

MFC bioanodes constituted of nickel sulfide nanoparticles and electroactive biofilm.

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Microbial Fuel Cell (MFC)

Microbial fuel cells (MFCs) are bioelectrochemical systems allowing the generation of electricity from the bio-catalytic oxidation of organic compounds by electro-active bacteria at the anode and the electrochemical reduction of a final electron acceptor at the cathode

Sustainable, wastewater treatment, ... but low power systems

At the bioanode

the transfer of electrons can be improved by several means :

Increase electrical conductivity (metal-based anode ?)

Promote the attachment of bacteria and biofilm (surface area, roughness, hydrophilic)

Introduce a compound which has suitable redox properties

Nickel metal

Schröder's study (ees 2015): Ni (0.4 mA cm^{-2}) < Ag, Au or Cu

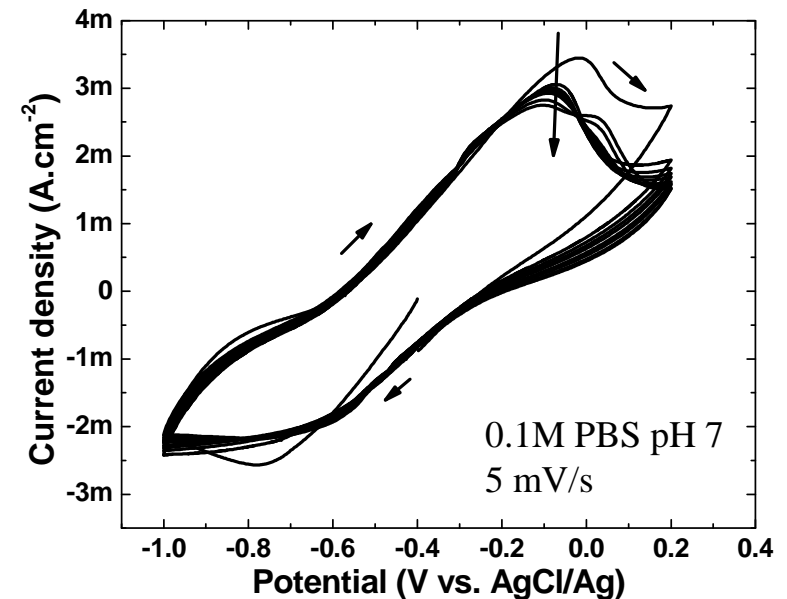
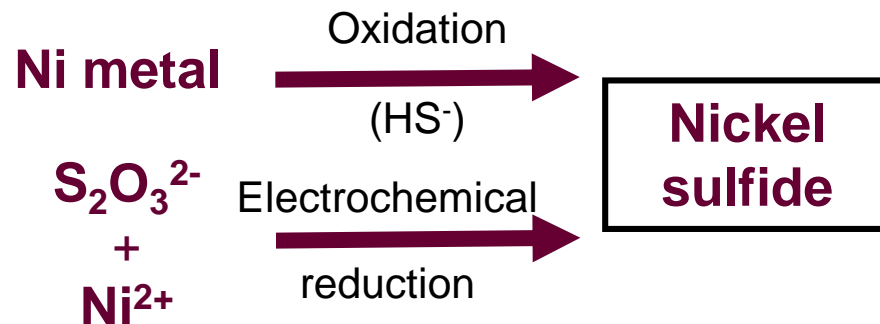
Ni = passivated metal ???

About nickel sulfide

- Sulfide species occur in reducing environments (stable in MFC anolyte)
- Redox couples involving sulfide species have low potential values

redox couple $\text{Ni}_3\text{S}_2 / \text{Ni}$ $E = -0.70 \text{ V vs AgCl/Ag}$
 (0.1 M Na_2SO_4 garden compost solution)

- Nickel sulfide displays stable electrochemical activity in a potential range of interest for bioanode application
- Low solubility and good electrical conductivity
- Formation of nickel sulfide



