Microbial Fuel Cell Based on Electrode-exoelectrogenic Bacteria Interface

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Outline

• Introduction to Microbial Fuel Cell (MFC)
  – Typical MFC
  – Previous Work

• In this study
  – Operation Principle
  – Design and Fabrication
  – Experimental Procedure
  – Results and Discussion

• Conclusion
Introduction

• The oil prices, global warming has motivated the search for alternatives to current energy technologies.

• Efficient and sustainable energy conversion is the focus of many research programs.

• Investigations include the production of biofuels, solar cells, and hydrogen fuel cells.

• Biomimetic approach involves the direct conversion of simple sugars and alcohols into electricity using microorganisms.
Introduction

- Microbial Fuel Cell

  - Direct conversion of simple sugars and alcohols into electricity using microorganisms.

  - Utilize enzymatic redox reactions to break down organic fuels and produce electric current.

  - Single/double chamber, with/without mediator
Introduction

• Previous work

Toxic mediator is required
In This Study

• Adopt exoelectrogenic bacteria that break down various organic fuels into electrons and protons.

• These bacteria transport the separated charge extracellularly, eliminating the need for toxic mediators.

• The bacteria produce “organic nanowire” appendages used as electrical connections to transfer electrons directly to the electrode for enhanced efficiency.
Operation Principles

- Exoelectrogenetic bacteria

![Diagram of exoelectrogenetic bacteria and electrochemical process](image)
Operation Principles

• Inside the Reaction Chamber

\[
\text{CH}_3\text{COO}^- + 2\text{OH}^- \rightarrow 2\text{CO}_2 + 8e^- + 5\text{H}^+
\]
Design and Fabrication

The total anode surface area is $1 \text{ mm}^2$
Design and Fabrication

Anode volume:
350μL for bacteria

Gold coil electrode
200μL
Experimental Procedures

Culture bacteria using anaerobic media in buffer solution

Bacteria washed and added to anolyte for colonization

Anaerobic media and acetate added to anodic chamber

Buffer and $K_3[Fe(CN)_6]$ added to cathode chamber

In a PIPES buffer using 20 mM acetate and 80 mM fumarate as electron acceptor at 30°C.

$$[Fe(CN)_6]^{3-} + e^- \rightarrow [Fe(CN)_6]^{4-}$$
Results

- Bacteria viability

Greater Growth on Au than SiO$_2$
Bacteria: ~1.5μm long and 300nm wide

Illustrating significant appendages attaching Au surface
Results

- **Performance**

  - Open circuit voltage and current density increases as the bacteria colonize the electrode.

  - Maximum current density obtained is $1.4 \mu A/mm^2$, power output $0.12 \mu W$ at $0.61 \mu A$.

  - Max. current/power can be increased using catholyte with higher redox potential (e.g. oxygen).
Results

- **Performance**
  - Upon bacterial addition to the anode, a $V_{oc} \approx 630$ mV is obtained.
  - After an initial “discharging” of the bacteria, the $V_{oc}$ reduces to 100 mV but increases over time.
  - After 10 days of respiration on the anode, $V_{oc}$ values ranged from 550-600 mV over 10 minute intervals.
  - The maximum steady state $V_{oc}$ was 619 mV or 98% of the maximum expected.
Conclusion

- Demonstrated a micro-fabricated MFC that uses **exoelectrogenic bacteria** as living catalyst and acetate as fuel.

- The system polarization (and power density) increases over time as the bacteria colonize the electrode surface.

- With a 1 mm$^2$ anode area, the fuel cell delivered $V_{oc} = 619 \text{ mV}$ and $P_{max} = 0.12 \mu \text{W}$ using potassium ferricyanide as catholyte.

- Performance improvements are possible by allowing the **bacterial biofilm to fully cover the anode** and **increasing the electrode surface area**.
Thanks For Your Attention!!!!

Q&A