BIOFUEL CELL:
An alternative Method for energy production?

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What is biofuel cell?

Biofuel cell ~ Fuel cell

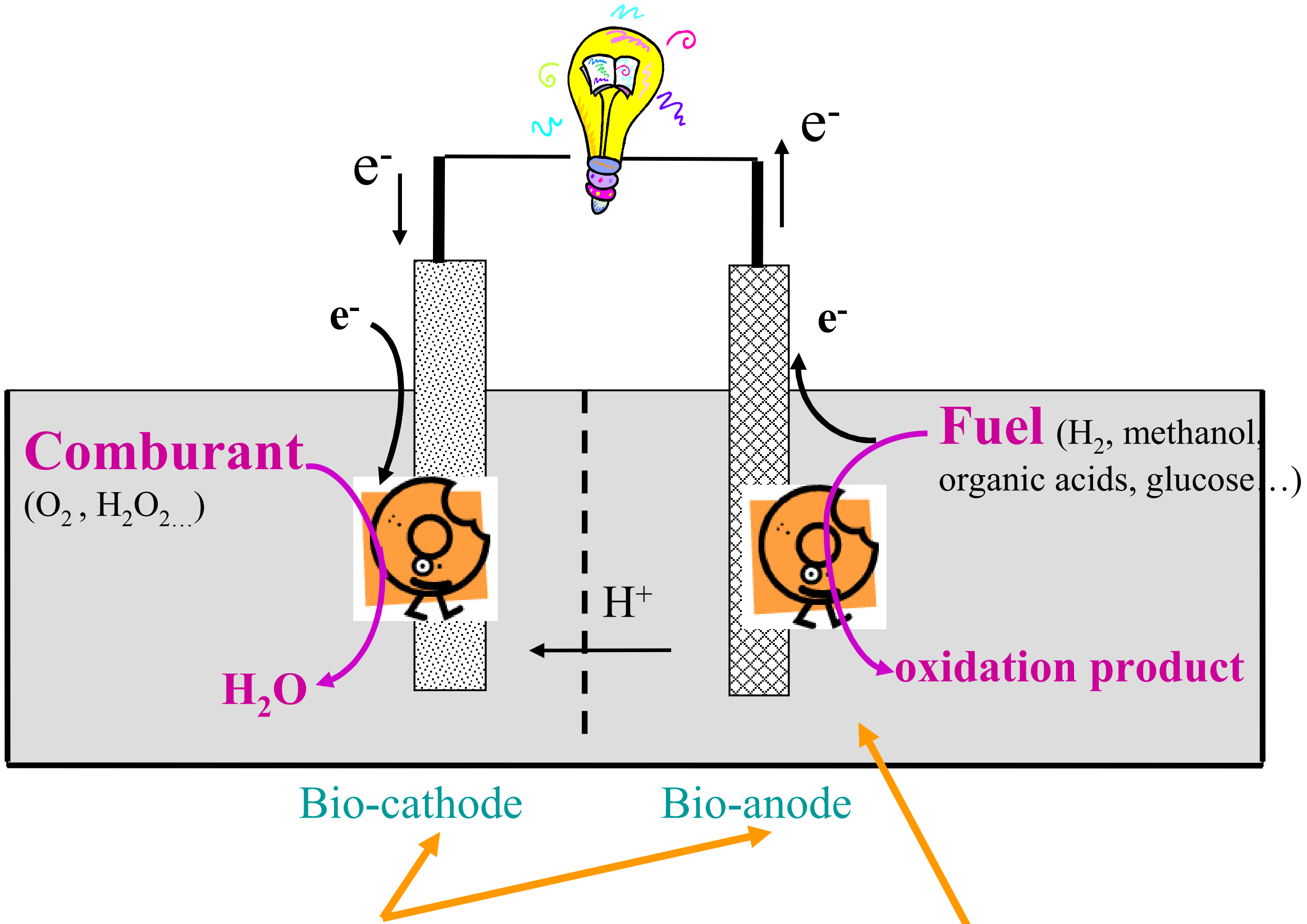
System using catalysts to convert chemical energy directly

in electric current.

Originality = catalysts  are biological

- enzymes
- cells
- microorganisms

Principle



Conductive electrodes

(collecting and carring e^-)

Electrolyte medium

(transporting ions between electrodes)

Fuel Cell / Biofuel Cell

Performances

Fuel cells

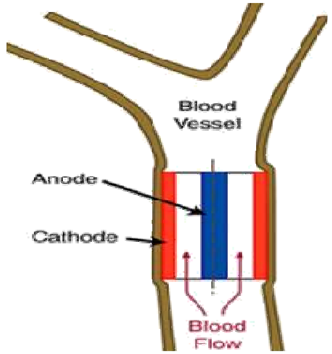
	Medium	*Power released*
alkaline	80°C, KOH concentrated	**100 mW/cm²**
polymer membrane	80°C, Nafion	**200-350 mW/cm²**
solid electrolyte	900-1000°C, solid oxide ceramic	**200-350 mW/cm²**

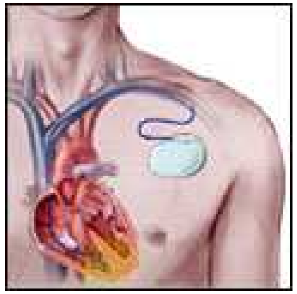
Biofuel cells

	Medium	*Power released*
methanol/O_2	ambient T°, neutral pH (physiological serum) selective catalytic activity	**680 µW/cm²**
glucose/O_2		**4-830 µW/cm²**

Potentials Applications

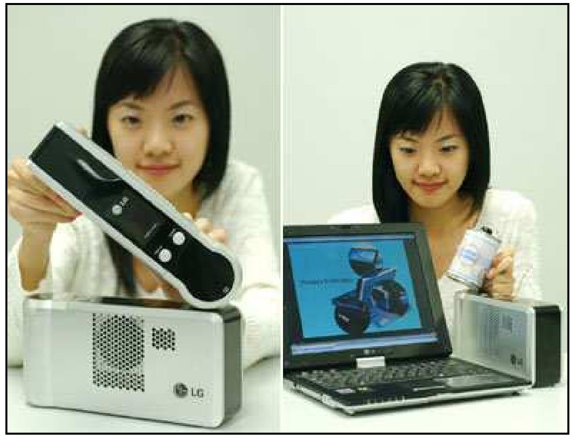
in medecine :





