Study of Electricity Generation Using Sediment Microbial Fuel Cell

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ABSTRACT

Microbial fuel cells present an energy-saving process for wastewater treatment that results in electricity generation. In this study, sediment microbial fuel cells (SMFCs) were adapted for use with wastewater as an organic substrate by using floating carbon cloth air cathodes coated with an oxygen reduction reaction (ORR) catalyst. The performance of a platinum ORR catalyst at the cathode was compared to a manganese dioxide ORR catalyst. Open circuit voltages of SMFCs with MnO2 cathodes dropped over time while those with Pt cathodes remained stable. Over 90% loss of MnO2 from the cathode surface occurred within the first two weeks of SMFC operation. After 55 days, Pt- SMFCs had a slightly higher average maximum power density during polarization than MnO2 SMFCs, 65.35 mW/m2 ± 4.59 and 48.32 mW/m2 ± 10.13 respectively. Based on power densities recorded throughout the study, the better ORR catalyst could not be conclusively determined.

Keyword : - *Alternative Energy, Chemical Oxygen Demand, Microbial Fuel Cell, Wastewater Treatmen*

1. INTRODUCTION

Sustainable electricity production is becoming one of the largest concerns of the twenty-first century. While nuclear power is a readily available alternative to fossil fuels, it is far from sustainable. More natural sources such as hydroelectric systems, windmills, and solar energy have been identified as some of the more promising sustainable alternatives. However, many regions do not lend themselves well to some or all of these options. As a new technology, microbial fuel cells (MFCs) have quickly gained attention by researchers in sustainable energy production. A number of recent studies have investigated these systems operating with wastewater as a fuel or energy. Typical wastewater treatment systems utilize biological treatment under aerobic conditions to biodegrade the organic components in the wastewater. Similarly, MFCs utilize microorganisms to biodegrade organic components under anaerobic conditions. Through this process, electrons are liberated and provide the current produced by the MFCs. MFC research has evolved over the last few decades. Early MFC studies concentrated on simple systems with single microorganisms and simple substrates Several microorganisms were found to behave ideally under anaerobic conditions, readily freeing electrons during biodegradation of the substrate, The use of electron mediators was accepted in early research, but the concept of mediator less MFCs became prominent only continues to be more widely researched over MFCs operated with mediator. Over the past decade, many advances have been made with respect to system design and materials, including the development of the single chamber microbial fuel cell (SCMFC), which eliminates much of the problem associated with the low solubility of oxygen in water by directly contacting air with the cathode Further studies have begun to focus on naturally diverse microbial systems and substrates, such as those provided in wastewater. Further research is needed in many areas, including the use of multiple MFC reactor systems, the inhence of various operational parameters, overall MFC performance and system responses to disturbance and upset.

2. Manganese oxide catalyst preparation

Manganese dioxide (MnO2) was synthesized by the reduction of potassium permanganate (KMnO4) in aqueous Sulphur acid solution (H2SO4) by hydrothermal treatment as described by . Specifically, 4 g of KMnO4 powder was added into 200 mL of 2.5M H2SO4 aqueous solution and was heated at 80 °C for 30 minutes under stirring. The precipitates were produced and the solution colour was changed. The reaction course was monitored by the colour

change from dark purple to dark brown. The solution was then cooled down to room temperature naturally. Subsequently, the precipitate (MnO_2) was filtered by using filter paper and washed thoroughly with distilled water to remove all the possible remaining ions, then dried for 48 h in a vacuum oven (Haier, 2450 MHz, 700 W) at 80°C.

A conventional method for preparing manganese dioxide is by hydrolysis of potassium permanganate in aqueous solution. This method has several drawbacks. Reaction occurs slowly, is time-consuming, and the resulting product, if it is to be used as a catalyst or catalyst promoter in organic oxidation reactions, must be dried to avoid physical operating difficulties, such as excessive foaming, phase separation, etc. The drying step causes agglomeration of the manganese dioxide particles, and these agglomerates are not as effective in accelerating the rate of the oxidation reaction as is more finely divided material. The particle size of the manganese dioxide greatly affects the oxidation reaction rate. The greatest rate is obtained when the manganese dioxide is in the form of a colloidal suspension.

