Electrospun Nanofiber Biosensor for Measuring Glucose Concentration

Young Jae Shin, Miao Wang and Jun Kameoka

\textsuperscript{\textcopyright}Department of Electrical and Computer Engineering, Texas A\&M University, College Station, TX 77843, USA

An amperometric biosensor was fabricated using electrospun composite nanofiber membranes which are consisted of among polyaniline-polystyrene nanofibers. Polyaniline was reacted with camphorsulfonic acid to produce a salt, which was then dissolved in chloroform containing polystyrene. By electrospinning this polymer solution, nanofibers were formed and collected at the counter electrodes. Glucose oxidase was immobilized onto these nanofiber mats using an electrostatic layer-by-layer adsorption technique. In this method, poly(diallyldimethylammonium chloride) was used as the counter ion source. The electrical property of this composite nanofiber was investigated from these nanofibers as a working electrode, and used to measure the glucose concentration accurately.

Keyword: electrospinning, biosensor, polystyrene, layer-by-layer adsorption

1. Introduction

An amperometric biosensor is an analytical device that converts the concentration of an analyte into an electrical signal by integrating biological sensing. Biosensors are portable, simple-to-use and high specificity analytical tools.\textsuperscript{[1]} Therefore, biosensors are expected to have promising applications in a variety of fields, such as pharmacology, health care, pollution monitoring, food and agricultural product processing etc. During the previous 20 years, several attempts have been made to create sensitive, selective, reliable, and low cost glucose sensors due to the clinical significance of measuring the blood glucose levels.\textsuperscript{[2]} In this paper, we will describe the economical and widely acceptable biosensors based on nanofiber mats as a working electrode.

2. Method

We used below materials and instruments to fabricate nanofiber mats and execute experiment concentration measurement experiment. Polystyrene (M\textsubscript{w} 350,000, M\textsubscript{b} 170,000), camphorsulfonic acid (CSA), titanium(IV) butoxide, poly(diallyldimethylammonium chloride) (PDDA), glucose oxidase (GOD), glucose, chloroform, polyaniline (emeraldine base, M\textsubscript{w} 300,000), sulfuric acid, hydrogen peroxide, 2-mercaptoethanol, ethanol, toluene were purchased from Sigma-Aldrich Co.

A 0.400 M stock glucose solution was prepared daily and stored overnight to reach mutarotational equilibrium prior to use. A syringe pump (Harvard Apparatus) and a high-voltage power supplier (Bertan 230) were used in the electrospinning apparatus.

Chronoamperometric detection was carried out using a potentiostat (BAS Votammograph CV-27) and digital converter (e-corder 201 eDAQ).

The first step is electrospinning of polyaniline with polystyrene. The solution for electrospinning was formed as follows. 0.66 g of polyaniline (PANI) and 0.84 g of CSA were dissolved in 10 mL of chloroform. Subsequently, 2.0 g of polystyrene was added to this solution. The solution was stirred magnetically for 18 hours to produce the solution for electrospinning. The apparatus for electrospinning included a glass syringe, an 18 gauge stainless-steel needle, a syringe pump, a high-voltage power supplier, and aluminum foil as the collector. The polymer solution was drawn from the needle tip with an electrostatic force generated from the high voltage applied between the tip and grounded collector. The polymer solution formed a Taylor cone and jetted through the tip of the needle to the collector. The flow rate of the polymer solution was 0.5 mL/hr, the applied voltage was 15 kV, and the distance between the needle tip and collector was 20 cm. The
nanofiber was deposited on the counter electrode (collector) in the form of a non-woven mat. These nanofibers were used after drying in a vacuum oven at 50 °C for 5 hr.

In the case of electrospinning polystyrene (PS) only, 3 g of polystyrene was dissolved in 10 mL of chloroform. This solution was electrospun with the same conditions for PANI.

The second step is Immobilization of glucose oxidase. 0.10 g of the dried nanofibers was placed into 20 mL of a 0.10 M titanium(IV) butoxide in ethanol solution for 3 min. The nanofibers were then rinsed with in pure ethanol for 30 sec, followed by another rinse with fresh ethanol. The nanofibers were then placed into distilled water for 1 min. These composite nanofiber mat was then added to 20 mL of 2.0 wt% PDDA aqueous solution for 30 min, rinsed with distilled water for 1 min, followed by a further rinse with fresh distilled water. The nanofibers were then placed into 20 mL of 2.0 mg/mL GOD in a pH 7 phosphate buffer solution for 60 min, rinsed with distilled water for 30 sec, followed by another rinse with fresh distilled water.

Our last step is characterization of glucose biosensor. A glucose biosensor was fabricated in 40 mL of a pH 7 phosphate buffer solution using the nanofiber mat onto which GOD had been immobilized as a working electrode. All the electrochemical experiments were carried out using a standard one-compartment three-electrode cell. The reference electrode was Ag/AgCl (3M KCl) and the counter electrode was a platinum wire (20 cm). All electrode potentials were referred to the reference electrode. A glucose stock solution was prepared and stabilized for 24 hour prior to use in order to allow the α and β anomers to equilibrate.

The result of glucose concentration measurement using one layer of GOD on the surface of nanofiber mat is shown in Figure 2. The conductive current is increased when the glucose concentration is increased.

The conductive current is increased when the glucose concentration is increased.

Fig 2. Amperometric detection of one layer GOD on a consecutive 1 mM increase in glucose concentration.

Acknowledgements

This research was supported by the National Science Foundation under Grant No. NSF-CMMI-0709283. The authors thank professor E. Soriaga (department of chemistry, Texas A&M university) for using the potentiostat.

Reference