Medical implants

Integrable into medical devices (Sensors, Drug delivery…)



in computing and communication:

Micro-chips, portable power supplies for mobil phone or laptop computer (systems releasing low powers on long time periods , and micro-engines realization)

Assets and Weaknesses

• ASSETS

- Selectivity of enzymes

specific and defined reactions

-Potentially low cost production

(Biotechnologies)

- Operational conditions
(physiological conditions)

• WEAKNESSES

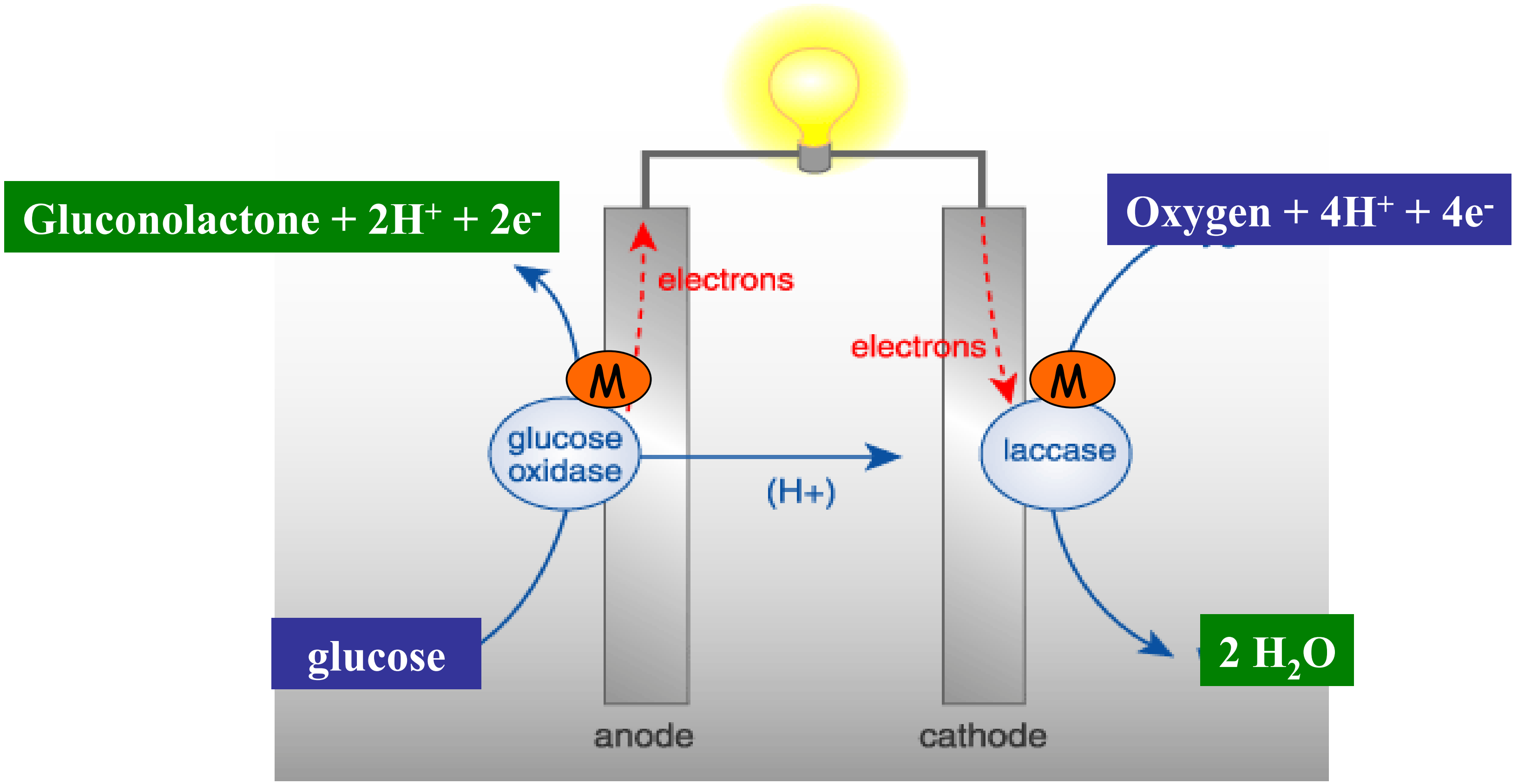
-Short lifetime

low stability of biocatalysts

-Low power density

electron conduction

Biofuel cell studied : Glucose/O_2

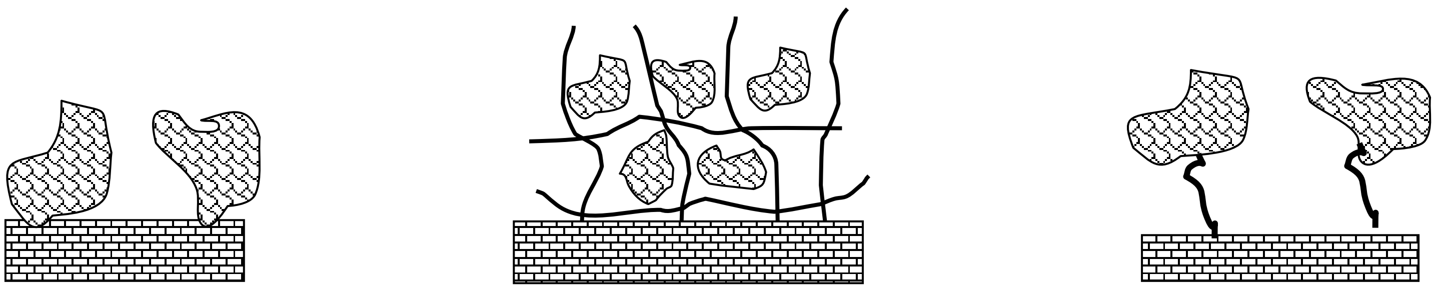


M Redox mediator

Glucose/O_2 biofuel cell

Differences between the existing biofuel cells

- ***1. Redox enzymes** (for biocathode: laccase, bilirubin oxidase..)*
- ***2. Redox mediators** (for glucose oxidation: ferrocene, Os, Ru, quinone…)*
- ***3. Immobilization methods***



At the European Membrane Institute…

• OBJECTIVE

Development of tubular bioelectrodes modified by co-immobilized enzyme/ mediator system. Application to glucose/oxygen biofuel cell.

