

Swamp Mud microbial fuel cell - Generating Electricity with Microbes!

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(Part 1 – Building the Microbial Fuel Cell)

(Part 2 – amplifying low power electricity sources using the simple 'Joule Thief' circuit.)



Background:

Anaerobic bacteria found in mud and soil generate small amounts of electricity as they metabolize biomass. This generates hydrogen ions (H^+). (an ion is an atom that has lost electrons) These have a positive charge that accumulates on a graphite anode that is submerged in mud at the bottom of the fuel cell. The potential difference (voltage) that develops

between this anode and the cathode (a piece of aluminum foil exposed to water and air at the top of the fuel cell) can be measured and also amplified to power small devices such as an LED.

This lab familiarizes students with some basic concepts of electricity, microbiology and (in Part II), simple circuit bending techniques using inexpensive analog components to amplify the microbially-generated power to light up an LED.

(Part 1 – Building the Microbial Fuel Cell)

Supplies:

Mud: Mud from a swamp or flooded ditch is best. Collect enough to fill each container $\frac{2}{3}$ of the way. This mud contains the necessary anaerobic bacteria that will power the fuel cells. Wear disposable gloves when handling swamp mud and do not contaminate any area where food is prepared as the mud may contain some pathogens. Garden soil can also be used but it will need to be submerged with water for a week or so to encourage anaerobic bacterial growth.

Here is where I collected mine:



Containers: Jars, Plastic containers, whatever you have that is wide enough to accommodate the graphite anodes (see below) which are 100mm in length. Minimum 3 or 4. Plastic or glass containers only - not metal!!

Jar lids or something similar: Try to find a deep lid that approximately fits the surface area of your container. The lid that comes with a jar is a good choice as long as it is heat tolerant (#5

PP plastic or metal). You will be pouring hot salt and agar solution into this and letting it cool to make a *proton exchange membrane* (more on that later!)

Graphite: This is the anode on which the anaerobic bacteria will grow. Anaerobic bacteria produce positively charged hydrogen ions (H^+) as a byproduct of their digestion. These positively charged ions cross the proton exchange membrane and accumulate on the aluminum foil cathode. This creates a voltage (potential difference) between the anode and the cathode that allows electrons to flow in the opposite direction, (from cathode to anode) if a load is connected across the two terminals. (See image below)

This microbial fuel cell uses inexpensive graphite rods purchased from Amazon. Pencil leads will work and there are many other recipes for making graphite anodes including carbon paper, graphite powder, aquarium charcoal etc. but these rods work quite well, are easy to handle and offer an adequate surface area for the anaerobic bacteria.

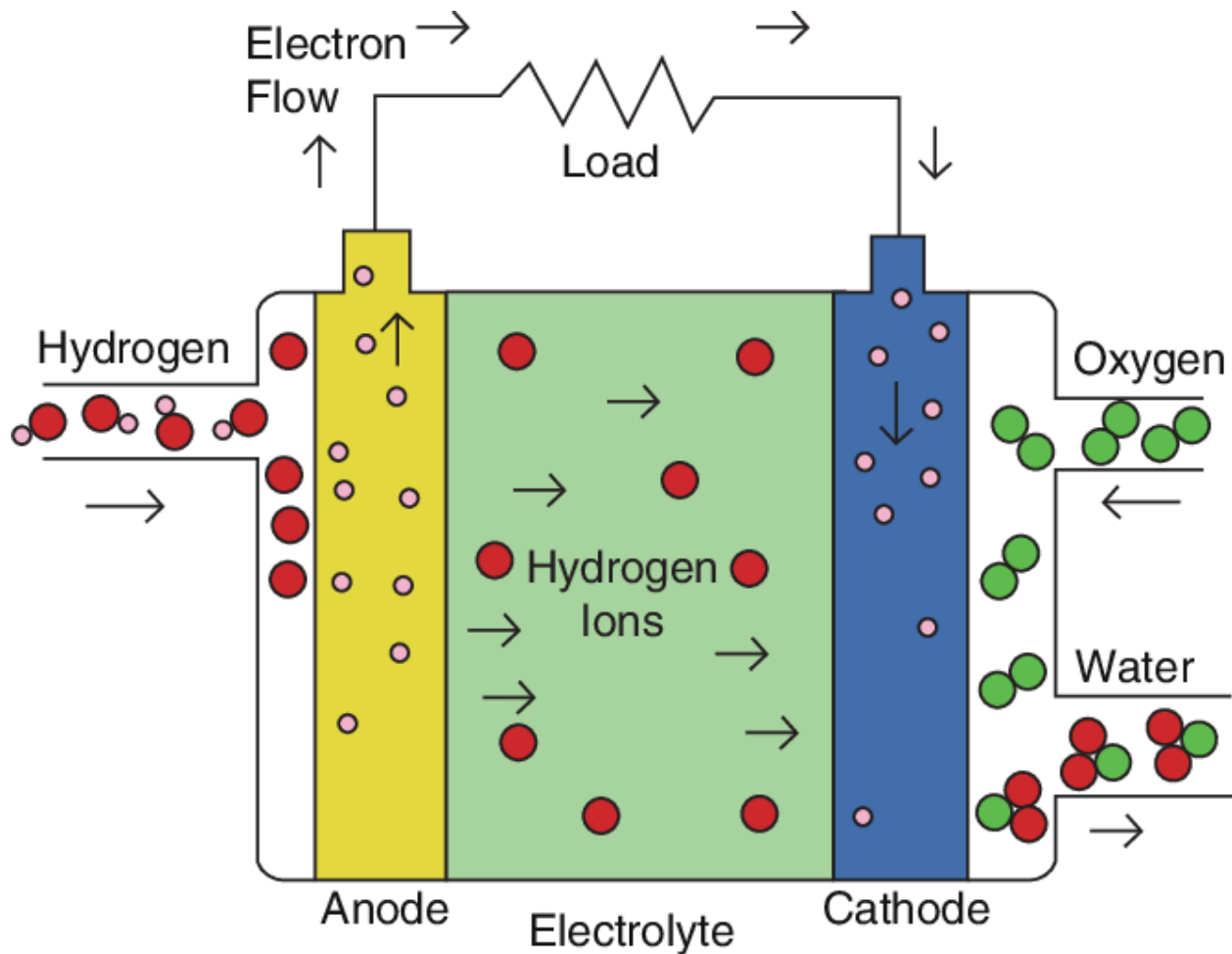
Amazon link:

