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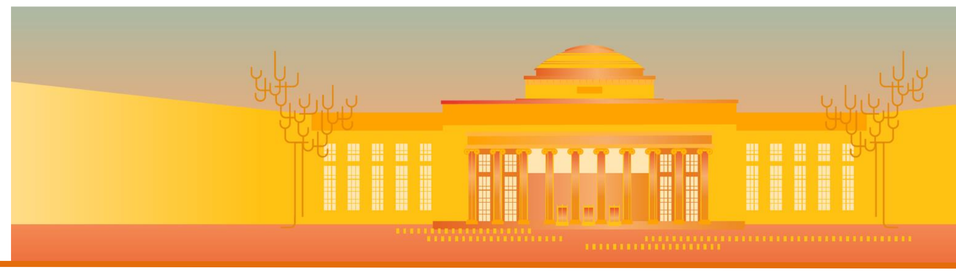

Microstructured Graphene Anode Fabrication for Microbial Fuel Cell Using Light

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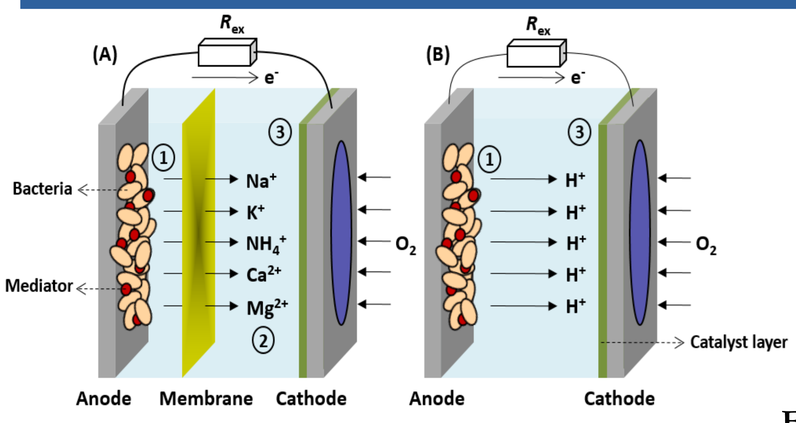
Introduction

Microbial fuel cell (MFC) is a technology of sustainable development which uses microorganism as a biocatalyst to convert the biochemical energy of organic matter into electrical energy (Scheme 1).

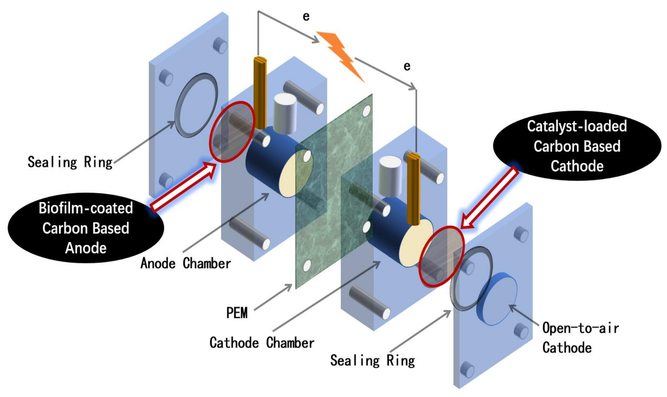
MFC is environmental friendly and low cost. It has great potential in bioremediation, bio-electrochemical energy production and wastewater treatment. Performance of MFC heavily depends on the properties of the anode materials for bacterial accessing, biocompatibility, and interface electron transfer resistance, which impact the output power of MFC significantly. Carbon materials such as carbon cloth (CC), carbon paper, graphite particles and graphite felt are the most common anode materials for MFC (Scheme 2). However, these materials show many disadvantages, for example, small specific surface area, poor conductivity, and poor biocompatibility. Identifying anode material with appropriate activity and affordable cost is critical for the practical application of MFC.