Experimental

Glass cell with 5 holes and containing 170 mL of electrolyte

Working electrode: bioanode

Disc 2 cm²

Nickel, carbon cloth

Low Surface/Volume ratio
 $S/V = 0,012 \text{ cm}^{-1}$



Reference electrode
AgCl/Ag, KCl 3M

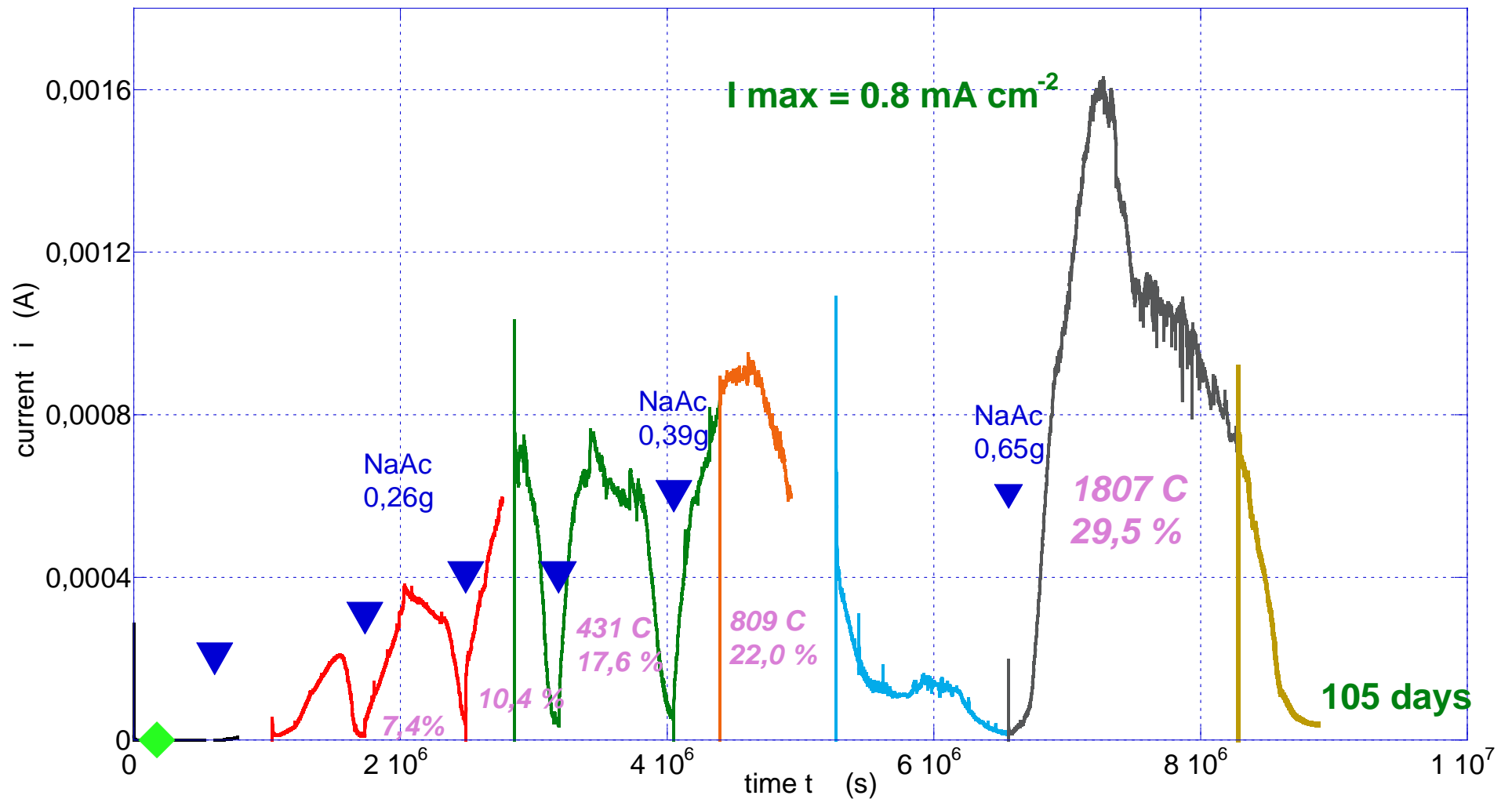
Counter electrode:
304 SS grid

Electrolyte 40°C = garden compost solution + 60 mM KCl
+ Acetate addition (20-60 mM)

