MICROBIAL FUEL CELLS: EDUCATION THROUGH APPLICATION

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OBJECTIVES

1. **Design an educational MFC** kit for high school students to help teach chemistry, biology, physics and scientific measurement.
2. **Design a μMFC power source** that could be used to power implantable medical devices as an application of this new technology.

INTRODUCTION

The push for sustainable energy sources has brought recent attention to microbial fuel cells (MFCs). **MFCs use biological processes to generate power by converting chemical energy in organic compounds into electrical energy.**

Benefits of MFCs:

- Energy can be derived from many different substrates.
- No harmful byproducts.
- They operate at neutral pH and room temp. – no harsh conditions.

Limitations of MFCs:

- Limited understanding of biological mechanisms.
- Research lacks uniform standards.
- Materials can be costly.
- **Power densities are currently too low for most applications.**

Applications:

- Power source for low-power devices
- Waste-water treatment
- Gastrobots
- Sensors

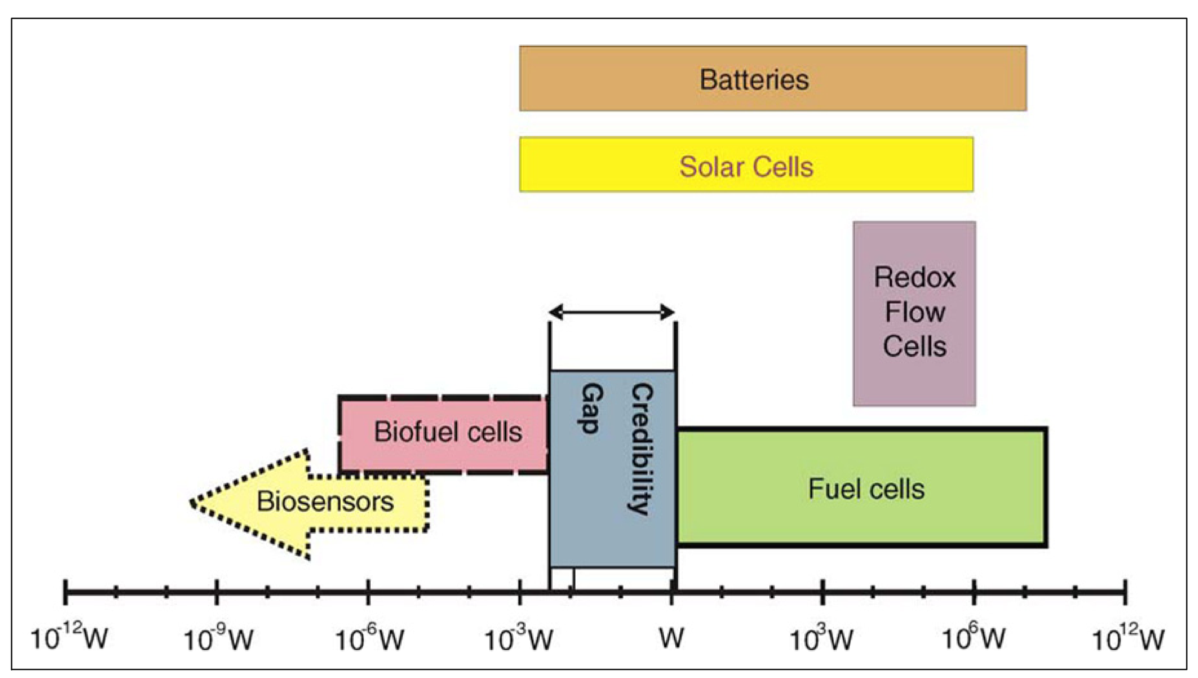

Figure 1: Comparison of power output ranges, illustrating the scale of the credibility gap challenging biofuel cells including MFCs (Bullen et. al. 2006).

Key Components of an MFC:

- **Electrodes** (Anode and Cathode)
- **Organic Fuels** are digested by microbes into energy, waste, and charged particles.
- **Microbes** metabolize the organic fuel and separate charge in the process.
- **Proton Exchange Membrane (PEM)** allows positively charged particles to move between the two chambers to keep charge neutrality.
- **Mediator Molecules** work as intermediate electron acceptor from the microbe to the anode.

REFERENCES

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[2] B. E. Logan, *Microbial Fuel Cells*, 2008.
[3] C.-P.-B. Siu and M. Chiao, "A microfabricated pdms microbial fuel cell," Journal of Microelectromechanical Systems, vol. 17, no. 6, pp. 1329–1341, 2008.

