A Graphene-based Anode For Microbial Fuel Cells

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Introduction: Microbial fuel cells (MFCs) are a promising source of green energy because of their ability to harvest electricity from organic matter using electron transferring microorganisms, exoelectrogrens[1]. However, their low power densities and high-associated costs have limited their practical applications. Anode performance is a key factor limiting MFC power densities and has been improved upon by many groups with the use of carbon-based anodes[2]. Recently graphene nanoribbons (GNRs) have demonstrated improved power performance as the anode material in MFCs because of their high electrical conductivity and high specific surface areas that enable faster electron transfer and higher sites for bacteria attachment[3]. Nanoribbons can be synthesized easily via longitudinal unzipping of carbon nanotubes[4] and then further reduced chemically using hydrazine in solution. In this study, we developed an inexpensive solution-phase method for the preparation of graphene nanoribbon films on multiple substrates such as stainless-steel mesh and polyethylene terephthalate using a simple vacuum filtration setup with dimethylene formamide (DMF). Compared to bottom up approaches to graphene synthesis such as chemical vapor deposition (CVD), vacuum filtration and solution based unzipping of nanotubes is much less expensive and easier for large-scale manufacturing requirements in the future. As a proof-of-principle, these GNR film anodes were tested in single-chambered, soil-based MFCs.

Methods: Graphene oxide nanoribbons (GONRs) were prepared via longitudinal unzipping of multi-walled carbon nanotubes[4]. A 1 mg/mL solution of GONRs in a 1:9 mixture of distilled water (4 mL) and DMF (36 mL) was reduced using a hydrazine reduction method[5]. In short, hydrazine is added (1 uL/3 mg of nanoparticle) and stirred constantly for 12 hours at 80 degrees C to yield reduced graphene nanoribbons (GNRs). Films were prepared using a simple vacuum filtration process. Each film was formed with 12 mL of 0.33 mg/mL GNR solution in a mixture of DI water and DMF with a volume ratio of 1:2, respectively. Films were transferred onto stainless steel mesh and polyethylene terephthalate substrates with the membrane still attached. A 0.5 kg weight was used to aid in adherence to substrates and afterwards, the films-substrates were left to dry in a 60 degree C oven for 3 hours. Consecutive acetone washes were used to remove the remaining ester membrane and allowed to air-dry.

Results and Discussion:
The fabricated GNR films showed some uniformity and reproducibility using our method for both substrates. Transmission electron microscopy (TEM), Raman spectroscopy, and scanning electron microscopy (SEM) were used to characterize the synthesis and fabrication of GNR films.

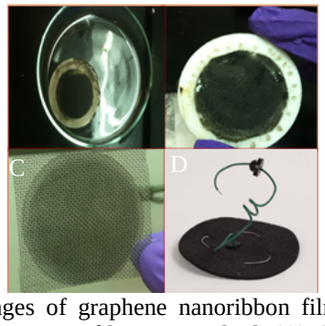

Figure: Images of graphene nanoribbon films prepared via a simple vacuum filtration method. (A) GNR film on membrane after filtration process, (B) GNR film on PET substrate, (C) GNR film on SS mesh substrate, (D) Mudwatt anode (graphite fiber felt) purchased from KeegoTech and used for comparison.

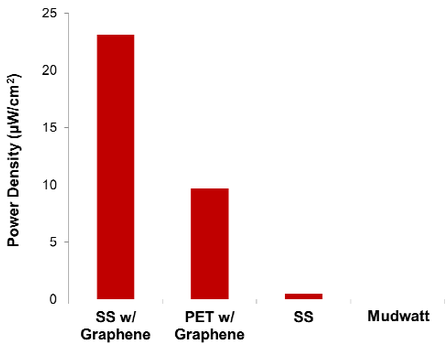

Figure: Peak power densities of the GNR film anodes in soil-based MFCs. The stainless-steel mesh and PET substrates with a deposited graphene film exhibited higher power densities than the stainless-steel mesh alone and graphite fiber cloth anode. (SS) – stainless steel mesh, (PET) - polyethylene terephthalate.

Conclusion: Our method is simple and can be used to fabricate graphene film anodes on multiple substrates inexpensively. The observed power output peaks and power-current curves (not shown) for the MFCs with different anodes demonstrates as a proof of principle that our graphene-based anodes may enhance power production in MFCs. Future studies include optimization of the method and detailed investigation of the power capabilities of our anodes in wastewater MFCs.

References:

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