Chronoamperometry -0.2V Voltammetry

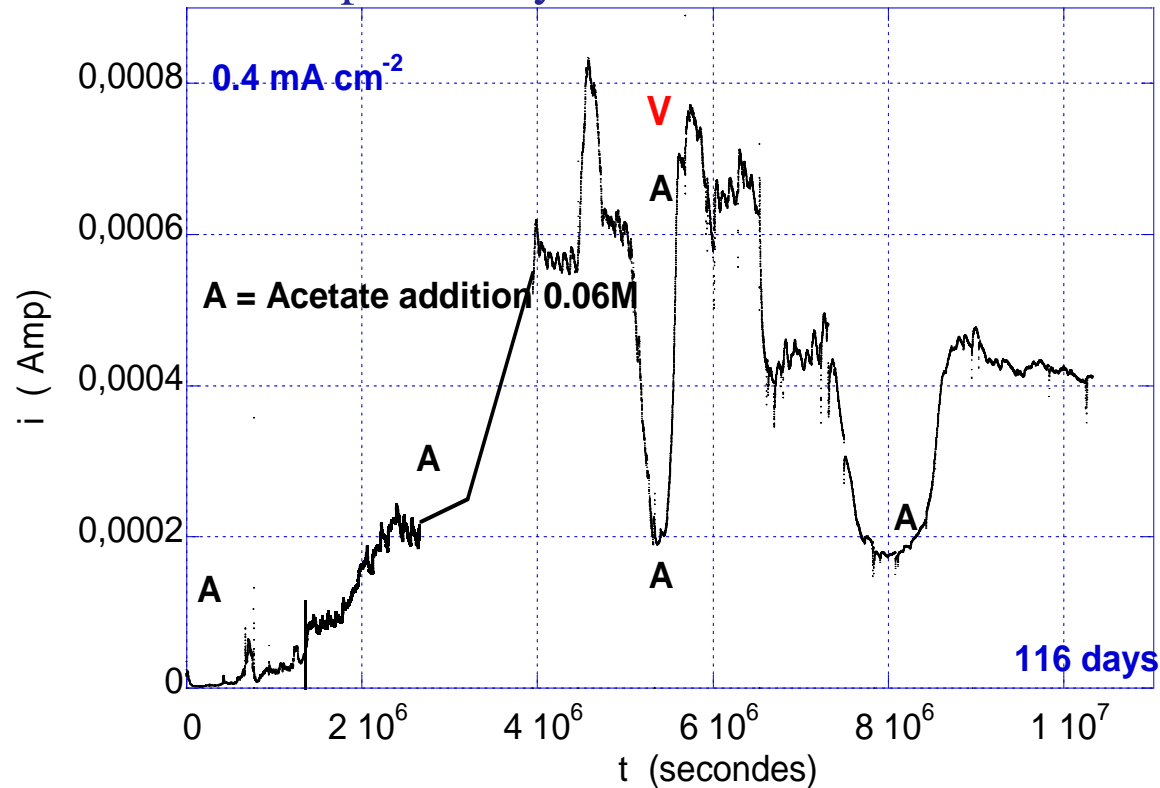
Biofilm growth on Ni disc 1

Chronoamperometry

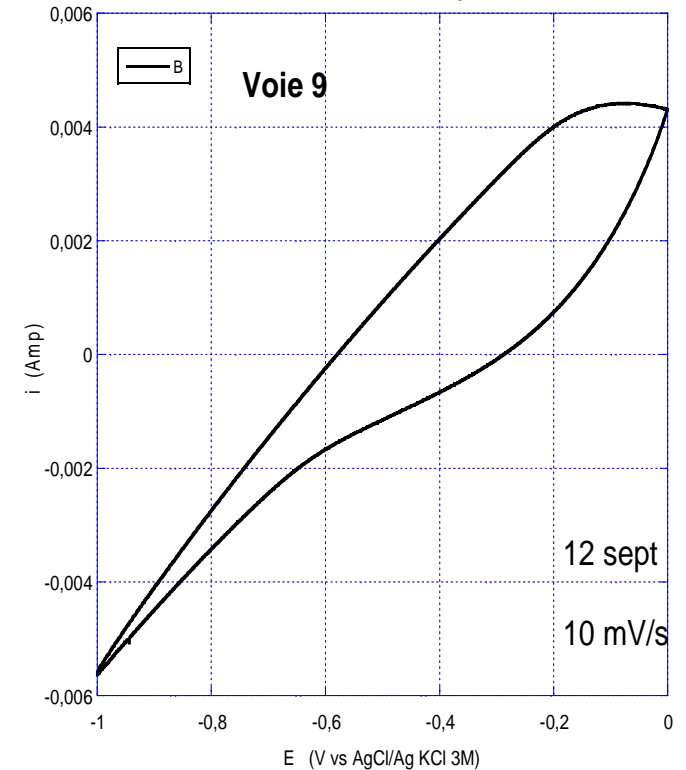


Nickel disc 2

Chronoamperometry



Voltammetry



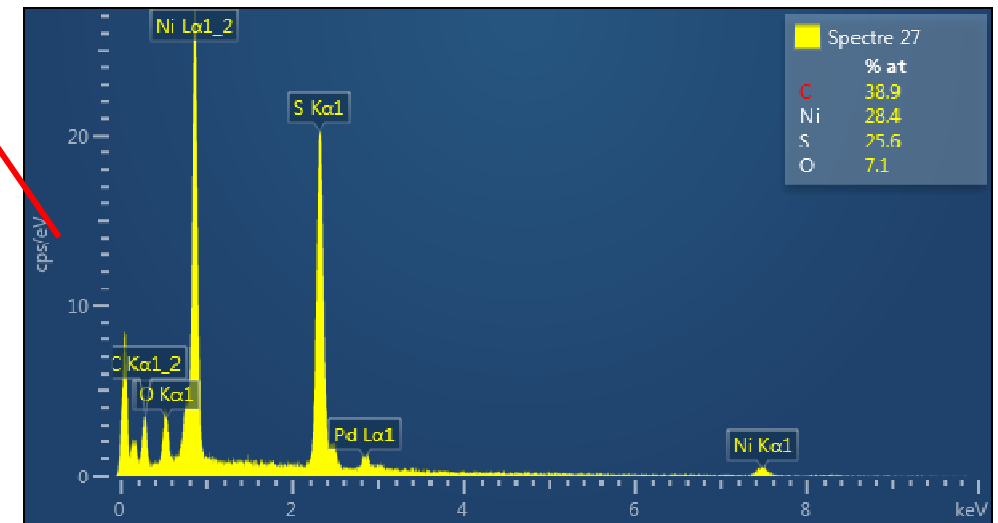
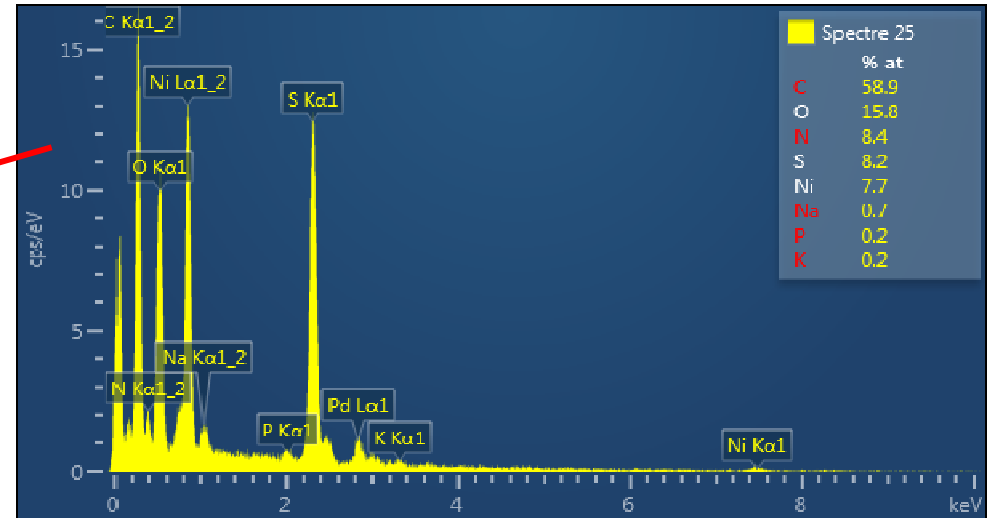
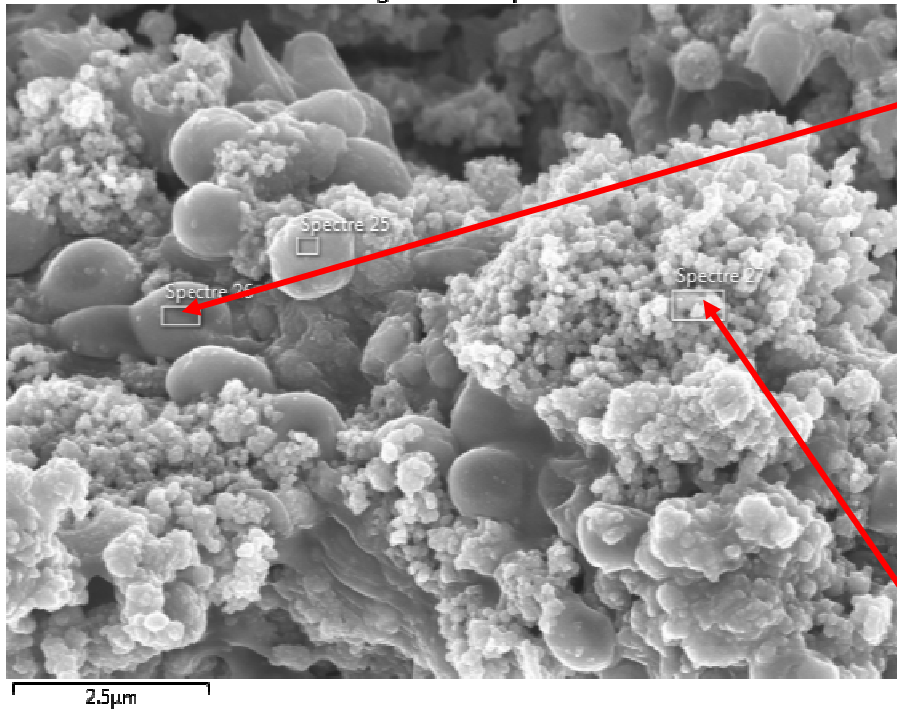
- Black and thick layer of biofilm and nickel sulfide (2-3 mm)
- Low consumption of Ni metal ... (if low H_2S amount)
- $I_{\text{max}} 0.4 \text{ mA/cm}^2$ (value in agreement with Schroeder 2015)
- Voltametric response displaying mainly nickel sulfide redox processus