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HOW MFCs WORK

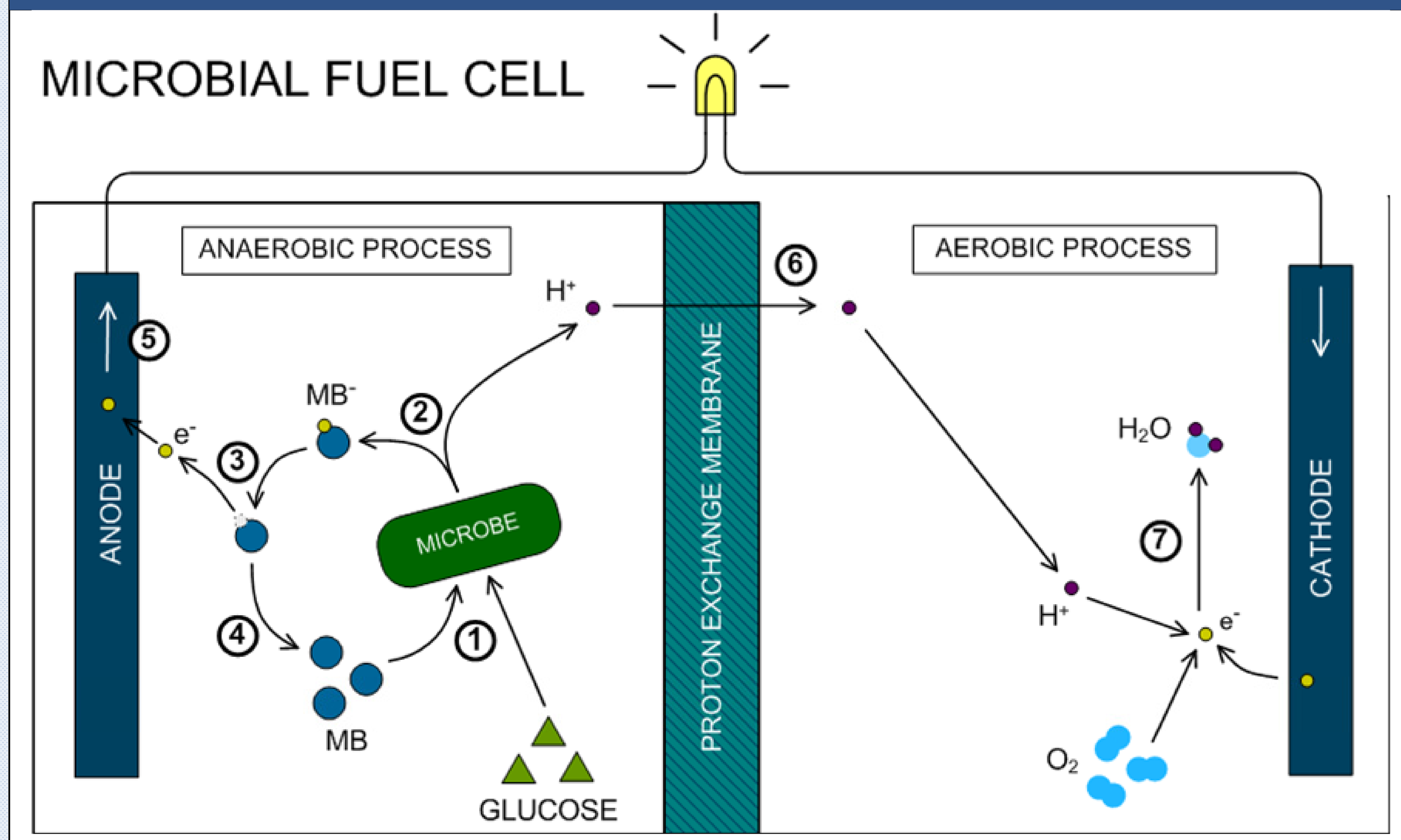

Figure 3: Diagram of Processes in a Two-Chamber MFC

1. The microbe intakes glucose and the mediator molecule, methylene blue (MB), and digests the glucose. During this process, an electron (e^-) binds to MB.
2. The microbe excretes the negatively-charged MB^- and a proton (H^+) into the surrounding fluid.
3. e^- is transferred from MB^- to the anode.
4. MB is recycled.
5. e^- travels from the anode to the cathode.
6. Meanwhile, H^+ travels across the proton exchange membrane (PEM) to the cathode chamber to retain charge neutrality between the chambers.
7. H^+, O_2, and e^-, react to form water (H_2O).

EDUCATIONAL MFC KIT

MFCs have the potential to be a **multidisciplinary, hands-on tool** for high school education. Using a new, developing technology in the classroom can inspire learning and curiosity in the future engineers and scientists.