Graphene is one of the most efficient alternative materials to improve the performance of anodes in MFC. However, it is challenging to adapt existing graphene synthesis technologies like micromechanical exfoliation, chemical vapor deposition, and chemical reduction of graphene oxide (GO) for MFC fabrication. The present work demonstrated an efficient and cost-effective fabrication for photochemically reduced graphene oxide (PRGO), presenting physical properties comparable to pure graphene.

Methods



Scheme 1. The schematic of MFC (A) dual-chamber (DC) and (B) sectional single-chamber (SC).



Scheme 2. The schematic representation of MFC setup.

Materials

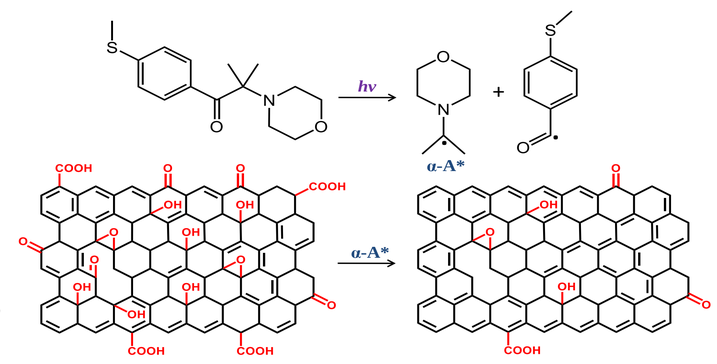


Fig. 1. Mechanism for generating α-A* free radicals by photosensitizer Irgacure-907 and photochemical reduction of GO.

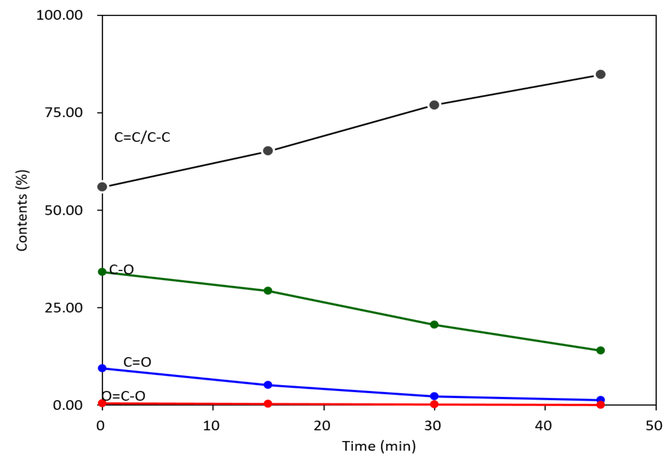


Fig. 2. Variation of contents of the functional groups with respect to reaction time during photochemical reduction of GO by Irgacure-907. The data were derived from the C1s XPS spectra.

We have estabished an easy and economical way for rapid manufacturing MFC anode with photochemically reduced graphene oxide (PRGO). The strong reducing α-aminoalkyl (α-A*) radicals generated by illuminating the photoinitiator Irgacure-907 using UV (λ=320-420 nm) light (Fig. 1), The extent of oxygen reduction can be continually controlled by manipulating light dosage. PRGO were quantitatively characterized for its structure, morphology, chemical composition(Fig. 2), and electrical conductivity.

Results and Discussion

The developed photochemical-reduction technology generated high-quality PRGO, making it ideal for MFC anode with microstructures presenting large specific surface area and efficient charge transfer process. This method can adjust the structure, size, conductivity and hydrophilic effect of graphene sheet in the electrode (Fig. 3), which are important for electrode performance improvement. Electrochemical properties of electrodes are assessed using cyclic voltammetry and electrochemical impedance spectroscopy. Results showed the PRGO anode had higher charge storing capacity and lower charge transfer resistance in photochemically reduced graphene oxide electrodes. It can be clearly observed that there is a considerable decrease in Nyquist diameter after modification of CC with PRGO (Fig. 4). Synergistic effect of the large surface area for bacterial colonization and high conductivity of PRGO microstructure are beneficial for MFC of superior performance (Fig. 5). The present work demonstrated the efficient and cost-effective fabrication for PRGO electrodes. With proper optimization, the preparation time of graphene sheet can be further reduced, presenting a great promise for MFC application.