Nickel disc 2

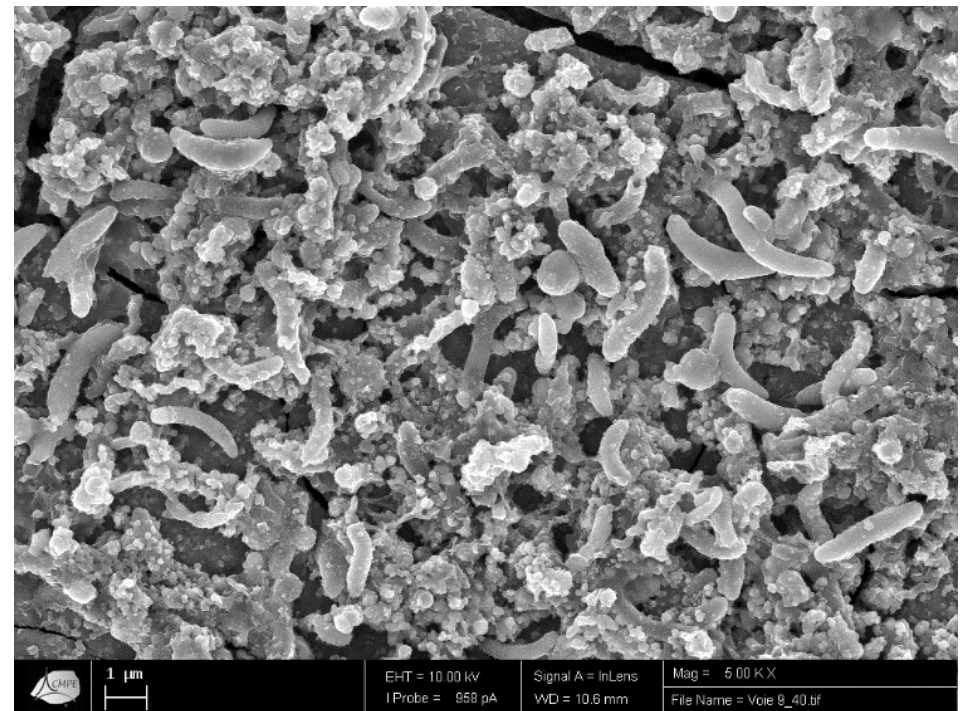
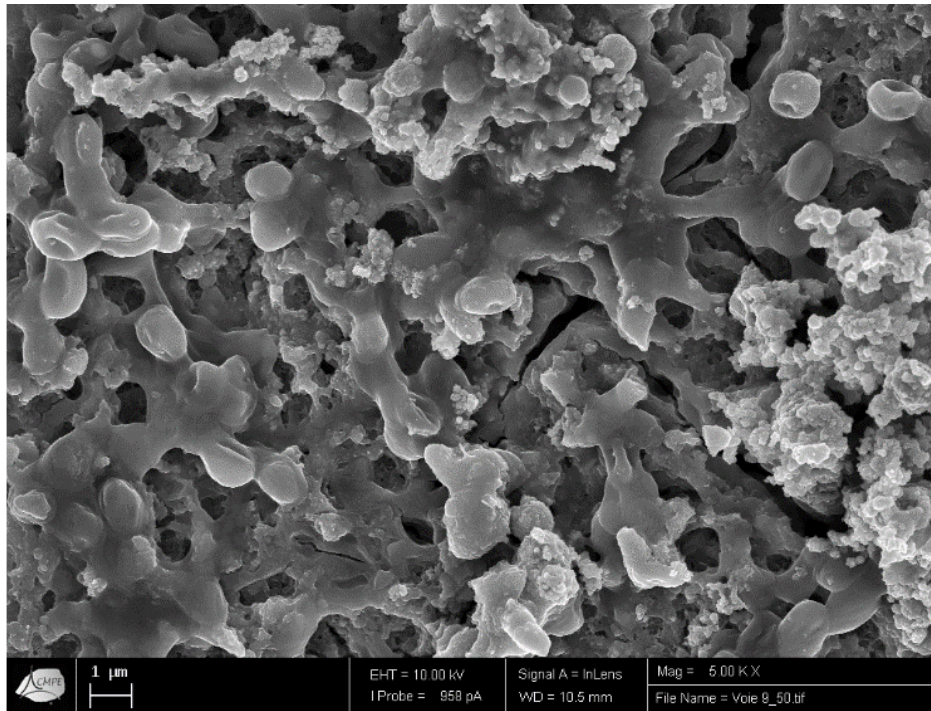
SEM and EDS

