Electrospun Nanofibers for Microbial Fuel Cells

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The global energy crisis and climate problem are being aggravated in recent years due to the increasing demand of fossil fuels, especially oil, coal, and natural gas. Renewable bio energy is viewed as one of the ways to alleviate these problems. Major effort is devoted to develop alternative electricity production methods. New electricity production from renewable resources without net carbon dioxide emission is much desired. Microbial fuel cells (MFCs) as one renewable bio energy resource for the conversion of energy from organic matter to electricity attracts more and more attentions. A microbial fuel cell or biological fuel cell is a bio electrochemical system that drives a current by mimicking bacterial interactions found in nature. A typical microbial fuel cell consists of anode and cathode compartments separated by a cation specific membrane (Figure 1). In the anode compartment, fuel is oxidized by microorganisms, generating electrons and protons. Electrons are transferred to the cathode compartment through an external electric circuit, and the protons are transferred to the cathode compartment through the membrane. Electrons and protons are consumed in the cathode compartment, combining with oxygen to form water. In general, there are two types of microbial fuel cells: mediator and mediator-less microbial fuel cells. Microbial fuel cells have a number of potential uses including wastewater treatment, microbial electrolysis for hydrogen production, conversion of bio energy from biomass into electricity, biosensor, bioremediation, and sediment MFC for remote power [1].

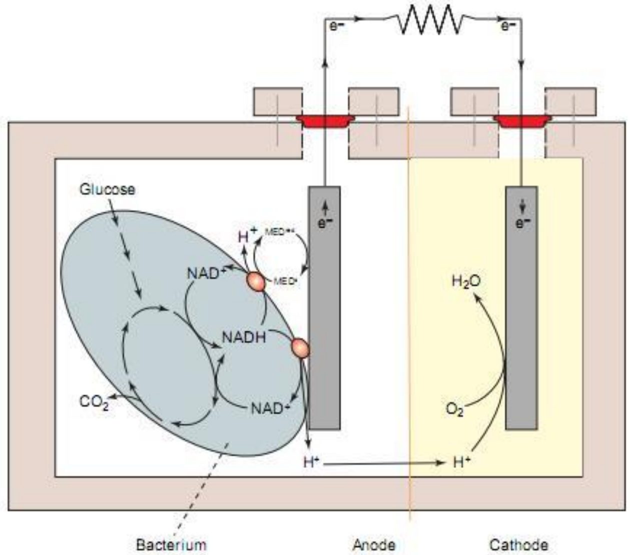

Figure 1. The working principle of a microbial fuel cell. (Substrate is metabolized by bacteria, which transfer the gained electrons to the anode) [2].

Concurrently, recent advances in nanoscale science and technology are fueling a new wave of revitalization in the field of biocatalysis. Synergizing with materials chemistry, various nanostructures have manifested their great potential in stabilizing and activating enzymes with performances well beyond the scope of traditional immobilization technologies. Especially, the large surface area, which these nanostructures provide for the attachment of enzymes, will increase the enzyme loading and possibly improve the power density of bio fuel cells. In that sense, nanoscale engineering of the bio catalysts appears to be critical in the next stage advancement of bio fuel cells.

Electrospun nanofibers provide a large surface area for the attachment or entrapment of enzymes. In the case of porous nanofibers, they can reduce the diffusional path of the substrate from the reaction medium to the enzyme active sites because of the reduced dimension in size, leading to better enzyme activity. Electrospinning can generate nonwoven mats or well aligned arrays of nanofibers with controllable compositions and sizes in a matter of minutes. Electrospun nanofiber mats are durable and easily separable and can also be processed in a highly porous form to relieve the mass transfer limitation of the substrate through the mats. Because of these attractive features, electrospun nanofibers have generated much attention as supports for enzyme immobilization. Although the electrospinning process typically uses harsh organic solvents and extreme conditions that generally are harmful to bacteria, in one study it has been demonstrated that the encapsulated microbes were viable for several months, and their metabolic activity was not affected by immobilization; thus they could be used in various applications. The present results demonstrate the potential of the electrospinning technique for the encapsulation and immobilization of bacteria in the form of a synthetic biofilm, while retaining their metabolic activity [3]. In another study, authors successfully developed an active and stable enzyme system using electrospun nanofibers. They fabricated the enzyme aggregate coatings on the surface of electrospun polymer nanofibers. This approach employs the covalent attachment of seed enzyme molecules onto nanofibers, followed by the glutaraldehyde (GA) treatment crosslinking additional enzyme molecules or aggregates onto the covalently attached seed enzyme molecules. The apparent activity of the enzyme coatings based on per unit mass of fibers was nine times higher than that of covalently attached enzymes on nanofibers. This new approach of enzyme coatings on nanofibers, yielding high activity and stability, creates an economically viable enzyme system for using expensive enzymes with potential applications in various fields, such as biofuel cells, bioconversion, bioremediation, and biosensors [4].

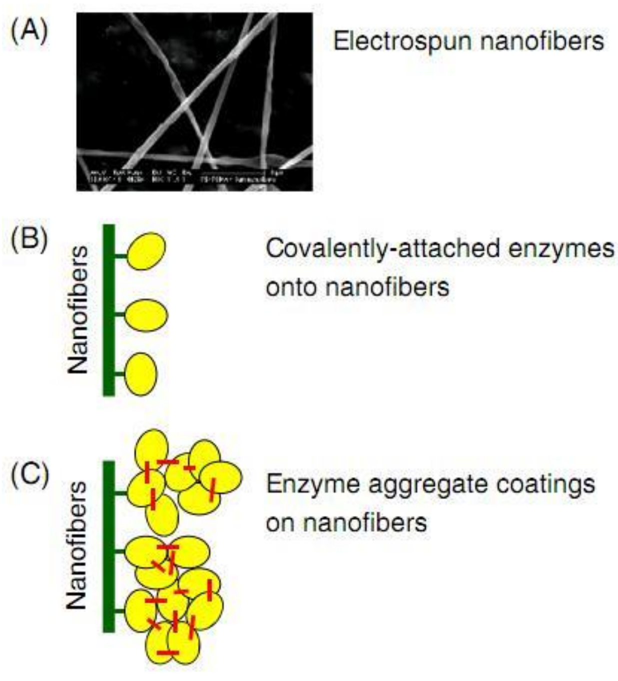

Figure 2. Enzyme immobilization on electrospun nanofibers [4].

Microbial fuel cells are evolving to become a simple, robust technology. Certainly in the field of wastewater treatment, middle term application can be foreseen at market value prices. However, to increase the power output towards a stable 1kW per m^3 of reactor, many technological improvements are needed. Provided the biological understanding increases, the electrochemical technology advances and the overall electrode prices decrease, this technology might qualify as a new core technology for conversion of carbohydrates to electricity in years to come.

References

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