Our First Prototype:

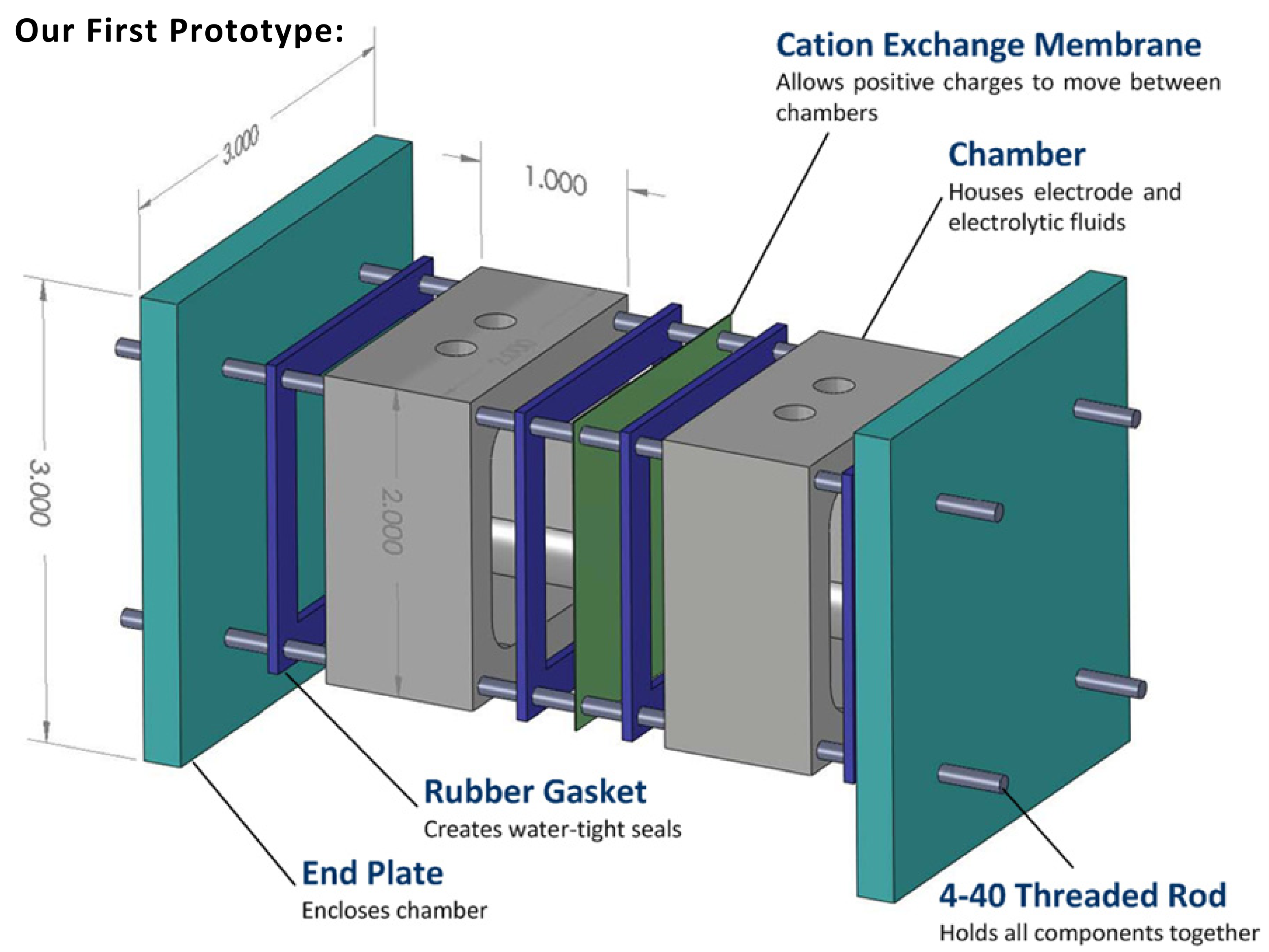

Figure 4: Exploded SolidWorks Assembly of MFC. Dimensions are in inches.

Design Requirements:

- Although MFCs are generally not dangerous, **safety** precautions must be taken when dealing with live microbes.
- Our design must also minimize **cost** by using cheaper alternatives. Currently, we project the material cost for one MFC to be between **$25-45**.
- Our design also allows for **different configurations**. Controllable degrees of freedom include types of electrodes, exchange membrane, microbes, and concentrations of solution reagents.

IMPLANTABLE μMFC POWER SOURCE

μMFCs have gained attention as potential power sources for implantable medical devices by using blood as a fuel. Siu and Chiao have designed a PDMS gold-plated electrode for a μMFC using an 8 step manufacturing process.

We propose to build a similar μMFC, but simplify this mold manufacturing process to a single step.