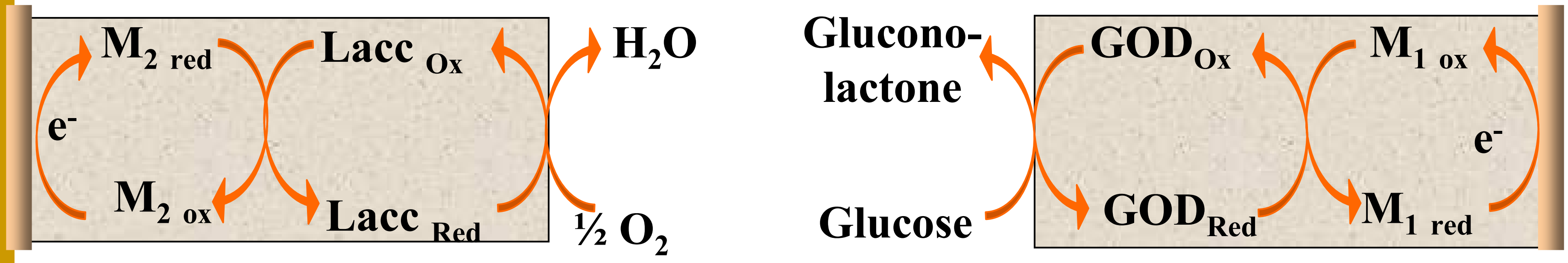
• ORIGINALITY

1. *design of the system*

2. *co- immobilization of enzyme/mediator system on electrode*

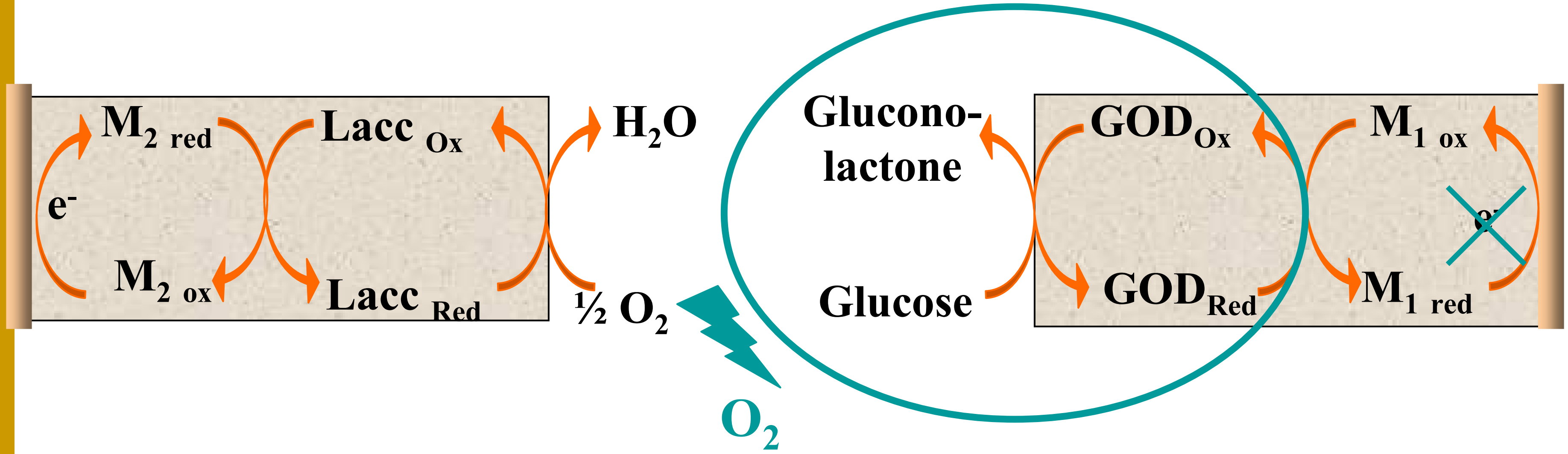
Glucose/O_2 biofuel cell

1. Design of the system



Limit of the system!

1. **Design of the system**



secondary reaction

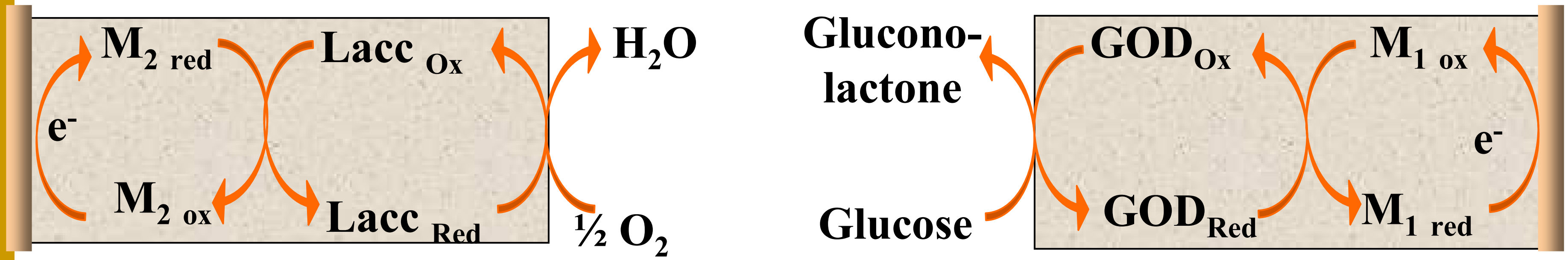
$$C_6H_{12}O_6 + O_2 + H_2O \xrightarrow[GOD]{} C_6H_{12}O_7 + H_2O_2$$

