Fuel 236 (2019) 325–337

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

Biomass derived activated carbon cathode performance for sustainable power generation from Microbial Fuel Cells

Debajyoti Bose[a,*], Shanmathi Sridharan[b], Himanshi Dhawan[b], Parthasarthy Vijay[b], Margavelu Gopinath[c]

[a] Department of Electrical, Power & Energy, University of Petroleum & Energy Studies, Energy Acres, Bidholi, Dehradun 248007, UK, India
[b] Department of Chemical Engineering, University of Petroleum & Energy Studies, Energy Acres, Bidholi, Dehradun 248007, UK, India
[c] Department of Biotechnology, Selvam College of Technology, Salem Road (NH-7), Pappinaickenpatti (Post), Namakkal 637003, Tamil Nadu, India

ARTICLE INFO

Keywords:
Activated carbon
Bioelectricity
Biofilm
Cathodes
Fouling

ABSTRACT

Significant amount of wastewater is generated from Sewage, and treating this wastewater consumes huge amount of energy. Microbial Fuel Cells can be used to treat this wastewater and generate electricity in the process. Traditionally, Platinum catalyst on Carbon Cloth is used as the cathode for oxygen reduction. In this work, an advanced cathode material in the form of an activated carbon derived from biomass sources was evaluated in terms of cathode performance, stability of operation and cost. For activated carbon cathode, an open circuit voltage of 580 ± 30 mV was achieved between fed-batch cycles. Constant external load produced a peak current density and power density of 0.40 mA/m^2 and 110 ± 6.58 mW/m^2 respectively. Further polarization curves reveal system stability with varying resistances with a change in COD for the wastewater from 780 ± 20 mg/l to 260 ± 30 mg/l over two weeks of operation, achieving a removal efficiency of around 64%, the BOD content of the wastewater also reduced from 520 ± 20 mg/l to 165 ± 25 mg/l with a dissolved solutes removal efficiency of 51% during time of operation. Activated carbon derived from biomass sources is a promising alternative to expensive platinum; further it has a low surface pH, lacks any acidic surface functional group, and can be regenerated to more than 85% of its initial performance with dilute acid wash as compared to platinum which cannot be reused once fouled, thus implicating a sustainable solution.

1. Introduction

When we talk about sustainable energy for the future generations, much of the debate shifts to exploring non-combustion based pollution free technologies [1]. An added incentive to these clean forms of energy is if it can be successfully integrated with the water treatment infrastructure. Wastewater generation from both domestic and industrial sources contribute significantly to the inadequate water supply for sanitation and for industries, [2] this contributes to use of expensive chemicals to treat the wastewater before discharging them to an environmentally acceptable level [3,4].

Microbial Fuel Cells or MFCs can effectively treat the wastewater, and at the same time, use the process to generate electrical power [5,6]. This is possible by the bacteria present in the wastewater, which grows on one electrode, consumes the organic matter and releases electrons, thus reducing the organic load from the water, and the electrons released travel through the length of the circuit where the load is connected and the reaction completes at the cathode [7]. In recent years, while evaluating feasibility of making MFCs a commercial success, a key area of exploration has been the material used for the development of the cathode [8]. Traditionally Platinum (as a catalyst) on carbon cloth is used as the cathode, which is expensive and gets fouled over six months of operation [9]. Thus, finding low cost alternatives to Platinum, which can produce comparable power densities are a key area of exploration. The criteria for a new MFC cathode should include; good catalyst for oxygen reduction, can be derived from carbon-based sources, less susceptible to fouling and can be easily regenerated [10].

In this work, a novel indigenous activated carbon (AC) cathode is prepared with PVDF (Polyvinylidene fluoride) used as a binder on a Stainless Steel Mesh (Type 316L) through a single step phase inversion method [11]. Activated carbon is prepared from sugarcane refuse using a pre-treatment method, and a comparative assessment is made for AC cathode performance derived from other biomass sources [4]. Surface characteristics and functional group analysis for the prepared AC is done using XRD (X-Ray Diffraction) and FTIR (Fourier Transform Infrared Spectroscopy) respectively. Particle size analyser is used to

* Corresponding author.
E-mail address: dbose@ddn.upes.ac.in (D. Bose).

https://doi.org/10.1016/j.fuel.2018.09.002
Received 17 May 2018; Received in revised form 29 August 2018; Accepted 1 September 2018