Image électronique 11



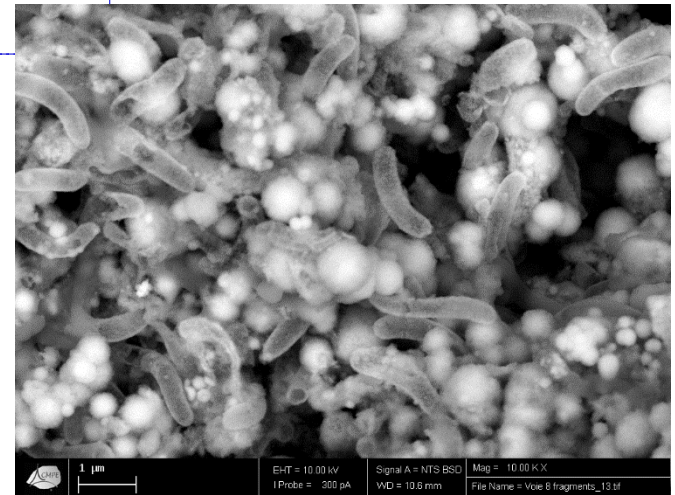
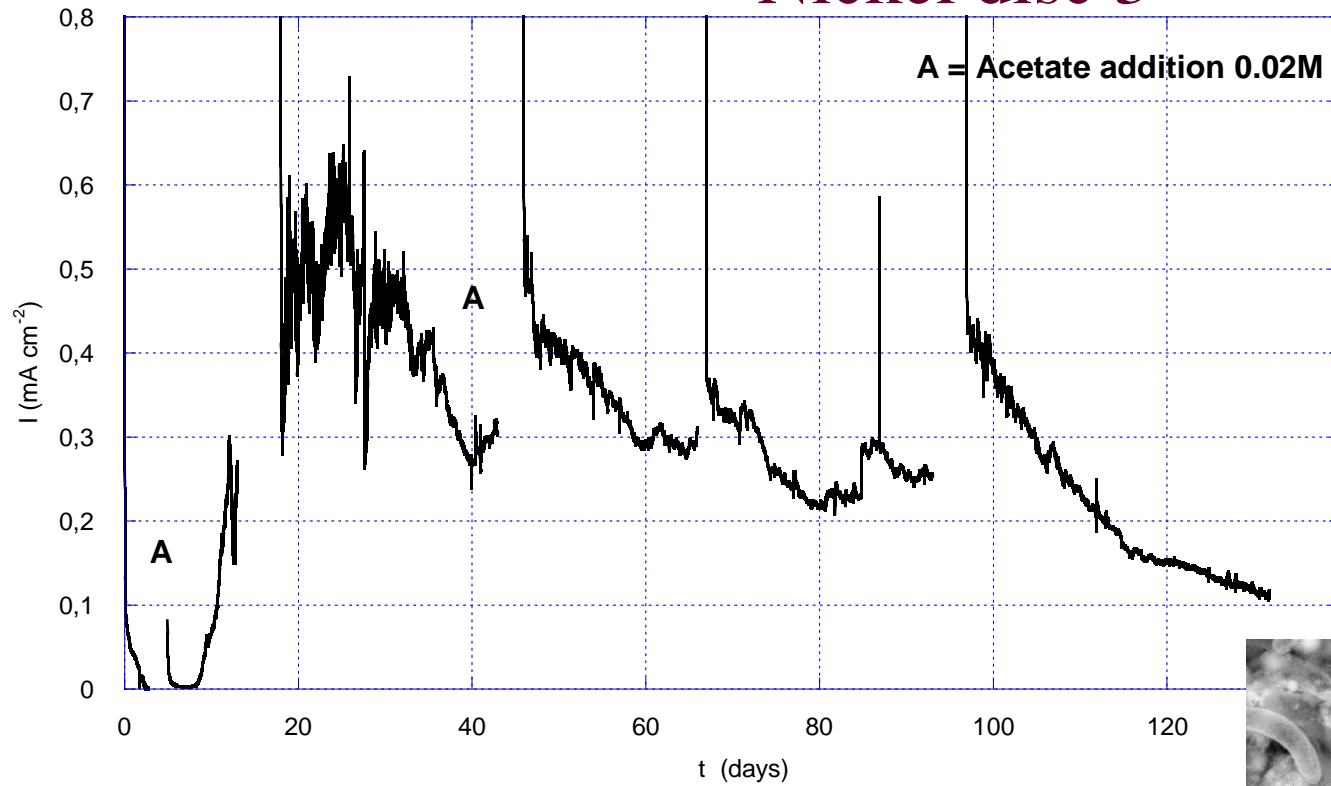
Nickel disc 2

SEM and EDS



- Mix of biofilm and nickel sulfide nanoparticles
- Coccus and bacillus bacteria
- Porous structure
- Incidence of bacteria activity on the formation of nickel sulfide nanoparticles ?