✓ electron flow through the anode ↘

✓ output voltage ↘

Strategy

1. **<u>Design of the system</u>**



1. Engineering of the enzymes and mediators

- Reconstituted GOD less sensitive to the presence of oxygen

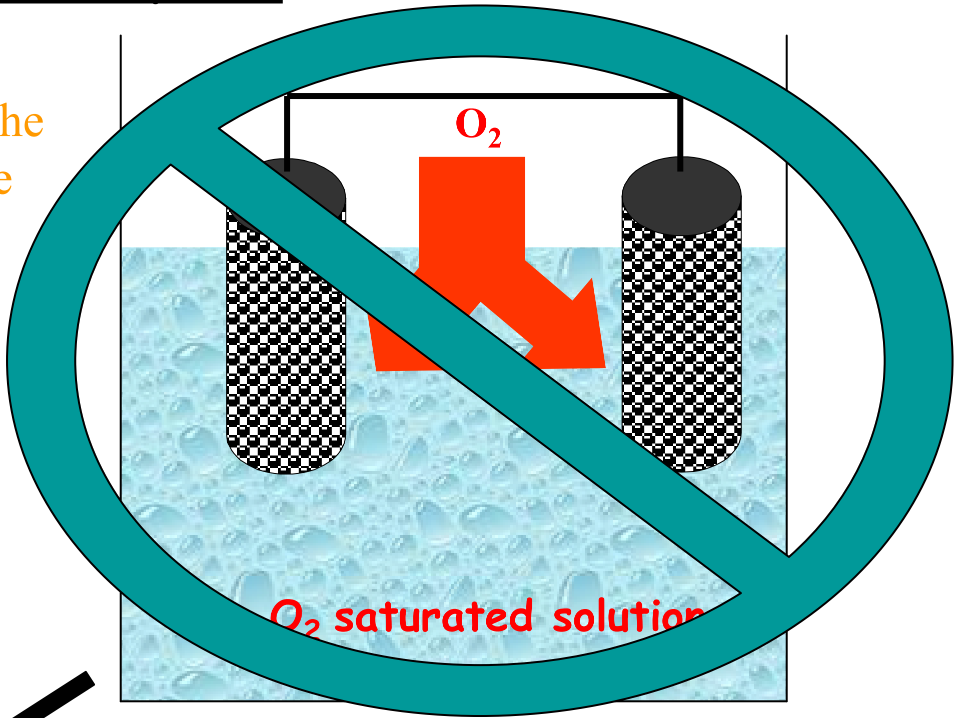
- Mediators generating more effective electron mediation with GOD than O_2

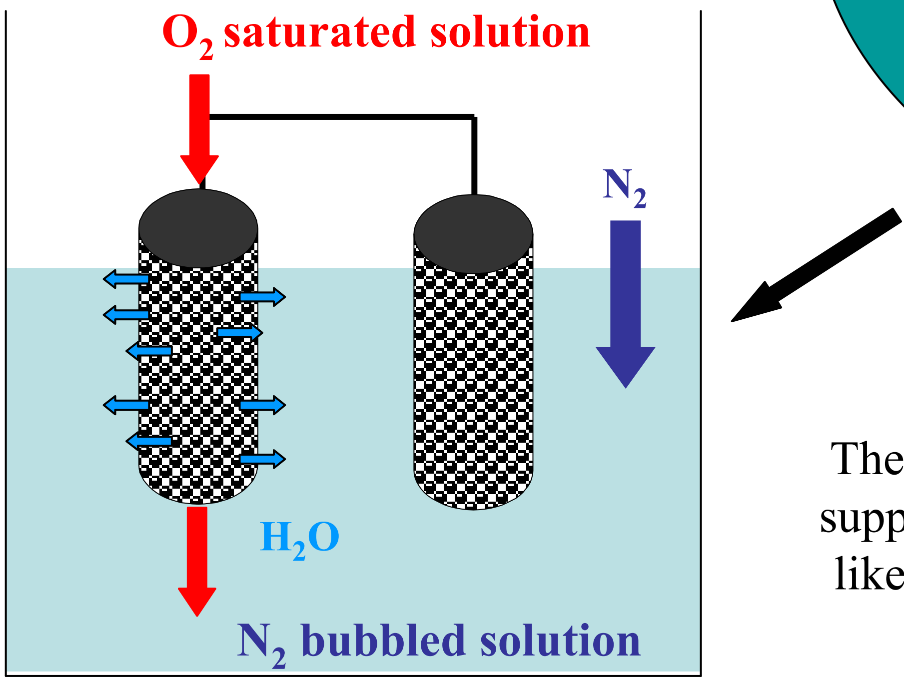
2. Engineering of the system

Strategy of the work

1. Design of the system

Development of a new configuration of the system to supply O_2 separately from the electrolyte

