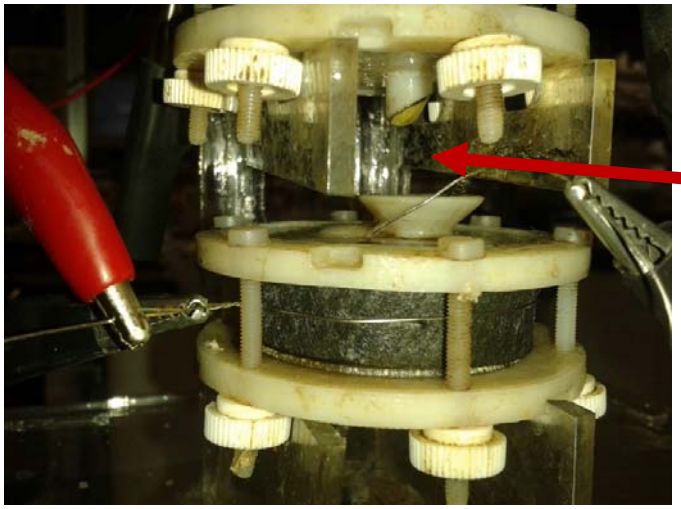






Operation as a stack





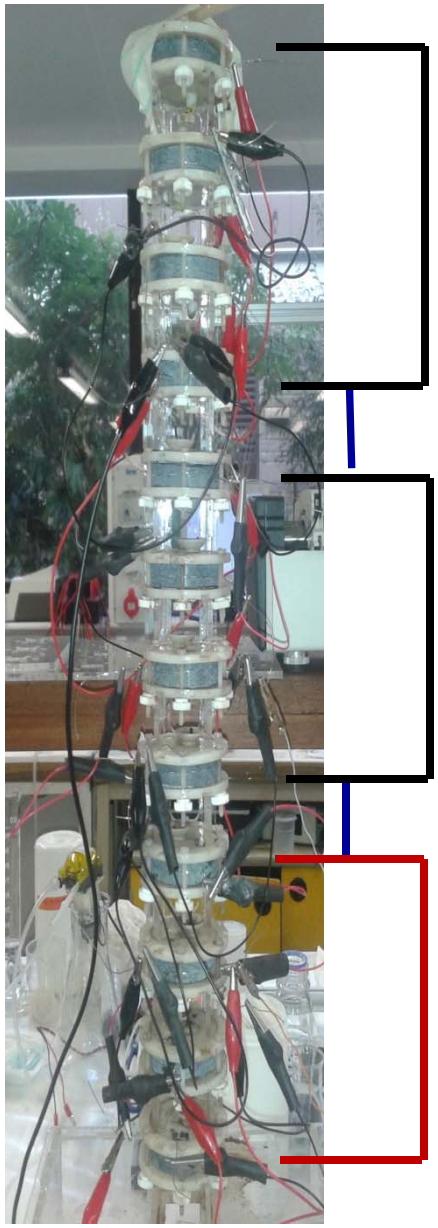
✓Two similar stacks were constructed with two different types of ceramics. Each stack consisted of 12 cells.

Terracotta: (OD 40mm x ID 34mm x Length 11mm)/ Open porosity 25%. ***Mullite:*** (OD 40mm x ID 30mm x Length 11.5 mm) Open porosity 27 %

✓ Anode electrode: carbon veil (s.a. 64.8 cm^2)

Cathode electrode: carbon veil and activated carbon (s.a. 13.75 cm^2)