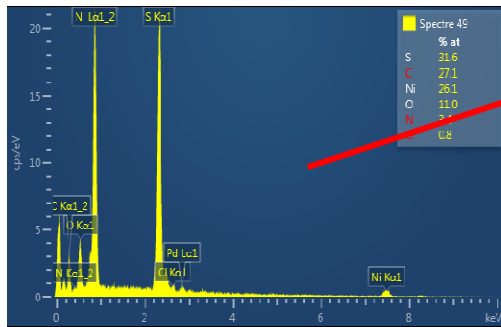
Nickel disc 3



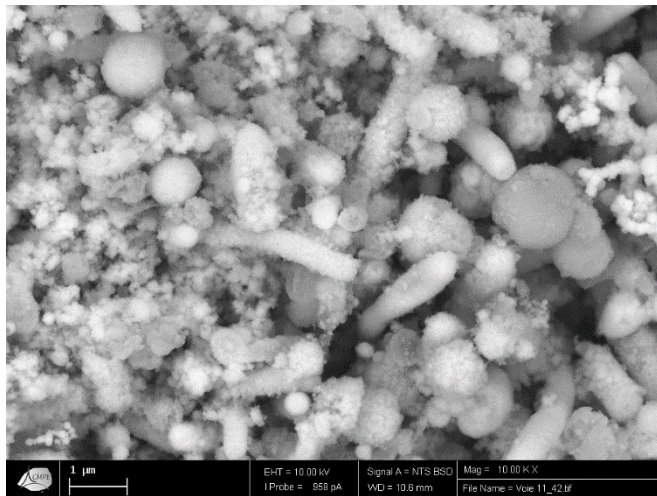
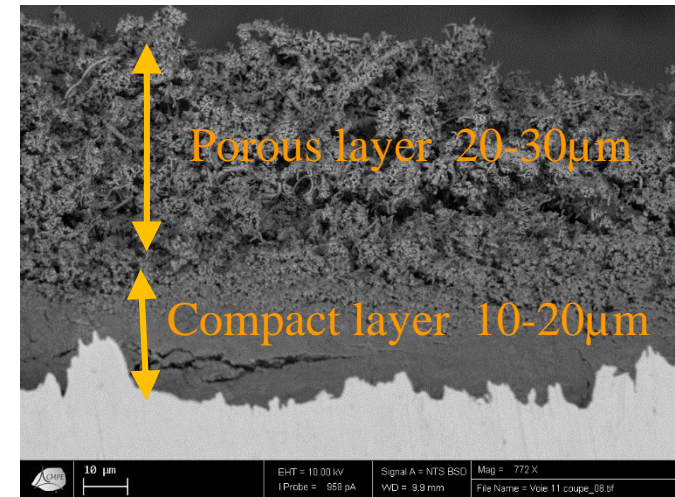
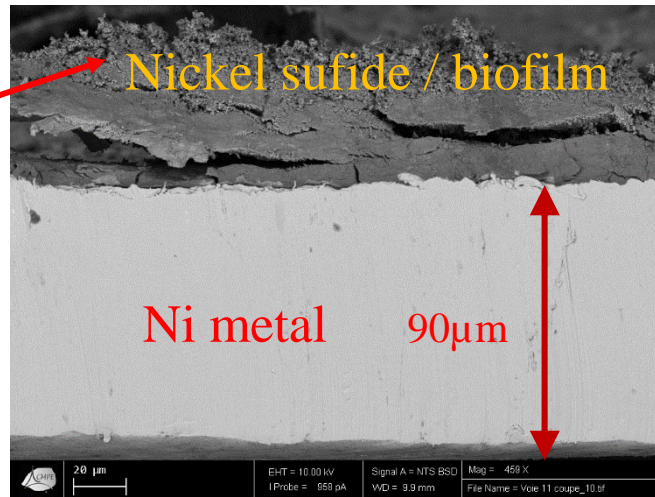
- idem
- +
- Coulombic efficiency for acetate oxydation ~100%

Nickel disc 4

SEM and EDS



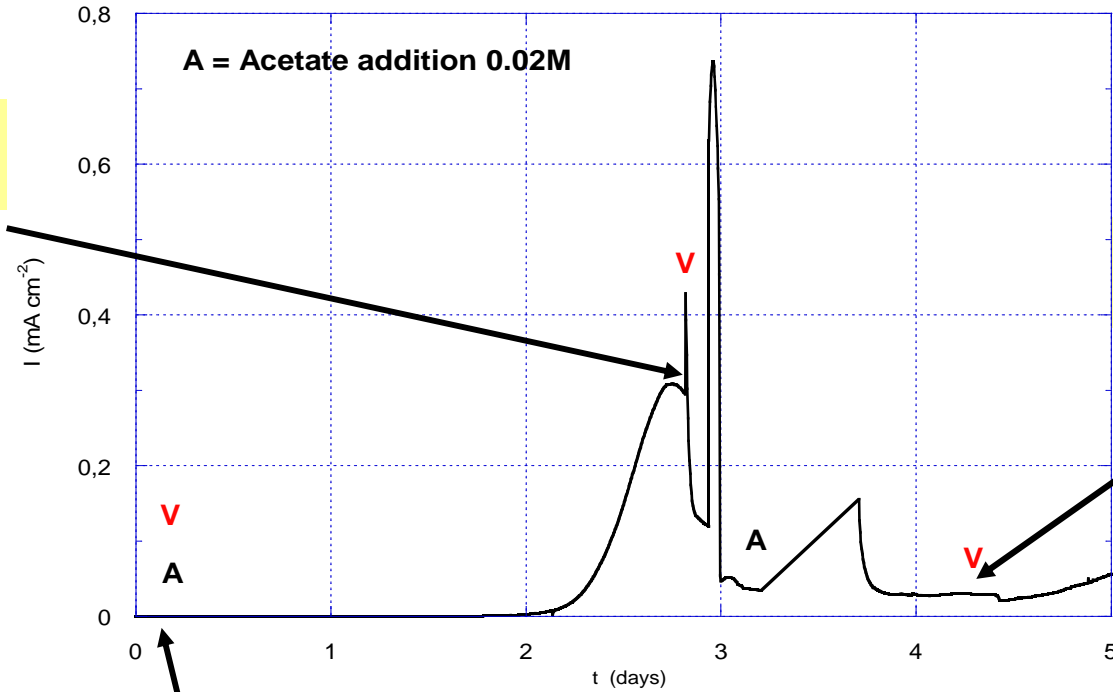
Cross-sectional



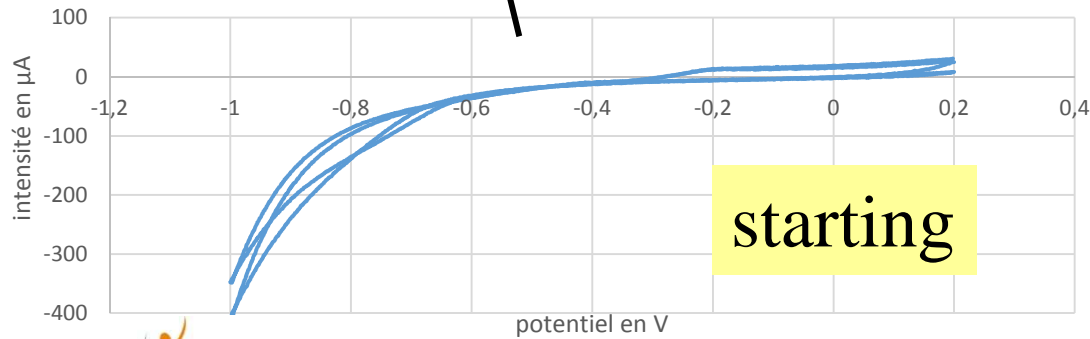
- Dual structure compact / porous
- Transport of electrons accross both layers (mechanism?)
- Bacteria look like they were covered by nickel sulfide nanoparticles (??)