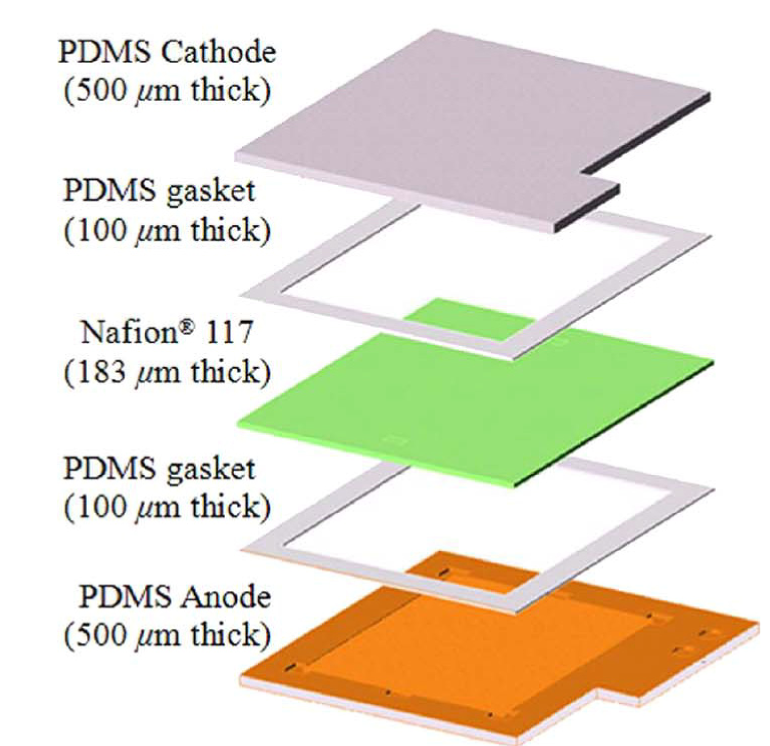

Figure 5: Exploded view of uMFC assembly. (Siu et. al. 2008).

Manufacturing a PDMS-Gold Electrode:

To increase efficiency, the electrodes have micro-pilli structures which increase the surface area by up to 80%. **We laser-cut microstructures into a polypropylene or acrylic mold instead of using traditional μ-manufacturing techniques.**

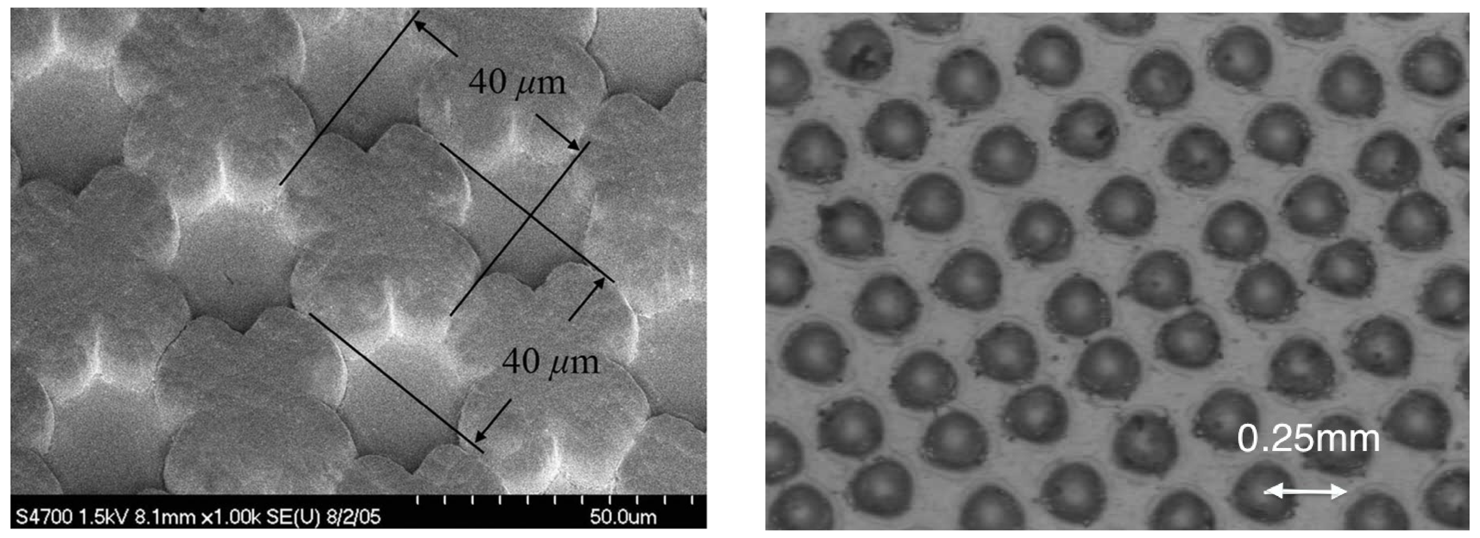

Figure 6: Microstructures. (a) Scanning electron micro-scope image of PDMS-gold electrode microstructures from Siu et. al. 2008. **(b)** Optical microscope image of laser-cut microstructures. Structures are about 0.12 mm deep and 0.2 mm wide.