✓Continuous operation mode (HRT: 0.8 h; flow rate: 7.51 ml/h; V: 6 ml)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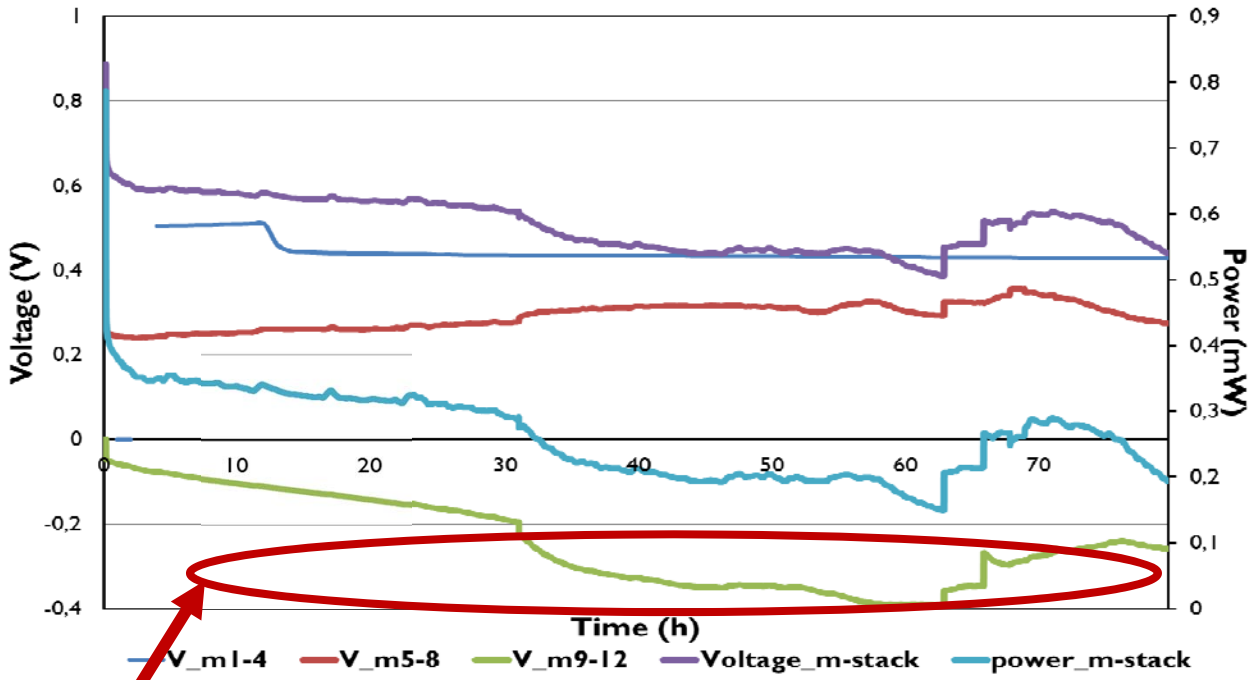
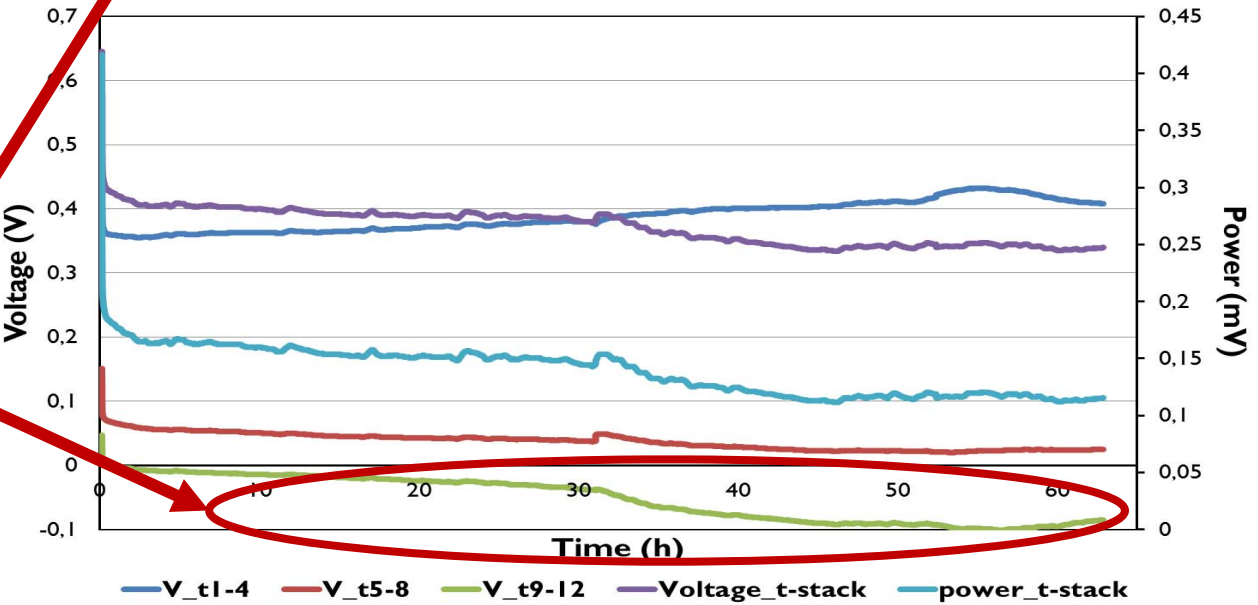

