Microbial Fuel Cells for Power Generation

EE 47008

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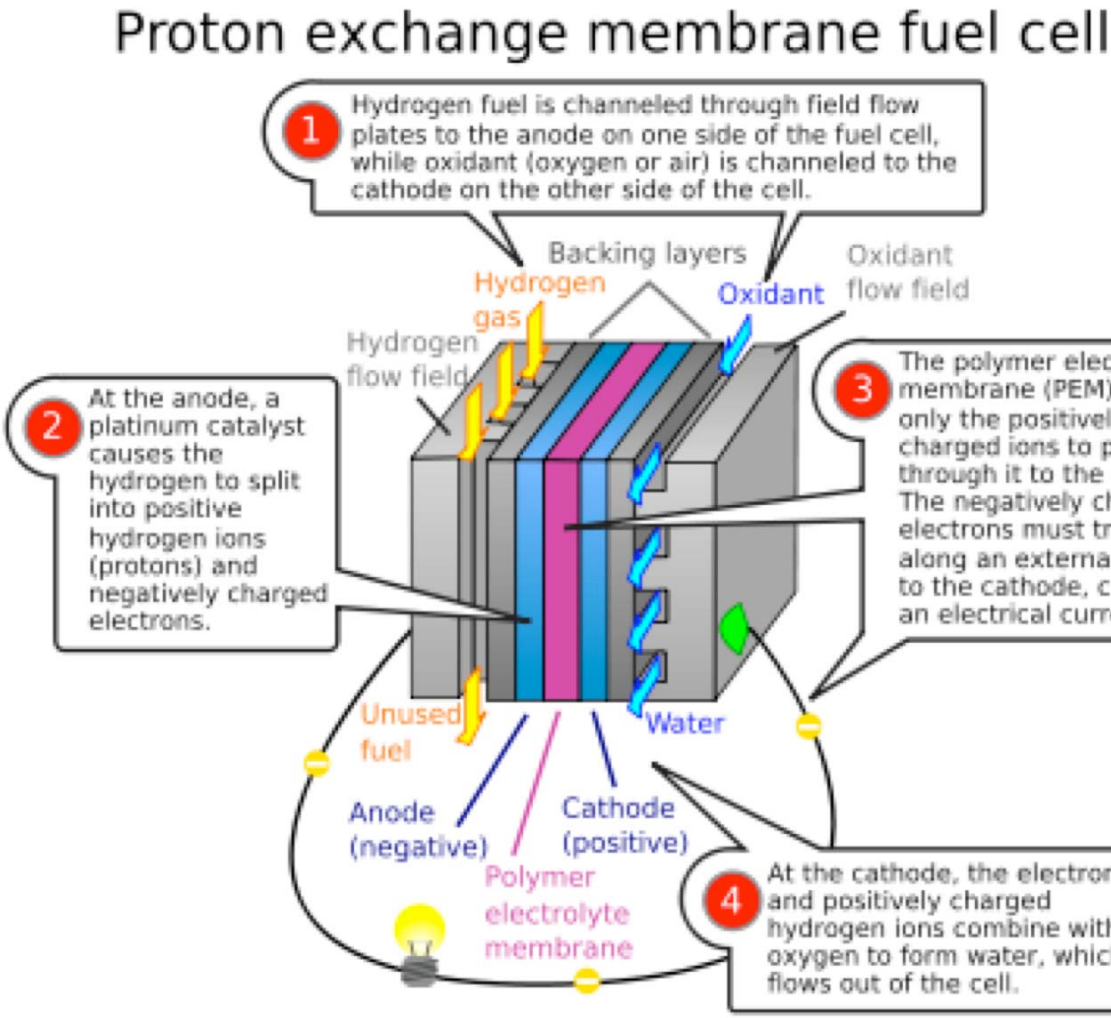
Overview

- Microbial Fuel Cells (MFCs) mimic natural biological action to produce free electrons
- Substrates and cultures vary
- Currently installed in wastewater treatment facilities