Nickel disc 5 (at short time)

Turnover



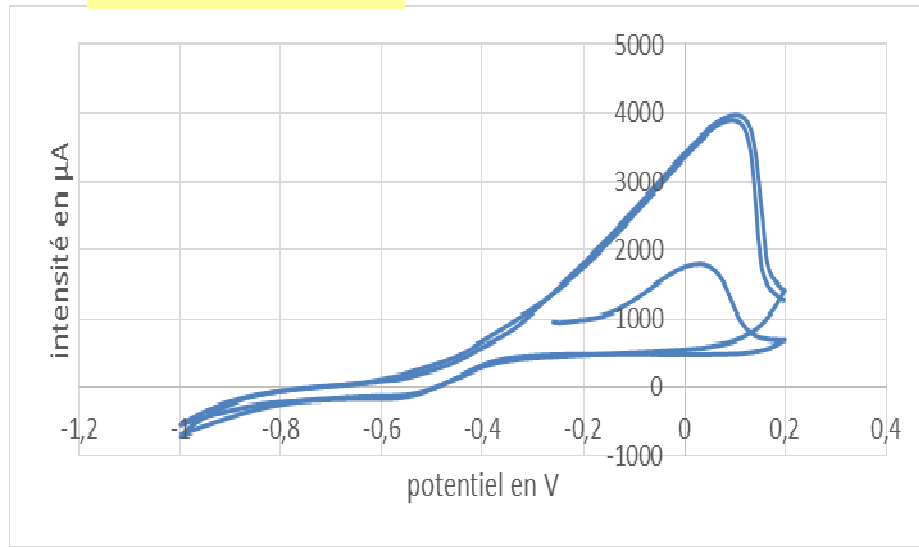
Non-turnover



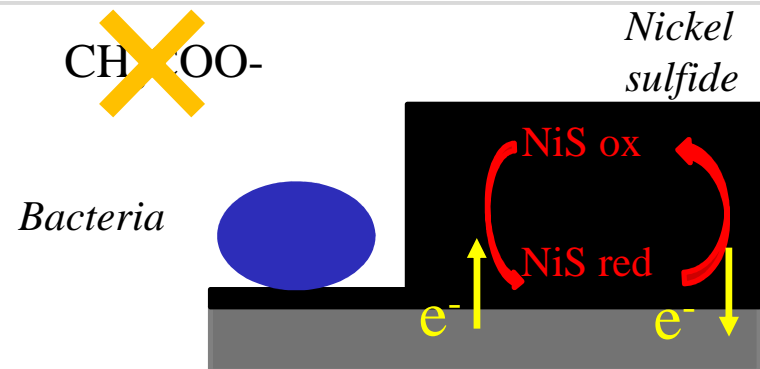
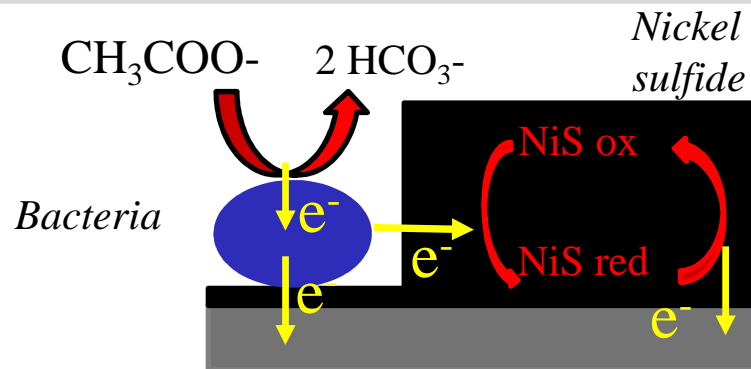
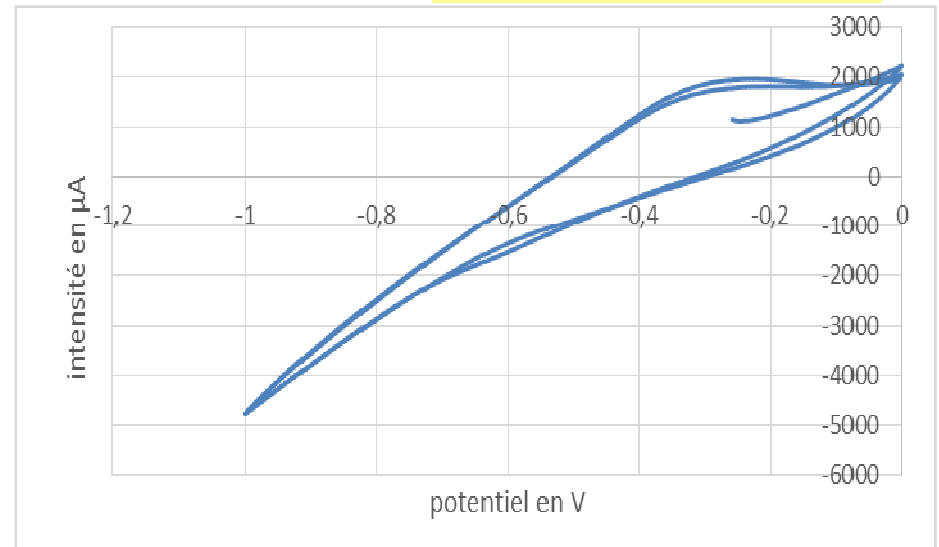
- Low oxidation current at -0.2V

