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Study of ITO glass electrode modified with iron oxide nanoparticles and Nafion for glucose biosensor application

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Abstract

In this study, we report the fabrication of the indium tin oxide (ITO) glass electrode modified with iron oxide nanoparticles (IONPs) and nafion for glucose biosensor applications. The IONPs was synthesized using the precipitation method and functionalized with citric acid (CA) to provide hydrophilic surface and functional group for glucose oxidase (GOx) enzyme immobilization. The structural and morphological studies of CA-IONPs were characterized using X-ray diffractometer (XRD) and transmission electron microscope (TEM). The size of the IONPs measured from TEM image was ~ 17 nm. The bioelectrode designated as Nafion/GOx/CA-IONPs/ITO was developed by drop casting of the CA-IONPs, GOx and nafion on the ITO glass. The Nafion/GOx/CA-IONPs/ITO bioelectrode showed good electrochemical performance for glucose detection. The functionalized CA-IONPs acted as the catalyst and help to improve the electron transfer rate between GOx and ITO electrode. In addition, thin nafion film was coated on the electrode to prevent interference and improve chemical stability. The Nafion/GOx/CA-IONPs/ITO bioelectrode showed high sensitivity of 70.1μAmM^{-1}cm^{-2} for the linear range of 1.0-8.0 mM glucose concentrations.

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*Keywords:*Iron oxide nanoparticles; glucose biosensor; citric acid; nafion

Nomenclature

ITO indium tin oxide

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IONPs	iron oxide nanoparticles
CA	citric acid
GOx	glucose oxidase
FeCl	iron (II) chloride
NaOH	sodium hydroxide
H_2O_2	hydrogen peroxide
PBS	phosphate buffer saline
RCA	Radio Corporation America
XRD	X-ray diffraction pattern
TEM	transmission electron microscopy
CV	cyclic voltametry

1. Introduction

Diabetes is a world-wide public health problem that is a leading cause of death and disability in the world. The diagnosis and management of diabetes mellitus require a tight monitoring of blood glucose[1]. Therefore, a simple and low-cost method that can be used at home to monitor blood glucose level is required. For that, glucose electrochemical biosensors are widely used. Generally, the glucose biosensor is based on the GOx enzyme. The glucose can be detected through measuring the increament of the anodic current during the oxidation of hydrogen peroxide (H_2O_2) produced from the oxidation of glucose by dissolved oxygen in the presence of GOx enzyme[1-2]. However, it is difficult for an enzyme (protein) to exchange electrons directly with bare solid electrodes due to its insulation-shelled redox center[2-4]. Therefore, enzymes were incorporated with metal nanoparticles to allow direct electron transfer.

Among various metal nanoparticles, IONPs have recently gained interest in glucose biosensor applications due to their properties of chemically and biological inert, low toxicity and super paramagnetic. It was observed the existing problems of IONPs are the agglomeration due to high volume to surface area of the IONPs that tend to attract them together in order to minimize their high surface energies[4]. The agglomeration can be prevented by functionalization of the IONPs with organic, inorganic and biopolymeric material such as chitosan, silica, polymers and carbon[5]. Among them, small molecules like citric acid and oxalic acid could be more suitable for IONPs functionalization due to their short chain tricarboxylic acid[6]. The carboxylate group presence may prevent particles agglomeration, provide surface hydrophilic and provide functional group for biomolecule attachment[6-8]. Deb et al.[7] have fabricated citric acid functionalize IONPs by using the co-precipitation method. IONPs produced showed less aggregation and contained anti-platelet activity to be used as the drug carriers in the treatment hyperactive platelets. Recently Sharma et al.[8] reported the efficient immunosensor for diarrhea and acidosis by utilizing IONPs functionalized CA for electrode modification. The CA-IONPs provided more specific surface area for larger biomolecule binding and the magnetic force attraction has improved the biosensing properties. Nafion encapsulation of enzyme is a common practice to prepare biosensors. Nafion is a sulfonatedtetrafluorethylene copolymer that has been widely used as a proton conductor for proton exchange membrane in biosensor applications. The main advantages of Nafion in biosensor applications are its biocompatibility, excellent thermal and mechanical stability, mechanical strength, and antifouling properties.

In this work, the sensing performance of IONPs functionalized with CA for glucose sensing application was evaluated. CA-IONPs were synthesized and drop casted on the ITO glass electrode. To the best of our knowledge, there is no work reported on the CA-IONPs used in electrode modification for glucose sensing. Here, the electrochemical and electrocatalytic performance of the Nafion/GOx/CA-IONPs/ITO bioelectrode in glucose sensing was evaluated. The surface functionalization of CA on the IONPs prepared the favourable microenvironment for biomolecule loading, prevent agglomeration between IONPs and increase electron mobility between the analyte and bioelectrode.