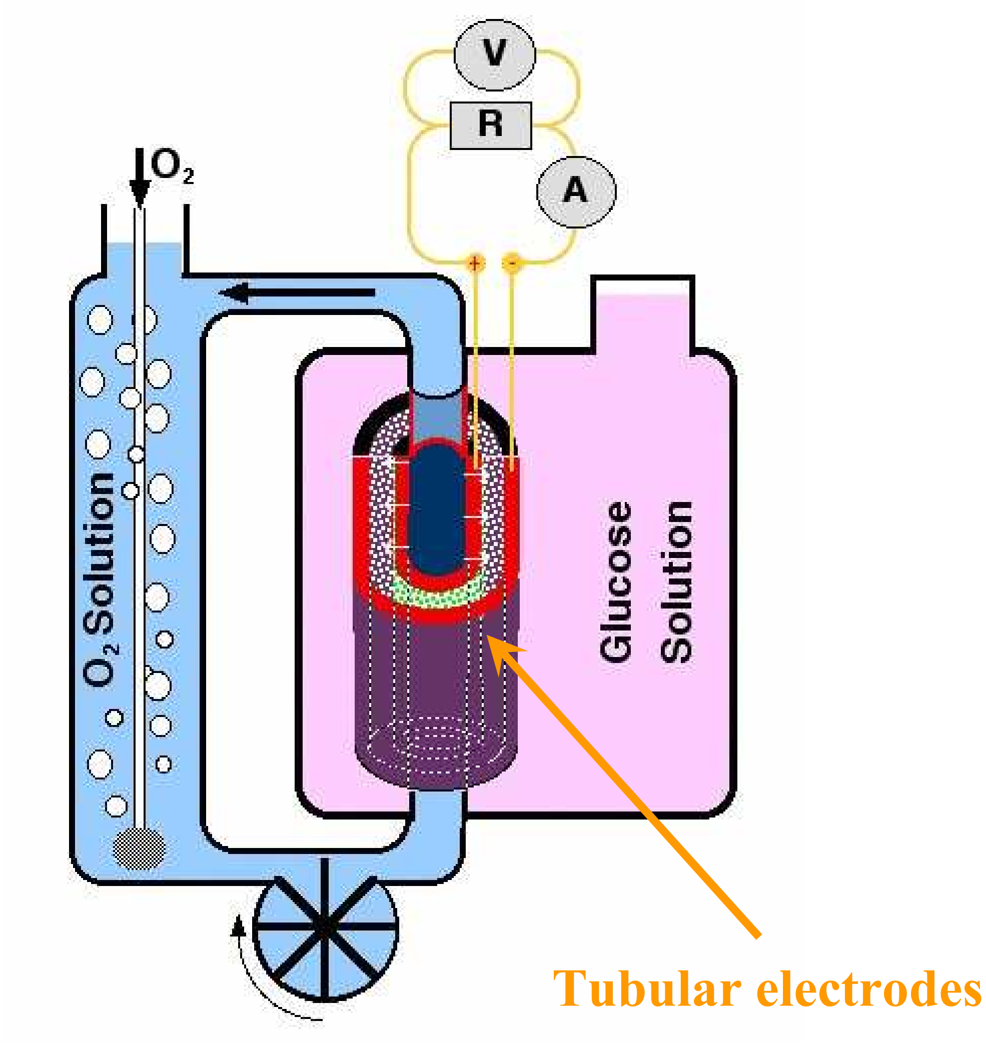




The inside of the cathode tube is continuously supplied by saturated dioxygen solution that is likely to diffuse from the inner to the external surface of the porous tube.