Nickel disc 5 (at short time)

Turnover



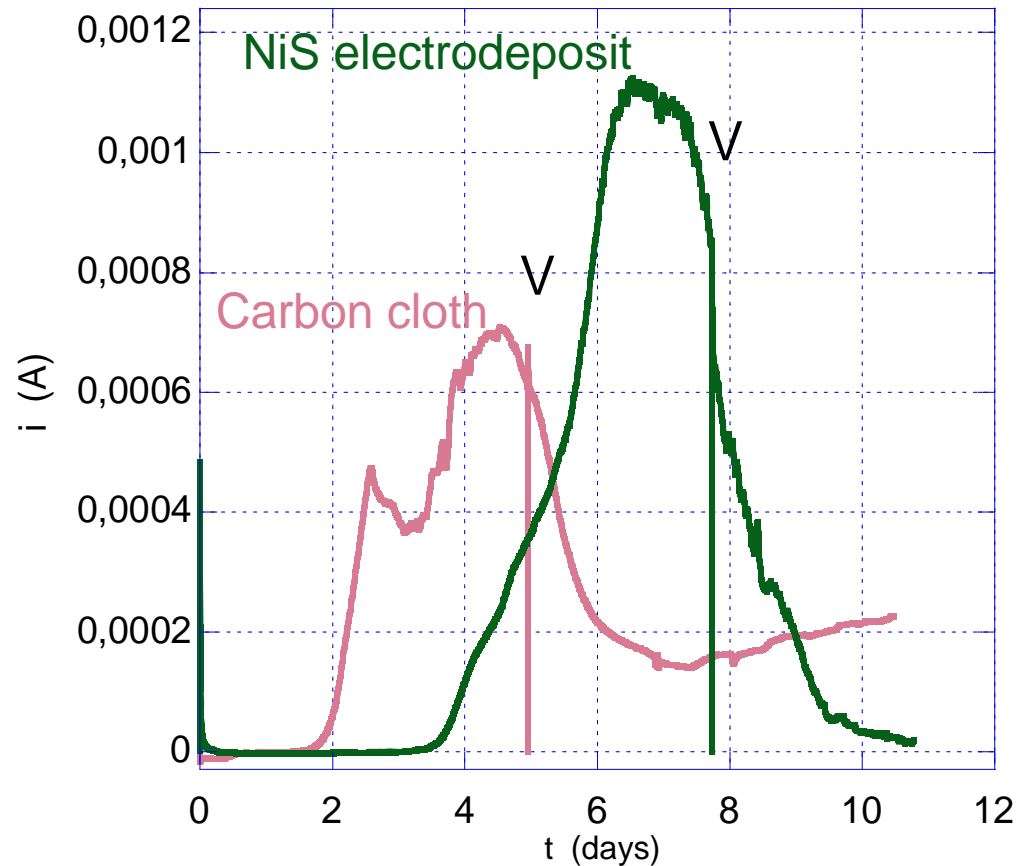
Non-turnover



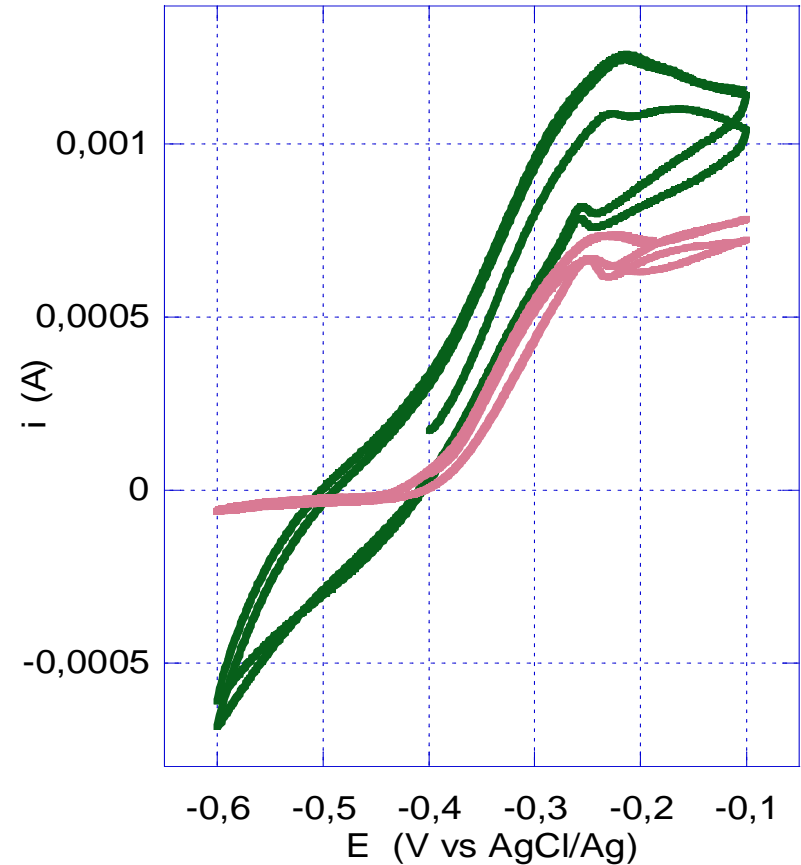
- Electron transfer from bacteria to nickel sulfide and then to current collector

Carbon cloth disc, Nickel sulfide electrodeposit,

Chronoamperometry



Voltammetry



- Better with Nickel sulfide (I max, potential shift) but no obvious evidence of electron transfer (?)



Conclusion

Nickel metal and nickel sulfide are suitable materials for application in PCM bioanode,

→ good electrochemical performance

→ partial oxidation of Ni during operating, into nickel sulfide

→ mix of nickel sulfide nanoparticles and biofilm, dual structure

→ possibility of electron transfer between bacteria and nickel sulfide

On-going studies:

→ confirmation of electron transfer,

→ microbial community ?

→ ...

Acknowledgments

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BIO
ELEC

Thank you for attention