Voltage (V)
Power (mW)
Time (h)
V_m1-4
V_m5-8
V_m9-12
Voltage_m-stack
power_m-stack


Voltage (V)
Power (mV)
Time (h)
V_t1-4
V_t5-8
V_t9-12
Voltage_t-stack
power_t-stack

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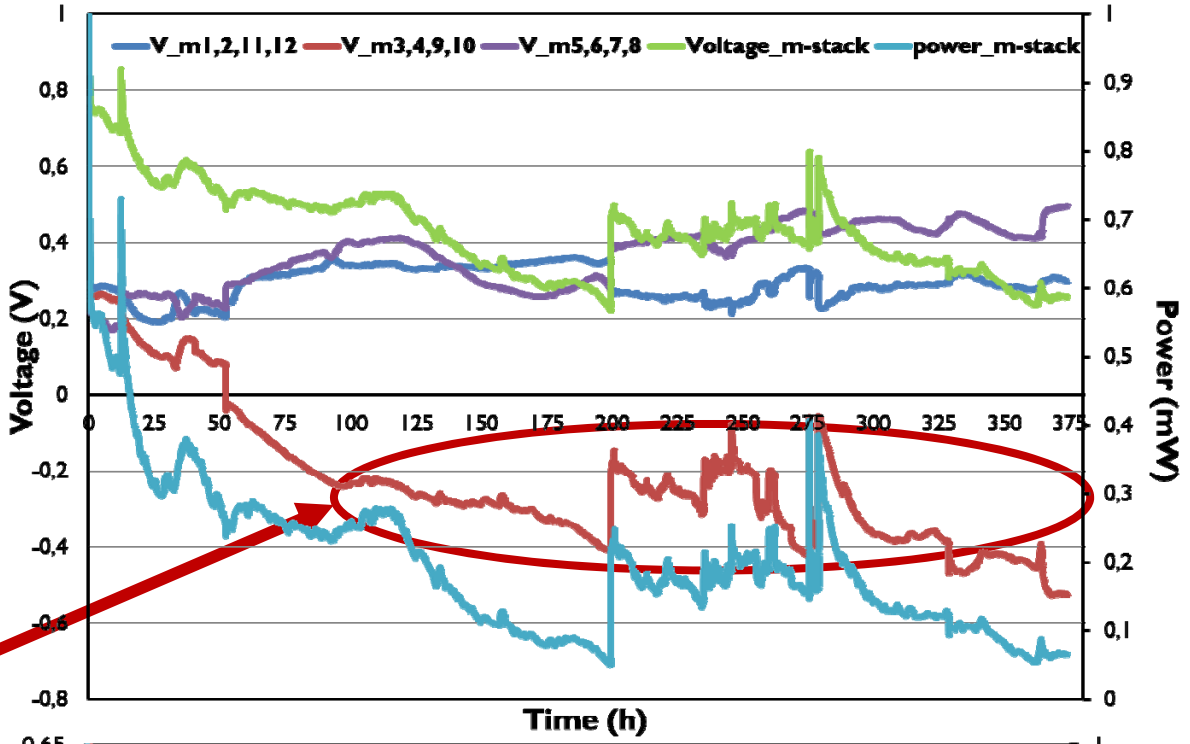