Fuel Cells

Electrochemical conversion

Fuel and oxidant required

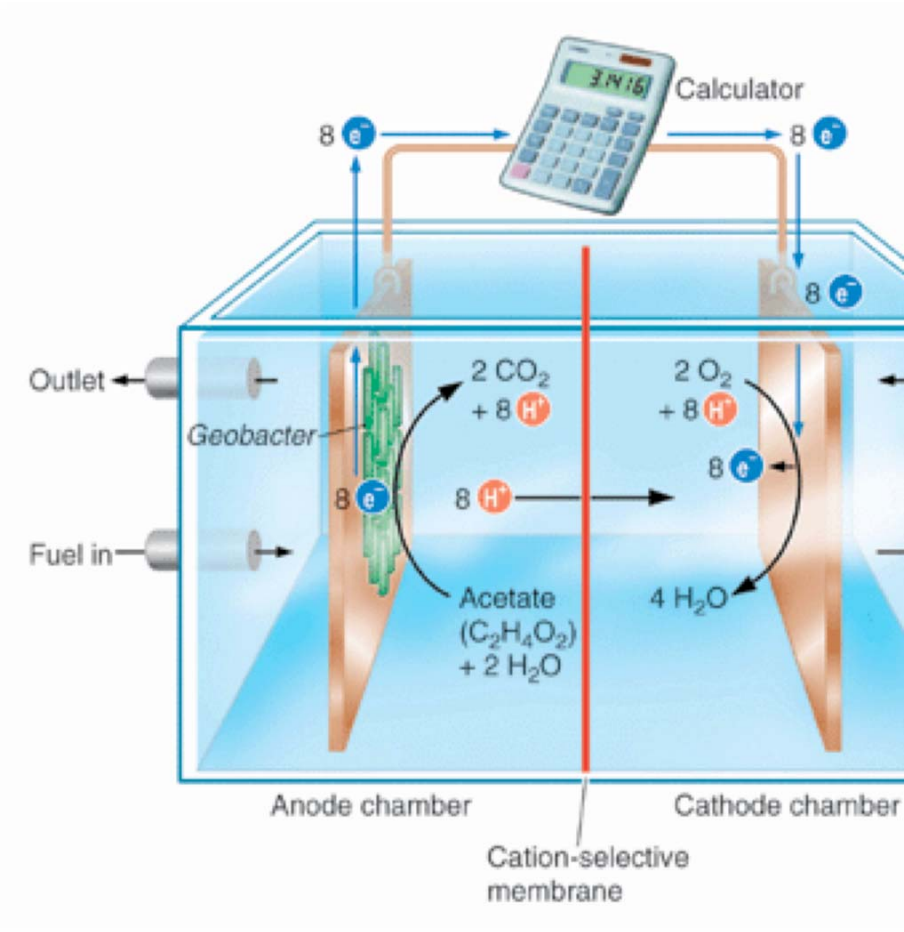


Terminology

- Catabolism - breaking down of molecules to release energy
- Reduction - gain of electrons (oxidant + e^- → product)
- Oxidation - loss of electrons (reductant → product + e^-)
- Aerobic/Anaerobic - with/without oxygen

Microbial Fuel Cell

- Mediator and mediatorless designs
- Specific biological action is unknown in many cases
- Self-optimizing



Anaerobic Catabolism

- Aerobic Catabolism
  $C_6H_{12}O_6 + 6H_2O + 6O_2 \rightarrow 6CO_2 + 12H_2O$
- Anaerobic Catabolism
  $C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$
- Mediators intercept free electrons

Energy Conversion

- $\Delta G = -n \times F \times \Delta E$
- Glucose (NADH) to O_2:

  $\Delta G = -2 \times 96485\ C/mol \times [(0.840\ V) - (-0.320\ V)]$

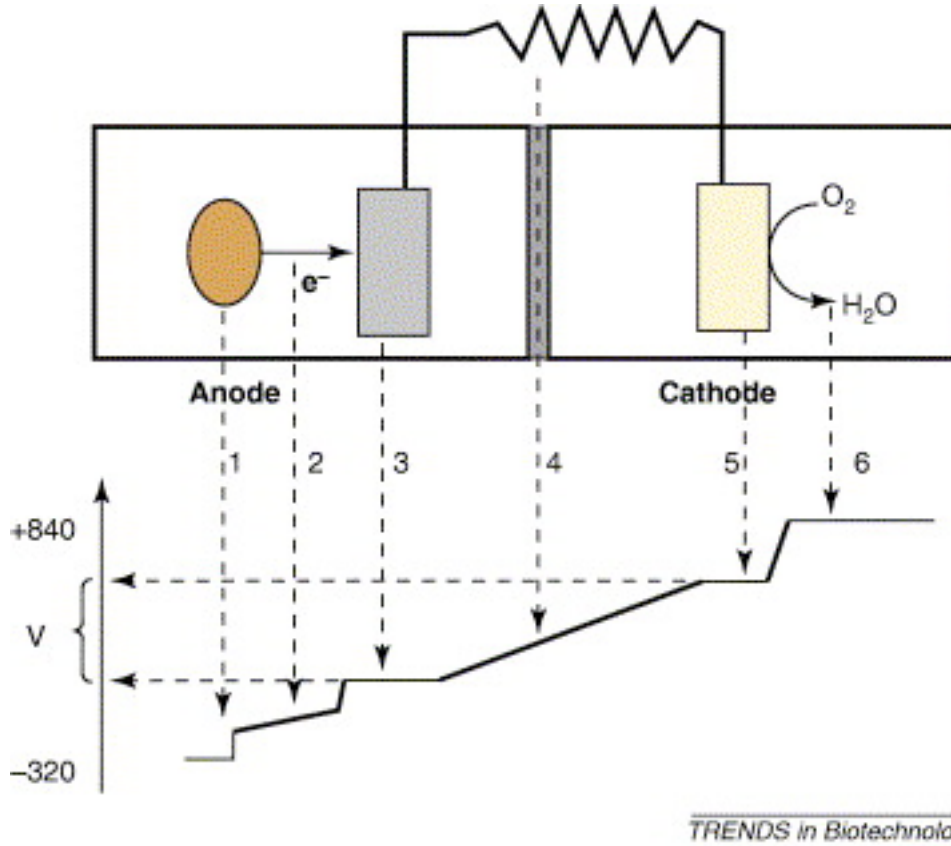
  $\Delta G = -2 \times 10^2\ kJ/mol$

- In anaerobic environment, anode can become preferable electron acceptor

Performance Losses

V_{OC} ~ 800 mV

Overpotentials:
Activation
Ohmic loss
Concentration
polarization



1. Loss owing to bacterial electron tran
2. Losses owing to electrolyte resistar
3. Losses at the anode
4. Losses at the MFC resistance and membrane

Power Output

- W/m^2 or W/m^3?
- Coulombic efficiency vs. energy efficiency
- mW/m^2 to several W/m^2

Applications

- Virtually any organic material can be used as fuel
- Biomass as food, energy crop, waste
- 1 kg Sugar contains ~ 4.41 kWh
  Ethanol, H_2, CH_4, biogas average 1 kWh
  1 kWh ~ €0.16
  1 kg Sugar costs €0.25, market value ~ €1
- Ambient temperature operation, wide array of electron donors, effective at low

Questions?