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Synthesis of Silver Nanoparticle for Improved Electricity Generation and Waste Water Treatment by Microbial Fuel Cell

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Abstract: A microbial fuel cell (MFC) is a bio-electrochemical device that harnesses the power of respiring microbes to convert organic substrates directly into electrical energy. Microbial fuel cells work by allowing bacteria to do what they do best, oxidize and reduce organic molecules. There are different aspects of Microbial Fuel Cells as well as different types of fuel cells. Microbial fuels cell can be used for different purposes such as electricity generation, Bio hydrogen production, biosensors and waste water treatment. However, the MFC technology still faces major challenges, particularly in terms of chemical oxygen demand (COD) removal efficiency. So in order to increase efficiency of MFC, coating of silver nanoparticles on electroplates has been proved a more efficient method nanoparticle's can be more economically formed by green chemistry using extracts of Ocimum sanctum (Tulsi Leaves) and then can be used for coating. Overall this article is fully focused on treating of waste water using MFC and generating electricity at different variations.
Keywords: anode; cathode; electricity generation; Microbial fuel cell; wastewater treatment.

I. INTRODUCTION

Current methods to produce energy are not sustainable, and concerns about climate and global warming require developing new methods of energy production using renewable and carbon-neutral sources. MFC is a device designed for the purpose of electricity generation in the process of wastewater treatment. Hence it is an ideal solution for sustainable nonrenewable source of energy. MFC can be defined as electrochemical devices that convert the chemical energy contained in organic matter into electricity by means of catalytic (metabolic) activity of the living microorganisms**.** Microbial fuel cells allow bacteria to oxidize and reduce organic molecules. Bacterial respiration is basically one big redox reaction in which electrons are being moved around. Whenever you have moving electrons, the potential exists for harnessing an electromotive force to perform useful work. A MFC consists of an anode and a cathode separated by proton exchange membrane. Microbes at the anode oxidize the organic fuel generating protons which pass through the membrane to the cathode, and electrons which pass through the anode to an external circuit to generate a current. This leads to two types of MFCs: mediator and mediator free.

A. Mediator based MFCs

Most microbial cells are electrochemically inactive. According to *B.G. Mahendra et.al.,2013* the Electron transfer from microbial cells to the electrode is facilitated by mediators such as thionine, methyl viologen, methyl blue, humic acid and neutral red. Most available mediators are expensive and toxic**.**

B. Mediator-free MFCs

Mediator-free microbial fuel cells use electrochemically active bacteria (*Shewanella putrefaciens, Aeromonas hydrophila , geobacter sulfurreducens etc*.) to transfer electrons to the electrode (electrons are carried directly from the bacterial respiratory enzyme to the electrode). *B.G. Mahendra et.al.,2013* told that some bacteria are able to transfer their electron production via the pili on their external membrane**.**

MFCs have demonstrated broad application in wastewater treatment, power generation, toxic metal recovery, biosensors, and energy recovery from human excrement in space. Unfortunately, the power density of the MFCs at present is significantly lower than the theoretical value. *Shenlong Zhao et.al.(2015)***,** stated low power should originate from current technical limitations such as low bacteria loading capacity and the difficult electron transfer between the bacteria and the electrode. To overcome this limitation, we can use electroplates instead of electrodes in order to increase surface area and coat it with silver nanoparticles to increase surface to volume ratio.

II. NANOPARTICLES AND THEIR MANUFACTURING

Nanoparticles are used immensely due to its small size and physical properties which are reportedly shown to change the performance of any other material which is in contact with these tiny particles. These particles can be prepared easily by different chemical, physical and biological approaches. But the biological method is the most efficient approach for the preparation of nanoparticles because it is eco-friendly and less time consuming. They are mostly prepared from noble metals, that is, silver, gold, platinum and palladium, silver nanoparticles (AgNPs) being most exploited. The leaves extracts of *Azadirachta indica* and *Ocimum sanctum* acts as a capping agent, reducing agents, and possess antibacterial activities and healing properties.

A. Synthesis of silver nanoparticles

Synthesis of nanoparticles can be done by following methods

1) Chemical synthesis
2) Physical synthesis
3) Photochemical synthesis
4) Bio-synthesis

In the above mentioned methods the biosynthesis is the cost effective and an easy method for synthesis of nanoparticles.

B. Procedure for bio-synthesis

1) 0.1M silver nitrate ($AgNO_3$) was prepared and stored at 4°C for future work.
2) 15 ml each of collected leaf extracts was added separately to 45 ml of the prepared solution of $AgNO_3$ at room temperature while stirring.
3) It was further stirred for 5 -10 minutes.
4) The solution was then kept aside for 24 hours for complete bio- reduction and saturation of AgNPs.
5) The experiment was repeated thrice. The formation of AgNPs was confirmed using spectrophotometric analysis.