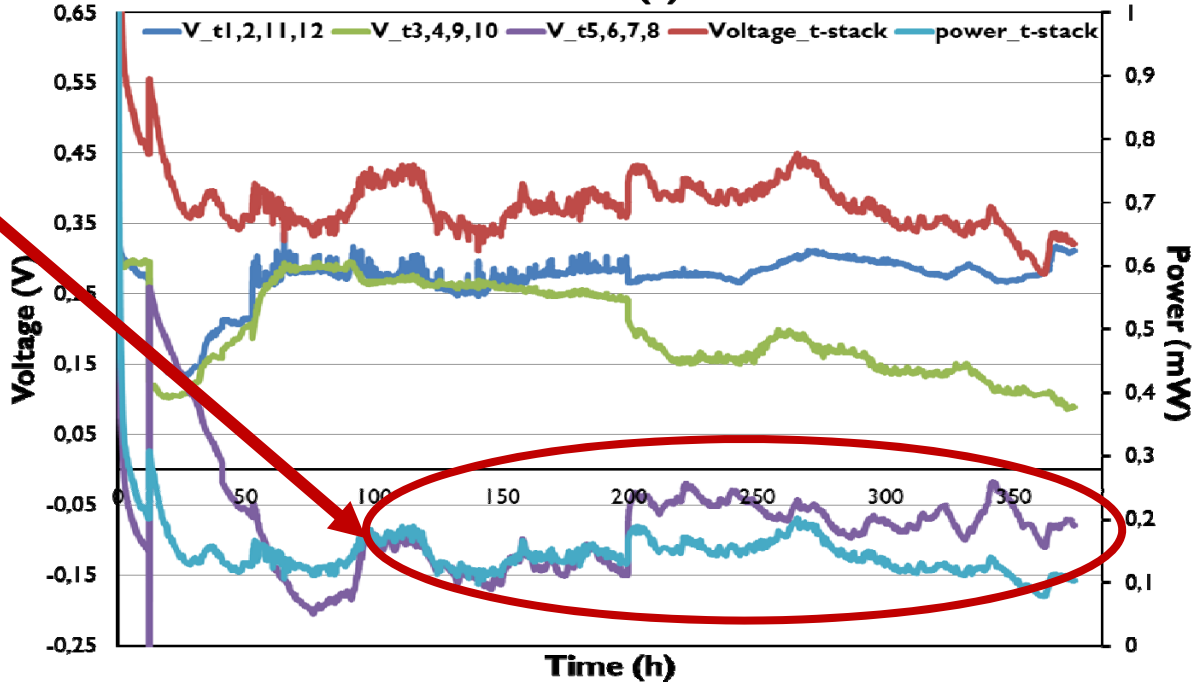
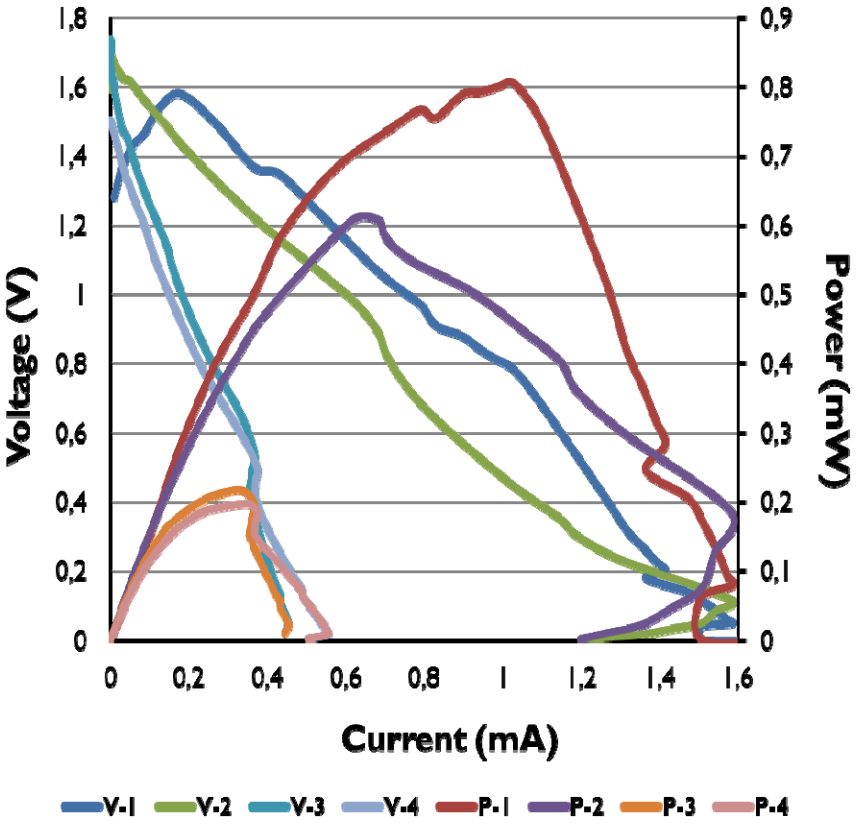
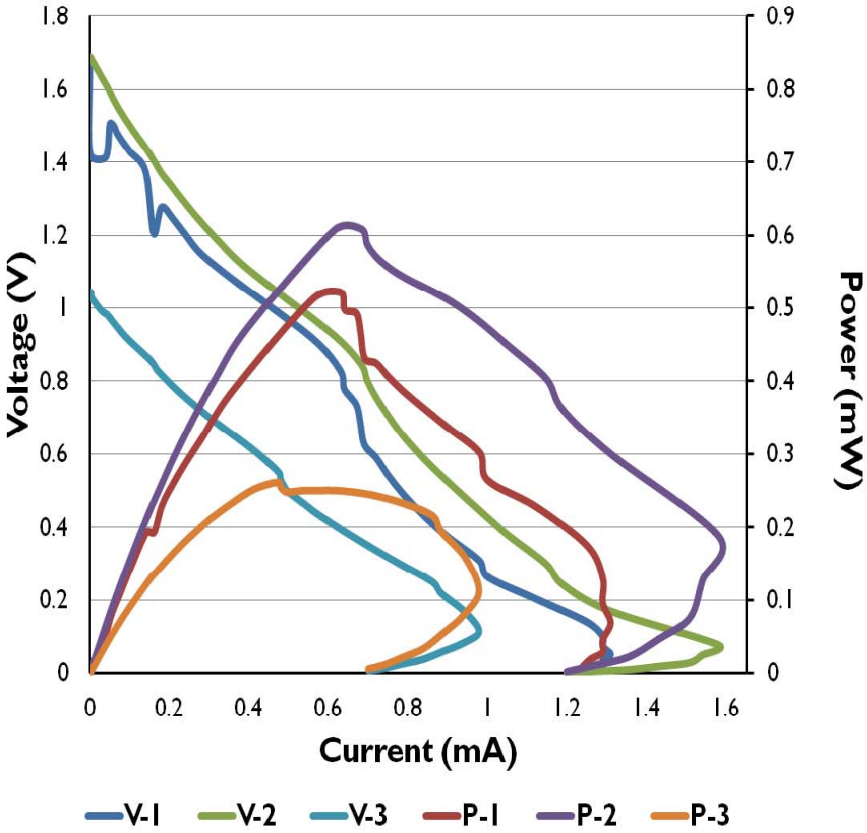