Actopus 5pcs 10mm OD Length 100mm 99.99% Graphite Rod Electrode Cylinder Tube Bar
by Actopus

https://www.amazon.com/dp/B01IN431J6/ref=cm_sw_em_r_mt_dp_XWSJ5B4F289VE89N5AG2?_encoding=UTF8&psc=1



Aluminum foil for cathodes: Thick, heavy duty aluminum foil for barbecuing gives the best results. Any aluminum foil will work but thinner foil will corrode faster.



Electrical Wire: AWG 14 (2.082mm) solid copper electrical wire (preferably 2 different colors). Available at any hardware store. 1.5 meters of each color should be plenty. Solid copper wire can often be salvaged from electrical wire being thrown out during renovations or demolitions. Any solid, insulated copper wire will do. Scavenging is fun!

Wire strippers or a knife: You will need to strip insulation of the ends of the wire. A pocket knife will work but a wire stripper does a better job. Cheap is fine. Some pliers have a built-in stripper.

Amazon link:

Eclipse Tools CP-301G Pro'sKit Precision Wire Stripper, 30-20 AWG

https://www.amazon.com/dp/B005JVJDIA/ref=cm_sw_em_r_mt_dp_5TED4CWXF7PXB96S7X5

Multimeter: A cheap one will be fine! A multimeter is a vital tool for measuring electricity. You can test 'dead' batteries to see if they are really dead, locate short circuits and broken wires. A multimeter can help you solve many everyday problems with electrical and electronic devices so it is a worthwhile investment for a designer's toolkit.

AstroAI Digital Multimeter with Ohm Volt Amp and Diode Voltage Tester Meter Continuity Test (Dual Fused for Anti-Burn)

by AstroAI Corporation

https://www.amazon.com/dp/B01ISAMUA6/ref=cm_sw_em_r_mt_dp_53QNX5P997GCMYYZQHYT

Agar Agar: Available in Asian grocery stores or Amazon

Amazon link:

https://www.amazon.com/dp/B01JRXXKSM/ref=cm_sw_em_r_mt_dp_HHAHN4FP9S37HN505JE2?_encoding=UTF8&psc=1

Salt: Non-iodized is best but use whatever you have around.

Alligator Clips: Not necessary but good to have - These make connecting and disconnecting components so much easier!

Amazon link:

https://www.amazon.com/dp/B07RTMSKSR/ref=cm_sw_em_r_mt_dp_SJQ0ZYV6NYP361W1K4BM?_encoding=UTF8&psc=1

How to do it! (The 'Protocol'):

- 1) You will need 2 lengths of wire per container, one for the anode and another for the cathode. The wires should be long enough to reach from the bottom of one container to the top of an adjacent one with a couple of inches extra to spare where you will strip off insulation and attach either a graphite rod (anode) or aluminum foil (cathode). Once you have stripped both ends of the wire, tightly wrap one stripped end around the graphite anode in a spiral manner (see picture) so the bare copper wire makes tight contact with the graphite. Put the graphite rod in the bottom of the container and bend the wire up and out of the container and attach a piece of thick aluminum foil to the other stripped end pinching it on securely. Cover the graphite with wet swamp mud leaving an inch or so of room at the top for the proton exchange membrane (see below) and a layer of water. The containers will be connected in series to increase the total voltage available.
- 2) *Making the Proton exchange membrane.* The proton exchange membrane allows the positively charged hydrogen ions to pass through it. You will be mixing boiling water, salt and agar powder so take appropriate precautions and don't burn yourself. The following protocol should be enough for several protein exchange membranes for a typical quart jar. •Bring 200 ml of water to a boil in a pot. Stir in 75 grams of salt. This is a lot of salt and it will take a while to dissolve. Once this is dissolved, stir in 5 grams of agar agar (or gelatin). Remove from heat and pour the liquid into the jar lids. Allow to cool and solidify.

- 3) Add enough tap water to the jars to cover the mud. Place the proton exchange membrane on top of the mud and cut two slits in it with a knife to allow the wires to pass through easily. Add more water to barely cover the proton exchange membrane. The aluminum foil cathode should be barely touching the proton exchange membrane just under the thin layer of water. The rest of the foil should be exposed to air.
- 4) Measure the voltage between the anode and the cathode. It might take a few days for the anaerobic bacteria to begin their metabolism and give off the H^+ ions that create the voltage (potential difference) between anode and cathode.. If working properly expect between 0.5 V and 1.5 V.
- 5) Connect your fuel cells in *series* to increase the voltage. This is the same idea as in many electrical devices. 2, 1.5 Volt AA batteries connected end to end (+ to -) will create 3 volts. Measure voltage between the cathode of the first cell and the anode of the last cell. Try and get 1.5 Volts total. You might have to reposition the aluminum foil cathodes slightly so just the ends are in the water and touching the proton exchange membrane.

(Part 2: Amplifying a weak power source using a simple 'Joule Thief' circuit)