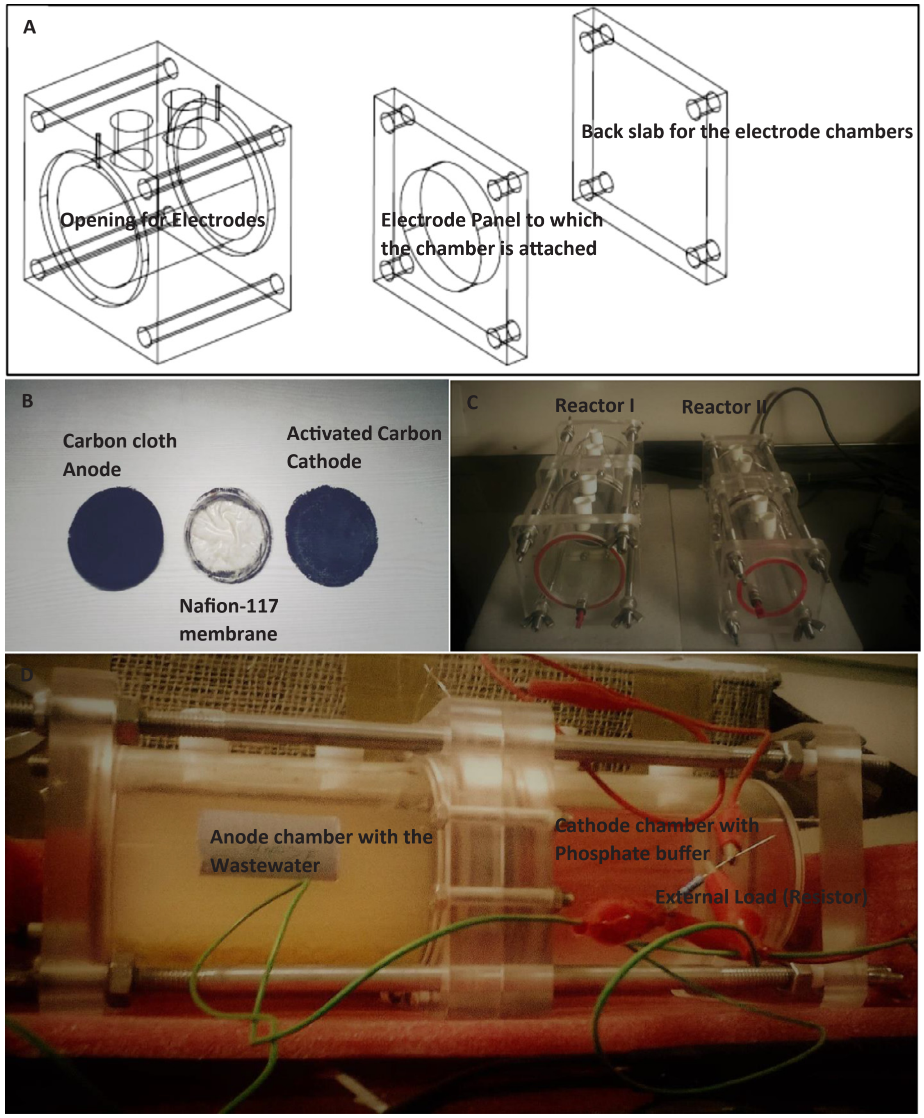

Fig. 1. (A) Plexiglass reactor constructed out of Lexan block, with two openings for the anode and the cathode (B) The anode, membrane and the cathode which constitute the membrane-electrode assembly (C) Two identical reactors used for evaluating MFC performance (D) MFC reactor with wastewater in the anode, and phosphate buffer in the cathode, the terminals of the anode and cathode are connected to an external load (resistor).

evaluate the average particle size. Microscopic analysis for the surface is done using AFM (Atomic Force Microscopy) and SEM (Scanning Electron Microscopy); SEM imaging is also used to see development of bacteria and nanowires on the anode. A control MFC setup was used with Platinum as catalyst on carbon cloth to see comparative performance of the MFC systems, in terms of power generation, oxygen reduction, operational stability, and water pressure handling capacity.

2. Materials and methods

2.1. MFC reactor

Cube double chambered reactors were used in all the studies. These were made from a lexan block having an inside cylindrical chamber for the anode and cathode liquid respectively [12]. The membrane is sandwiched between the anode and the cathode. As shown in Fig. 1A, the side of the reactor facing the anode holds the anode liquid, and the side facing the cathode will house the cathode liquid. The Membrane Electrode Assembly (MEA) was fabricated by a process which has been discussed previously [6] The anode is plain carbon cloth (E-TEK, USA) without wet proofing (having a surface area of 28.26 cm^2) for all the studies and the anode chamber is filled with wastewater (from sewage sources). Wastewater is collected from the University Sewage Treatment plant inlet. The cathode is platinum on carbon cloth, and a conductive phosphate buffer solution is used in the cathode chamber. Nafion-117 (Dupont, USA) is used as a membrane separating the anode from the cathode [13].

2.2. Advanced cathode material

As an alternative to expensive catalyst (such as Platinum), a comparative analysis is presented, with activated carbon cathode and PVDF as binder, where the cathode itself acts as a catalyst [14] A novel indigenous route was taken for the preparation of AC cathodes. Sugarcane refuse was collected from the local market, as these are freely available from local sugarcane juice suppliers. After collecting the same, the material was put in a dryer for moisture removal at 110 °C for three hours, this was followed by crushing the sugarcane to finer particles, followed by impregnation with 40 wt% Phosphoric acid (BDH Grade, Sigma Aldrich). This was followed by carbonization at 300, 400 and 500 °C at one hour intervals.

Here phosphoric acid acts as an activating agent and has several