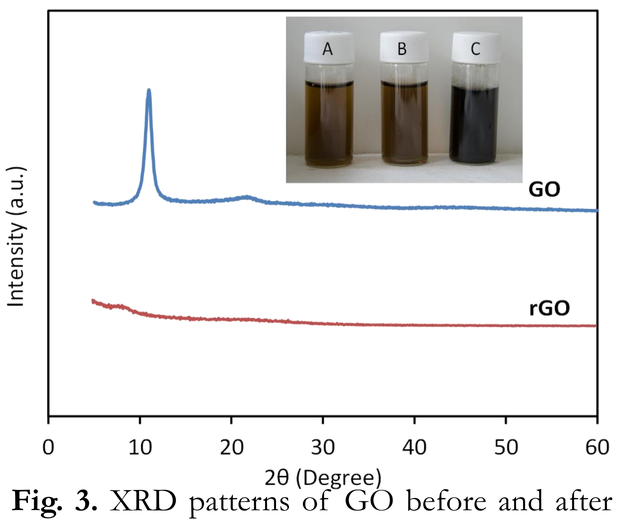


Fig. 3. XRD patterns of GO before and after 30-min photochemical reduction by Irgacure-907. The inserted figure shows the optical photographs of colour change of GO (A), the photochemical reduction of GO without (B) and with (C) photoinitiator Irgacuere-907 addition.

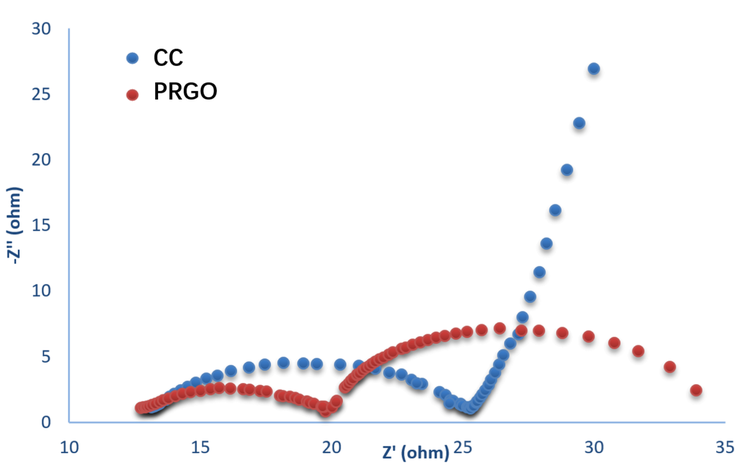


Fig. 4. Nyquist plots of electrochemical impedance spectroscopy measurements for CC and PRGO.

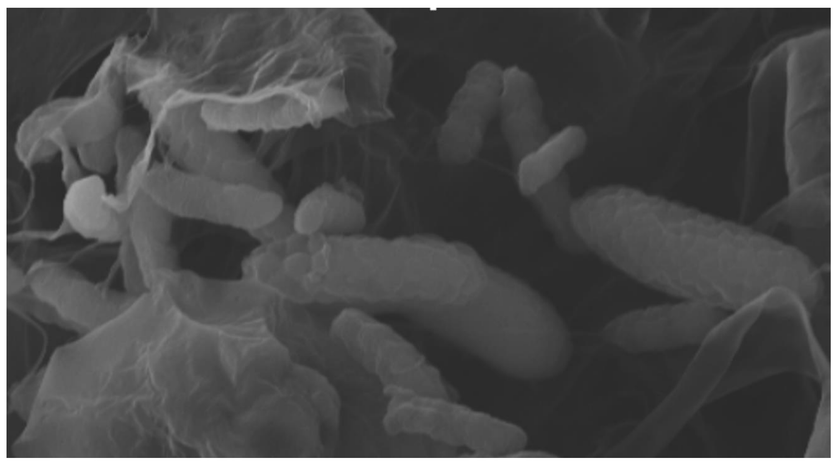


Fig. 5. SEM image of anode surface colonized by bacteria in MFC.