Prototype

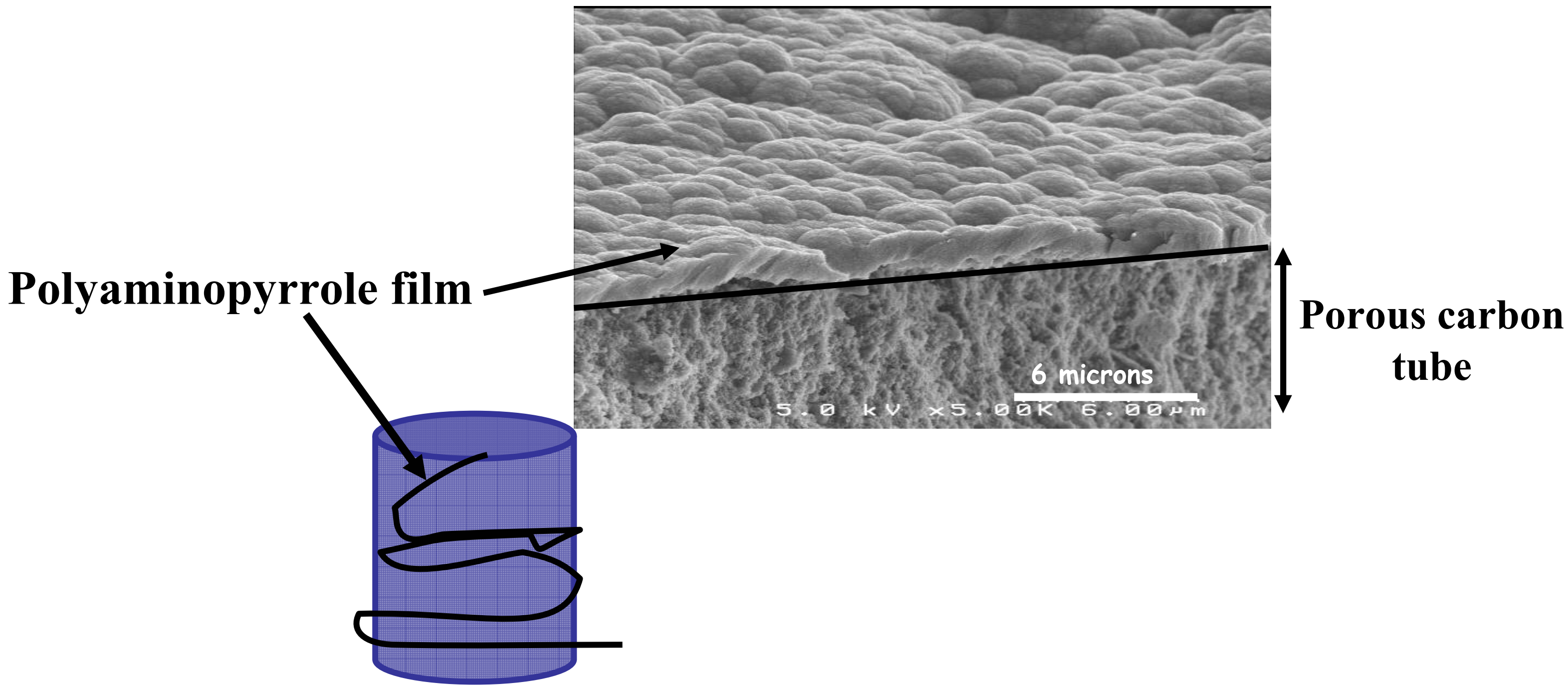
1. Design of the system



Originality of the work

2. Co- immobilization of the Enzyme/ mediator system on conducting support

Modification of the electrode surface with an original conducting polymer



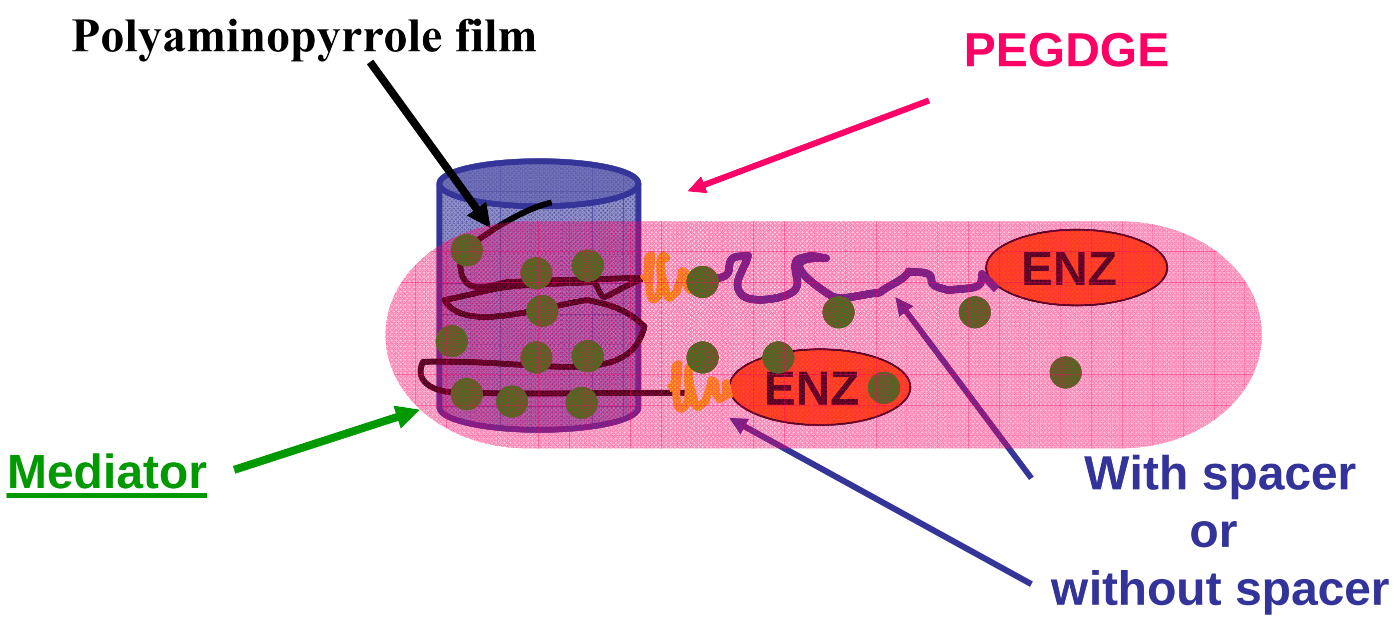
Originality of the work

2. Co- immobilization of the Enzyme/ mediator system on conducting support

⇨ *Modification of the electrode surface with an original conducting polymer*

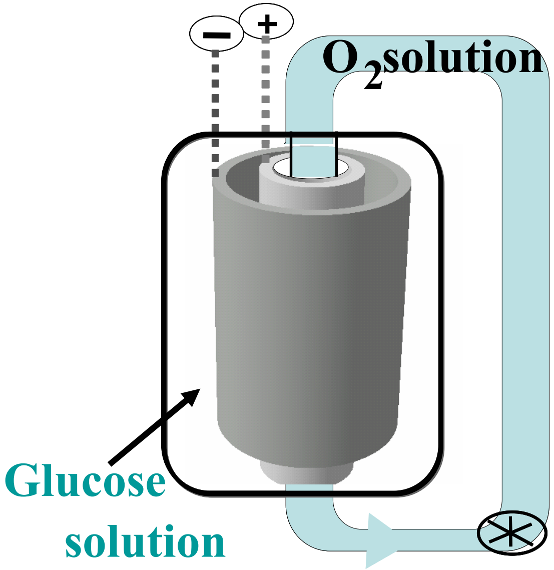
⇨ *Covalent binding of enzyme via an electropolymerized functionnalized film*

⇨ *Entrapment of mediator whitin an derivative of Polyethylene glycol matrix*



⇨ *Enzymatic activity of modified electrodes determined by UV spectrophotometry*

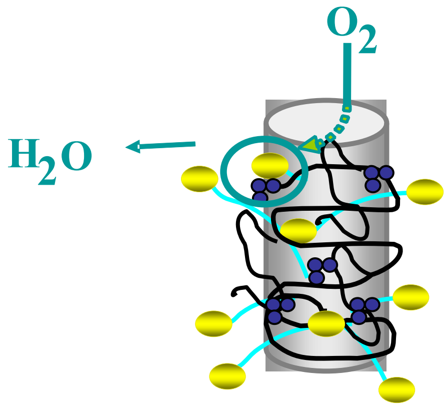
Construction of the Biofuel Cell



Bio- cathode:

•Covalent grafting of BOD with a long spacer,

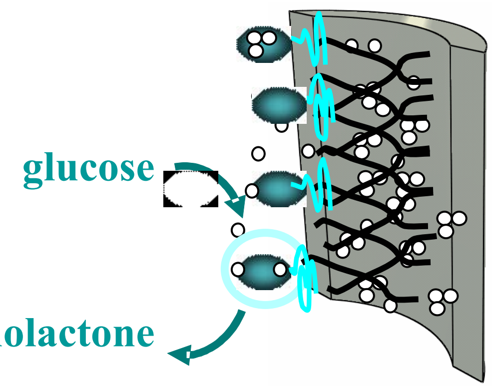
• Adsorption and entrapment of mediator in PEG