The method of our invention eliminates the several disadvantages associated with manganese dioxide prepared in accordance with prior art methods. In accordance with our invention, potassium or other permanganate salt soluble in alcohols is dissolved in anhydrous or substantially anhydrous methyl alcohol. Reaction between the alcohol and the permanganate occurs rapidly to form a colloidal suspension of finely divided manganese dioxide in the excess alcohol. It is an object of our invention to provide a novel method for preparing manganese dioxide. Another object of the invention is to prepare a colloidal suspension of finely divided manganese dioxide in a no aqueous medium. Further objects of the invention will become manifest from the following description:

In accordance with our invention, a permanganate salt, such as sodium, potassium, magnesium, lithium, calcium, or zinc permanganate is dissolved in substantially anhydrous methyl alcohol at temperatures ranging from room temperature, that. is, approximately 68-80 F., to the boiling point of methyl alcohol, and the solution is allowed to remain at this temperature until the reaction has reached completion. In order to obtain a stable suspension of manganese dioxide in the alcohol, it is preferred that not more than about 1.5 grams of potassium permanganate or equivalent amount of other permanganate be added per liter of alcohol. If larger amounts of permanganate are used, although finely divided manganese dioxide forms upon standing for a few hours, most of it is not colloidal, and upon prolonged standing, agglomeration into larger particles occurs. In order to speed up the reaction, it may be desirable to add to the methyl alcohol-permanganate solution a small amount of an aldehyde, such as formaldehyde, acetaldehyde, or iso-valeraldehyde. The aldehyde may be used in the form of an aqueous solution, but since the presence of water is undesirable with respect to both the characteristics of the manganese dioxide produced and the liquid phase catalysis for which the suspension is to be used, it is preferable to use anhydrous aldehyde, if possible, and any introduction of water should be kept to a The amount of aldehyde may be approximately 0.22% of the total solution but should be sufficient to perceptibly speed up the reaction.

. For example, if the manganese dioxide suspension is to be used in the oxidation of lubricating oils and waxes at temperatures of 250 to 300 F. it is preferred that the aldehyde have a boiling point not above that of is valeraldehyde (iso-pentanal) or lower. Although benzaldehyde and other aromatic aldehydes will catalyze the formation of the manganese dioxide, we prefer not to use them when the resulting manganese dioxide is to be used in lower temperature oxidation because of the high boiling point of the aldehyde (355 F.) and the difficulty of removing it without adversely affecting the oxidation product. However, where higher temperature oxidation is practiced, higher boiling aldehydes, including alkyl, aryl and aralkyl aldehydes can be used. In those cases where it is desirable to remove the aldehyde from the reaction mixture prior to oxidation the aldehyde should boil at least 50 F. below the initial boiling point of the material to be oxidized and preferably at least 50 F. below the desired oxidation temperature when the oxidation temperature is below the initial boiling point of the material to be oxidized.

1.The method of preparing substantially anhydrous manganese dioxide in a finely divided state comprising dissolving a permanganate salt in methyl alcohol in the substantial absence of water and in admixture with a small amount of an aldehyde sufficient to increase the speed of reaction, and maintaining the solution at 75 F., until formation of substantially anhydrous manganese dioxide is substantially completed.

2. The method in accordance with claim 1' in which the aldehyde. is an aliphatic. aldehyde boiling. below 240 F. V V

3. The method. in accordance with claim 11in which the aldehyde is formaldehyde.

4. The method in accordance with: claim1 17in. which the aldehyde is iso-valeraldehyde. g 5. The method in accordance with claim :1 in which the solution contains a small amount of water, less than about 5%, and a small amount of formaldehyde, su1fi client to, increase the speed of the reaction.

6. The method in accordance with claim 5 in which the water and, formaldehyde each are present in amounts of about to 6% by volume.

Fig-1 Manganese Di Oxide

Experimental setup for microbial fuel cell with manganese dioxide cathode catalyst In response to numerous questions about what happens to the collected algae this instruct able should help someone to build a microbial fuel cell (MFC) with household items and materials. As its name suggests, an MFC uses microbes to catalyze electricity-producing reactions.

2.1 Preparing Tablet or Powdered Agar

Dissolve 1 bar, 10 tablets or 7 grams of powdered agar in 1/2 quart of the soil water we prepared in the last step. Warm the agar in a hot water bath by placing it in a glass bottle. Heat water on the stove until just about boiling, remove from heat and place the agar bottle in the water. The microwave is another good way. Simply heat up a bowl of water and place the bottle with agar in the center. As it warms the agar will begin to melt, warm the agar until it becomes liquid. Add the salt and mix well to dissolve the salt in the agar. Remove from the heat.