Fig. 1: synthesis of silver nanoparticles

C. Characterization of silver nanoparticles

The biosynthesized silver nanoparticles can be characterized by using;

1) *UV – Visible Spectroscopy;* Ultraviolet–visible spectroscopy or ultraviolet-visible spectrophotometry (UV-Vis or UV/Vis) refers to absorption spectroscopy or reflectance spectroscopy in the ultraviolet-visible spectral region. This means it uses light in the visible and adjacent ranges
2) *XRD;* X-ray powder diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions
3) *TEM;* Transmission electron microscopy (TEM, also sometimes conventional transmission electron microscopy or CTEM) is a microscopy technique in which a beam of electrons is transmitted through a specimen to form an image.
4) *FTIR;* Fourier-transform infrared spectroscopy (FTIR) is a technique used to obtain an infrared spectrum of absorption or emission of a solid, liquid or gas.
5) *SEM;* scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons.

The size of biosynthesized silver nanoparticles was found to be within the range of 20-60 nm.

D. Uses

1) *Antifungal properties;* Nano silver is an effective, fast-acting fungicide against a broad spectrum of common fungi including genera such as Aspergillus, Candida, and Saccharomyces *(Huo S. et.al., (2006))***.** The exact mechanisms of action of silver nanoparticles against fungi are still not clear, but mechanisms similar to that of the antibacterial actions have been proposed for fungi *(Jacob et.al., (2008)).*
2) *Antiviral properties;* Silver nanoparticles (diameter 5-20 nm, average diameter (~10 nm) inhibit HIV-1 virus replication. In MFCs it helps to treat waste water by removing viral causing viruses from the waste water.

III. FUTURE WORKS

There are basic components of MFCs which are important in constructions. Electrodes, wirings, glass cell and proton exchange membrane have an important role. Apart from that fuel cells can be classified in two types on the basis of number of compartments or chambers:

A. Single chamber MFCs

The MFC has a cathode electrode with one side in contact with the liquid, while the other side is directly exposed to air. Oxygen in the air can passively diffuse through the cathode and involve in the reaction of oxygen reduction. *Bunpot Sirinutsomboon et.al., (2014)* study showed that the air–cathode MFC produced higher power output in the absence of PEM, which can obstruct the flow of protons. PEMs are also generally quite expensive. As a result, a membrane less single-chamber MFC is simple and inexpensive to build.

B. Double chamber MFCs

Both the cathode and anode are housed in different compartments or chambers connected via a proton exchange membrane (PEM) or salt bridge. PEM or salt bridge mainly functions as medium for transfer of proton to make the circuit complete. This not only completes the reaction process but also prevents anode to come in direct contact with oxygen or any other oxidizers. They are run in batches and can be used for producing higher power output and can be utilized to give power in much inaccessible conditions. It can be suitable designed to scale up to treat large volume of wastewater and other source of carbon.

In our project we will be going to use two double chamber MFCs having iron and copper electroplates respectively coated with the silver nanoparticles. Our setup consists two chambers, one for anode and other for cathode. Both the chamber is connected with the salt bridge of agar as medium for transfer of proton to make the circuit complete. the anode chamber is anaerobic. We will be going to compare the result of both the MFCs and going to find which electrode generate high potential and treat wastewater effectively.

IV. APPLICATION OF MFCS

A. Power Generation

In anode chamber, the bacteria oxidize and reduce the organic matter to generate life sustaining ATP. Byproducts such as protons, electrons and carbon dioxide are produced, with the anode serving as the electron acceptor. The electrons which is generated pass from anode to cathode using wire as conductive bridge and protons pass freely into cathode chamber through proton exchange membrane. Finally, oxygen present at cathode recombines with hydrogen and electrons to produce pure water, completing the circuit. Replace that wire with a light bulb or some other device that requires electricity and you have effectively harnessed the power of microbes to solve your energy needs.

B. MFC's and Wastewater Treatment

MFC provide clean, safe, and quiet performance in wastewater treatment. Microbes love sewage, and the conditions of a waste water treatment plant are ideal for the types of bacteria that can be used in an MFC. *Anand Parkash et.al., (2015)* study shows that bio-cathode in a dual chamber MFC to generate maximum voltage of 2.5 V. The use of bio cathode generates an internal resistance of 36-46 ohm, hence yielding maximum voltage generation (2.5 V) from MFC. *Saccharomyces cerevisiae* sp. was used as biocatalyst. Methylene blue (10 ml) was used a mediator and potassium ferricyanide (350 ml) was used as an oxidizing agent for the conversion of sewage sludge into voltage generation. In this MFC, anode solution was in batch and cathode was in continuous mode of operation under optimum conditions of the operating parameters like pH, oxygen flow rate and substrate concentration.

V. CONCLUSIONS

There is a wide scope for development of MFCs as the power density is too low for deployment in automobiles and other industrial applications. The intrinsic conversion rate of MFCs will need to be increased, or the design will need to be simplified so that a cost-effective, large-scale system can be developed. Designs that can most easily be manufactured in stacks, to produce increased voltages, will be useful as the voltage for a single cell is low. Advances in microfluidics will allow engineers to make increasingly smaller MFC devices that can take advantage of this high surface to volume ratio. Research into advanced microfluidics, bacterial strains, more robust separator membranes, and efficient electrodes are the key to unlocking the potential of MFCs.

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