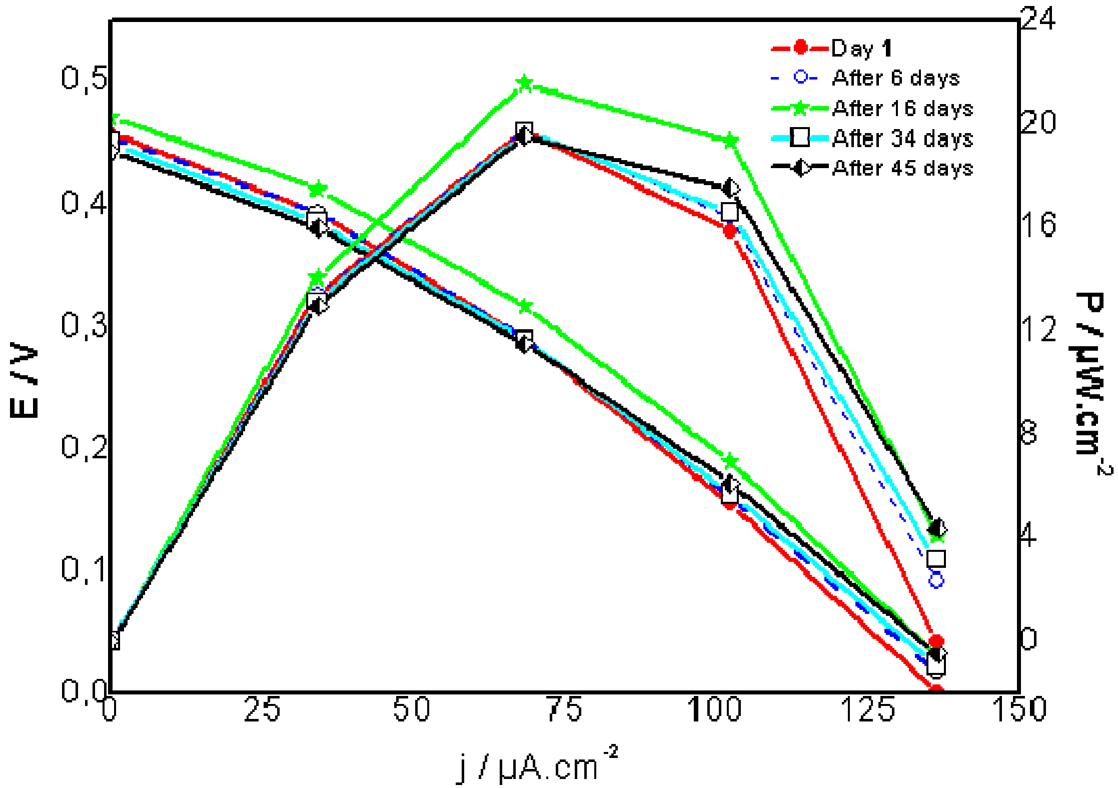
Bio- anode:

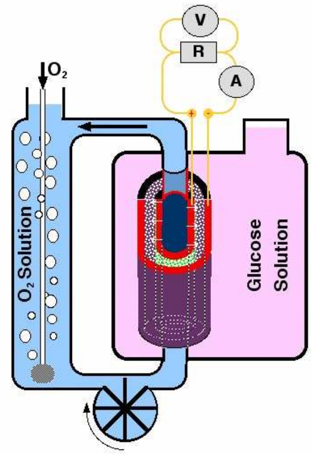
• Covalent grafting of GOD without spacer,

• Adsorption and entrapment of mediator in PEG



Performances of the biofuel cell (GOD, BOD)





Conditions:
37°C, pH 7.4
10 mM Glucose

P_{max} = 25 µW/cm² at 0.3 V

After 2 months, P ~ 99 % of its initial value!!!

Conclusion

➢ Nature of electrode:

Carbon porous tubes are original conducting supports :

for enzyme and mediator co- immobilization

for transport of dissolved O_2 solution via laminar flow through the porosity

➢ The feasibility of the co-immobilization of both enzyme and its mediator on a modified conducting support.

➢ Biofuel cell efficiency improved by using an electrode as membrane separator

Outlooks

2 objectives

• Improvement of the interaction between enzyme-mediator-electrode:
(in using another mediators :Ru and Os complexes)

• Improvement of the nature of the carbon tube. (porosity, surface)

MANY THANKS TO…

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novasep for the life sciences

Société Orélis

ministère éducation nationale enseignement supérieur recherche

ministère délégué à l'enseignement supérieur et à la recherche

ACI – Jeunes Chercheurs

Originality of the work

carbon porous tubes (porosity = 1-3 mm)

as original conducting support as cathode and oxygen contactor

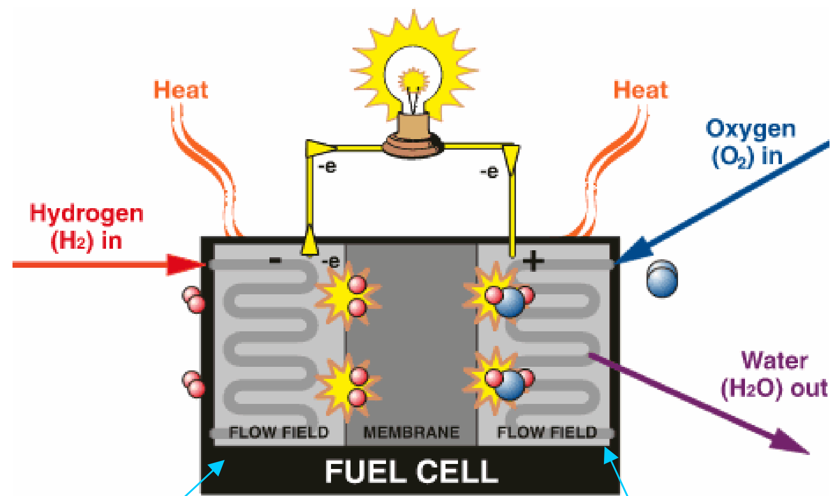
Orélis (Novosep Group)

Working principle

- Fuel cell core = cathode/electrolyte/anode assembly
  - Anode: Oxidation of hydrogen
  - Cathode: Reduction of oxygen
  - Electrolyte: diffusion of ions / tightness to input gases

- Exothermic reaction with production of water

Proton Exchange Membrane Fuel Cell (PEMFC)