V_m1,2,11,12
V_m3,4,9,10
V_m5,6,7,8
Voltage_m-stack
power_m-stack
Voltage (V)
Power (mW)
Time (h)


V_t1,2,11,12
V_t3,4,9,10
V_t5,6,7,8
Voltage_t-stack
power_t-stack
Voltage (V)
Power (mW)
Time (h)

Polarisation and Power Curves



m-stack



t-stack

- For mullite stack the power decreased from 0.8 mW to 0.2 mW
- For terracotta stack the power decreased from 0.52 mW to 0.25 mW

What causes the power drop during long term operation?

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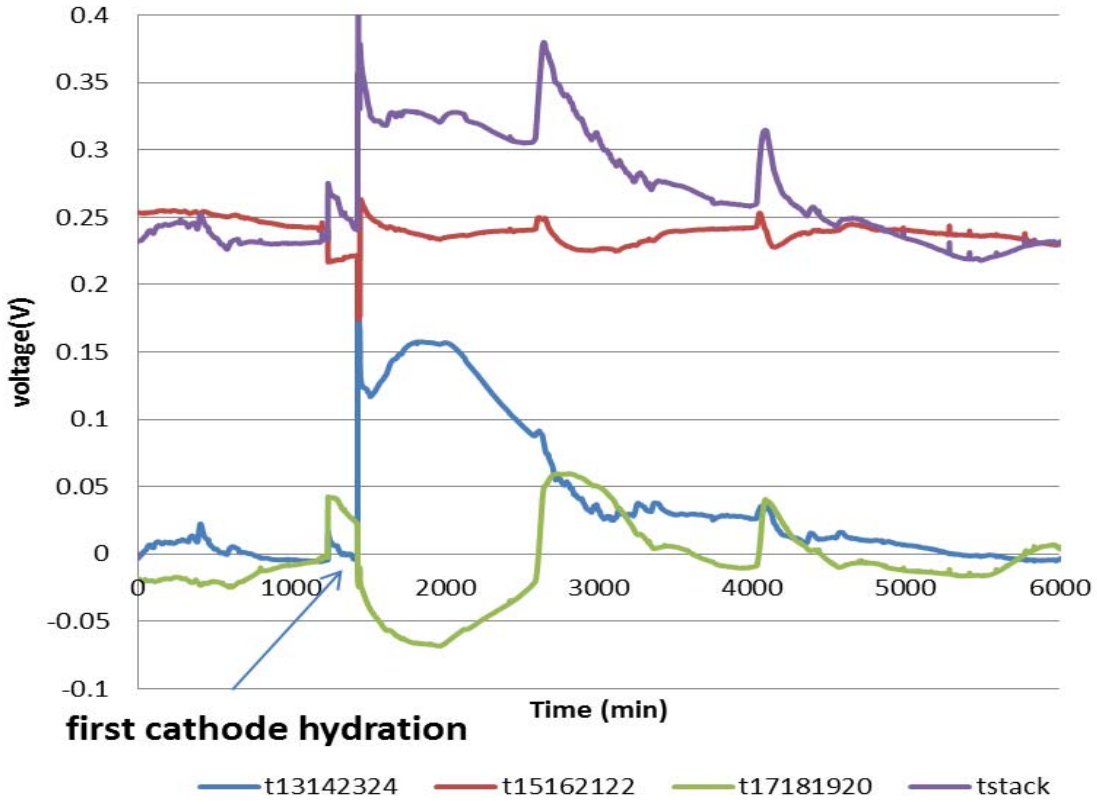

What causes the power drop during long term operation?

5. Increase of the flow rate

✓ **(no improvement)**

6. Struvite ($NH_4MgPO_4 \cdot$ e anode electrodes.

✓ **(no improvement)**

7. Replacement of the an odes with new identical ones

✓ **(no improvement)**

This result indicates that locked during the long term operation of the stacks

Main Conclusions

- **Both ways of electrical connections caused voltage reversal to the stacks.**
- **The voltage reversal shifted with the stack re-configuration.**
- **Maximum power output decreased during time (approximately two months period)**
- **Ceramic material was blocked by the struvite precipitation which was the result of low flow rate.**

Acknowledgements

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Thank you for your attention