# HIGHLY EFFICIENT MICROBE-MEDIATED ENERGY HARVESTING FROM WASTEWATER THROUGH NANOMATERIAL DECORATED THREE-DIMENSIONAL MULTI-LENGTH SCALE POROUS MATRIX ELECTRODE

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## ABSTRACT

*Microbial fuel cells (MFCs) are "green energy" devices utilizing microbial metabolism to directly generate electricity from organic substrates, and have generated excitement in environmental and bioenergy communities due to their potential for coupling wastewater treatment with energy generation. However MFC technology has not yet been put to practical use because of its low power density compared with other fuel cell technologies. Biogas such as biomethane and biohydrogen generated from organic waste are green energy sources of great interest. Recent developments in bioelectrochemical systems such as microbial electrolysis cells (MECs) that allow electrochemically active microbe-mediated methane and hydrogen generation have the potential for economic and high purity biogas generation. However these technologies have not yet been mature enough for practical use. Our goal is to develop a self-sustainable MFC-MEC coupled hybrid system that directly generates electricity from wastewater using locally available microbes, which is then utilized by the MEC part of the system to generate high-purity biogas as a clean combustible fuel source. This hybrid system can also function either solely in MFC mode or MFC/MEC mode, producing electricity or biogas depending on the need. As a first step toward realizing this system, we are developing a three-dimensional multi-length scale porous matrix electrode decorated with carbon nanotubes to significantly increase MFC performance to rapidly treat wastewater and generate sufficient energy for practical use. Our approach is to directly grow carbon nanotubes (CNTs) on stainless steel (SS) mesh to establish a tighter linkage between the CNTs and the underlying electrodes to enhance microbe-electrode coupling. Using our recently developed high-throughput MFC array, we have screened multiple electrode compositions in parallel, and showed that CNT-grown SS mesh showed close to 2725 times higher power density (550 mW/m$^2$) compared to bare SS mesh. This result is, to our knowledge, the largest improvement in power density of any nanomaterial-decorated electrodes for MFC/MEC applications, and paves the way towards a highly efficient and economical simultaneous wastewater treatment and bioenergy harvesting system.*

Key words: BIOHYDROGEN, CARBON NANOTUBES, ELECTRICITY, MICROBIAL ELECTROLYSIS CELL, MICROBIAL FUEL CELL, WASTEWATER

## INTRODUCTION

MFCs are an energy converting system from organic matters including wastewater to electricity (Kim et al., 1999). The electrons from organic matters are harvested by microbial oxidation of electrochemically active bacteria (EAB) (Chang et al., 2006) (Fig.1). It is applicable to biohydrogen production (Liu et al., 2005), wastewater treatment (Rabaey et al., 2005), environmental sensors (Kim et al., 2003) and bioremediation (Gil et al., 2003). However, MFCs shows the lower performance than chemical fuel cells due to high overpotential losses which majorly governed in the electron transfer to the anode electrode (Liu et al., 2005; Torres et al., 2008). Thus it is difficult that MFC is used for as a power source. Therefore, this study focused on MFC performance improvement with nano-sized anode materials such as directly grown carbon nanotubes on stainless steel mesh which can strongly linked with the underlying electrode. A three

dimensional porous structure of CNT provides larger active surface area, and nanomaterial synthesized electrode improves electron transfer route from EAB to anode current collector with higher conductivity.

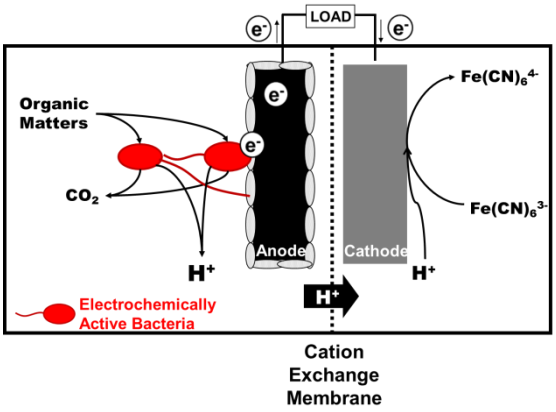


Fig.1. A schematic diagram of microbial fuel cell. Organic matters are degraded into proton ($H^+$) and electron ($e^-$). Protons are transported to the cathode via cation exchange membrane, while electons are moved to the cathode through the external circuit. Ferricyanide ($Fe(CN)_6^{3-}$) is electron acceptor in the cathode reduced to $Fe(CN)_6^{4-}$.

## MATERIAL AND METHODS

CNTs are grown on SS mesh by a chemical vapour deposition method which moisturized $C_2H_4$ and $H_2$ were supplied into a quartz tube furnace of 800 °C for 30 mins. CNT grown on SS mesh was used for the anode electrode. Our MFC device was MFC array type for electrode screening (Hou et al., 2009) (Fig.2). The microfabricated 24-well MFC array has 24 independent cells, therefore 24 different experiment conditions are available to compare in parallel. Anode inoculum was *Shewanella Oneidensis* MR-1. Anolyte was Tryptic Soy Broth (TSB), and catholyte was 100 mM of Ferricyanide.

## RESULTS AND DISCUSSION

CNTs grown directly on SS mesh resulted in the highest power generation of 550 mW/m$^2$ compared to power density of bare SSM which was 2725-times higher power output than bare SS mesh. This result shows physical properties of electrode influence MFC performance, and further research is required to develop the most efficient electrode to improve MFC power output for MFC-MEC coupled hybrid system application.

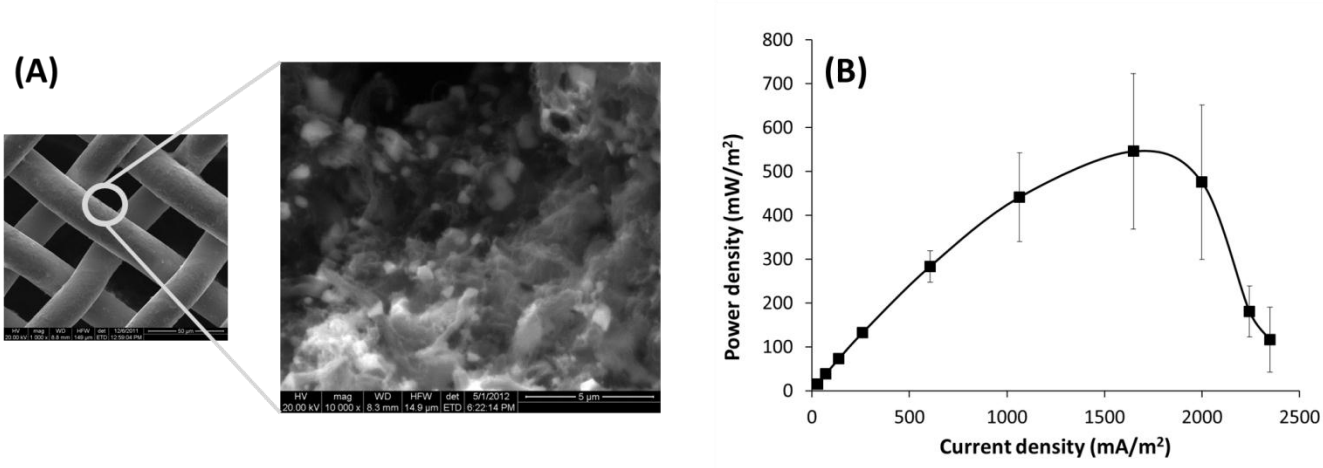


Fig.2. (A) SEM images of bare SS mesh (B) power density using CNT grown on SS mesh

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