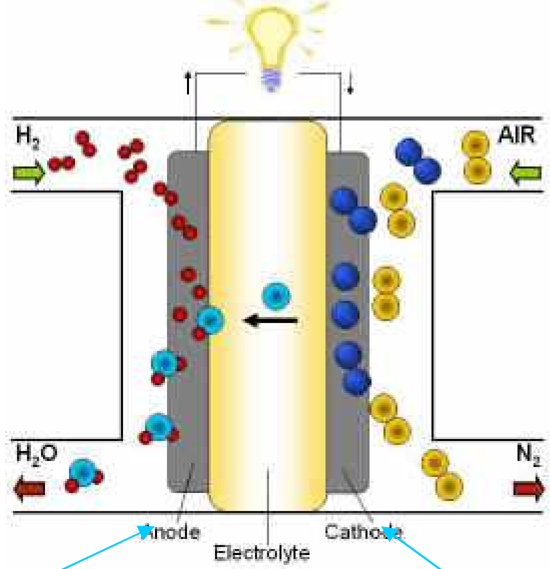


$H_2 \rightarrow 2H^+ + 2e^-$

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

Acid electrolyte

Solid Oxide Fuel Cell (SOFC)



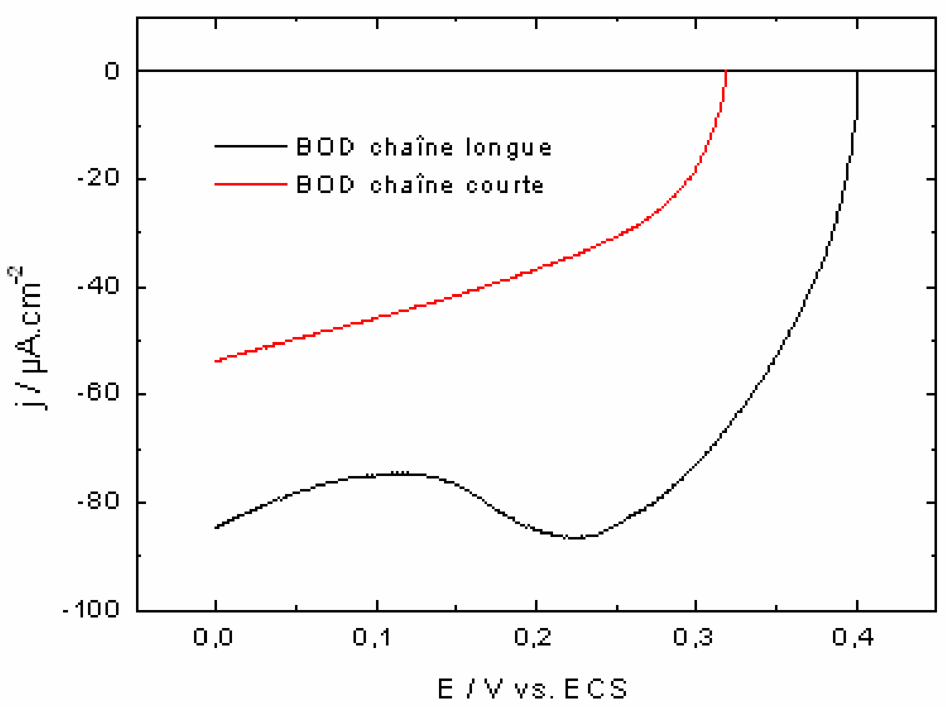
$H_2 + O^{2-} \rightarrow H_2O + 2e^-$

$\frac{1}{2} O_2 + 2e^- \rightarrow O^{2-}$

Alkaline electrolyte

Résultats électrochimiques

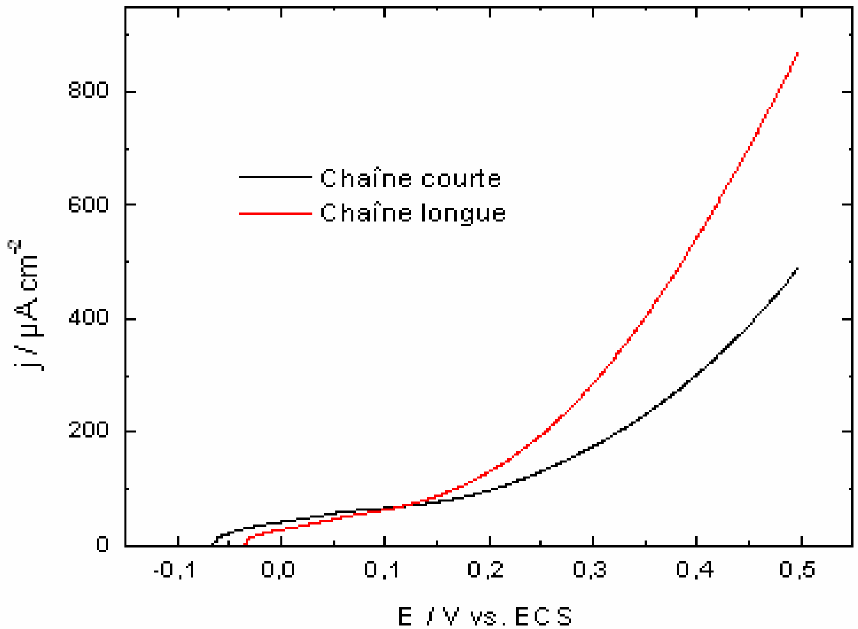
Courbes de polarisation en milieu tampon phosphate 0,2 M (pH = 7,4) à 37°C.



L'activité de la BOD greffée sur une chaîne longue semble très supérieure à celle de la BOD greffée sur chaîne courte. Vous noterez que l'écart entre les potentiels d'équilibre des deux électrodes est très important.

Résultats électrochimiques

Courbes de polarisation obtenues en milieu tampon phosphate 0,2 M (pH = 7,4) 37°C en présence de 10 mM de glucose.



Ces deux courbes montrent qu'aucune différence d'activité électrochimique significative n'est observée entre la configuration chaîne courte et la configuration chaîne longue