2.2 Dissolving salt

Finely ground salt such as Cannes salt or table salt dissolves much faster than coarsely ground salt (rock salt). It is not clear that all salt added must be dissolved if a solution is to obtain maximum electron exchange Salt dissolves much faster in hot water than in cold water. Salt dissolves much slower as the salt concentration increases. The last bit of salt may take a long time to dissolve. Agitation greatly increases the rate at which salt dissolves A layer of salt on the bottom may take days to dissolve if left undisturbed.

2.3 Making the Salt Bridge

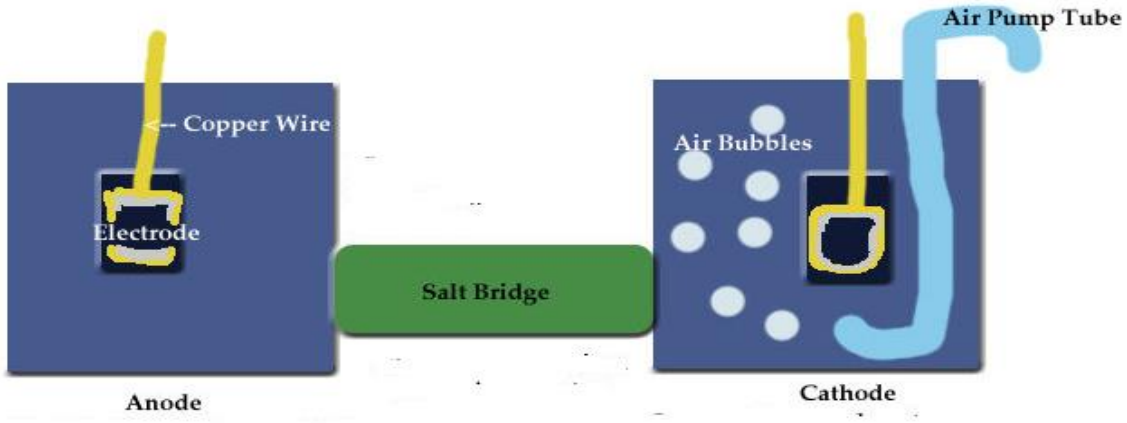

Fig -2 Micobial fuel cell design

Now that we've prepared the agar/salt electrolyte solution we're going to fill the salt bridge with it. Here's what I recommend. Get a short glass large enough to hold the bridge PVC upright. Cut a piece of cardboard large enough to span the glass and at least double the size of the bridge pipe. Cut a circular hole in the center that matches the outer diameter of the bridge. Place a PVC nipple on one end of the pipe. Insert the pipe though the hole in the cardboard and place in the glass so that it is standing on the flat end of the nipple. This should hold the bridge upright while the agar cools and solidifies. Now carefully take the melted agar/saline solution and using the funnel fill the salt bridge to the top. I found that wrapping a wash cloth around the base of the pipe where it exits the cardboard made overflow much easier to deal with when filling the bridge. Carefully place a second PVC cap on the end to prevent accidental spillage and allow to cool. Once the agar has cooled and solidified remove it from the assembly. It may be stored in the refrigerator. Now using a drill or drill press with a large diameter bit drill out the end of two PVC slip caps leaving a short collar around the end. When the slip is placed over the end of the salt bridge it should hold a circular piece of non-conductive/non-reactive mesh such as plastic silk screen material firmly in place.

2.4 Assembling the Reactor

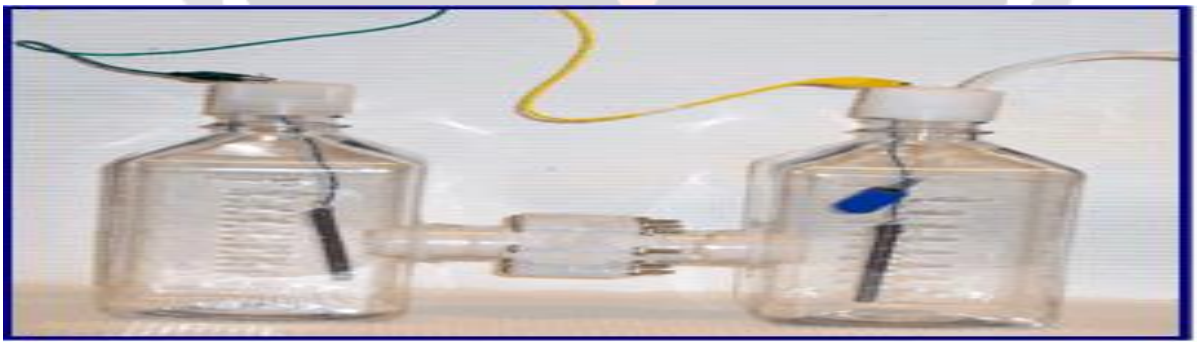

Fig-3 Reactor Assembling

Now we turn our attention back to the we obtained earlier. The collected water will be used as culture media and the mud in the pipe will be used to provide the culture. We'll be diverging from Abbie's design a bit. Where Abbie used the actual mud we're going to try to extract a sample and culture the bacterium. I have been advised by Dr. Logan at Penn State that they do not de-gas the influent since the bacteria will handle it due to the low solubility of oxygen. The material in italics may be bypassed but I left it in case anyone ever wants to de-gasify water for some reason. '"To do that we're going to de-gas the water using nitrogen, argon or other inert gas. Strictly speaking you don't have to do this but it will give our bacteria a better chance to breed.

We're going to do it slowly. Since the options for obtaining gas range from inner tube to pressure tank I give you the following simple instruction. Connect a section of aquarium air tube to the end of a hose that is connected to the gas reserve. Hopefully you have some way to regulate the gas. If you're using an inner tube I suggest filling a balloon (insert it over the valve and push the valve in) and using that to dispense the gas by inserting the air hose into the end and letting the gas slowly out of the balloon. Yeah, I know, it ain't easy being that cheap. Get over it or spend some money for a tank with a valve. Now having arranged by some mechanism to regulate the gas flow of the nitrogen into the air tube attach the bubbler stone to it. Fill the anode chamber (one bottle) with the culture media water. Agitate well. Insert the bubbler stone into it and slowly bubble nitrogen through the solution. How much nitrogen to bubble and for how long? A very, very good question and as soon as I have an answer I'll update this. I've asked the folks at Penn State so it's not impossible this will be updated. Try to stretch it out, say 15 minutes maybe stirring occasionally. If you've got the nitrogen do both bottles since we'll be topping off the culture media. Once you've de-gasified the water or not it's time to introduce the culture (mud).
This is also the time to put in some algae sludge if you have some. See I said it was an algae fuel cell.... Grab the sample pipe and place the mud end in the anode chamber preferably under water before removing the slip cap. You might need to push it off with a long screwdriver or kitchen fork. Pull the slip cap off of the other end and slowly begin pushing mud out with a dowel or broom handle. You want to push out the bottom 2-3 inches of mud then take out the pipe. This should give you a solid culture of primarily anaerobic bacteria. Top off the culture media if needed from the second jar and add 2 drops of vinegar for each quart of culture media in the jar to supplement the natural nutrients. Now place the anode cap and electrode in the anode jar and seal the edge with hot glue. The anode should be air tight and is not designed to be recharged at this time. Once the food is exhausted the bacteria will die. This will be indicated by a drop off in the output voltages. Because the MFC cannot be recharged it is properly called a battery. To rectify this (get, a little electrical joke...very little) use a container which gives a solid, air tight seal and add a feeder hole and tube to it. Remember to seal the feeder tube when not in use and preferably flush with nitrogen.

3. Conclusion

Two MFCs were operated in parallel successfully for a period of 182 days, or approximately 6 months. The system was operated at a controlled voltage of 0.3V and under a fed-batch sample/feed protocol. Several system variables were measured throughout the experiment: cell voltage, individual MFC current, waste activated sludge feed and wastewater anolyte variables (COD, TKN, FSA, and pH), ferricyanide concentration in MFC#2 catholyte, DO in MFC#1 catholyte, and the head space gas composition. The calculation of current and power densities was performed using two elective surface areas, EESA based on the entire cathode surface area and EMSA based on the Nano proton exchange membrane surface area. Power densities of up to 167 mW/m2 were observed from MFC#2 using the EMSA, while the same power production resulted in a power density of 4.15 mW/m2 using the EESA. These areas represent upper and lower bounds on the elective surface area. The power density calculated with the EMSA was comparable to reported literature values in similar systems operated with a glucose feed.

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