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Comparative analysis of single-walled and multi-walled carbon nanotubes for electrochemical sensing of glucose on gold printed circuit boards

Ruby Alhans[a], Anukriti Singh[b], Chaitali Singhal[a], Jagriti Narang[a,*], Shikha Wadhwa[a], Ashish Mathur[b,*]

[a] Amity Institute of Nanotechnology, Amity University, Noida 201301, UP, India
[b] NIBEC, Ulster University, Jordanstown Campus, Newtownabbey, Belfast BT37 0QB, UK

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ABSTRACT

In the present work, a comparative study was performed between single-walled carbon nanotubes and multi-walled carbon nanotubes coated gold printed circuit board electrodes for glucose detection. Various characterization techniques were demonstrated in order to compare the modified electrodes viz. cyclic voltammetry, electrochemical impedance spectroscopy and chrono-amperometry. Results revealed that single-walled carbon nanotubes outperformed multi-walled carbon nanotubes and proved to be a better sensing interface for glucose detection. The single-walled carbon nanotubes coated gold printed circuit board electrodes showed a wide linear sensing range (1 mM to 100 mM) with detection limit of 0.1 mM with response time of 5 s while multi-walled carbon nanotubes coated printed circuit board gold electrodes showed linear sensing range (1 mM to 100 mM) with detection limit of 0.1 mM with response time of 5 s. This work provided low cost sensors with enhanced sensitivity, fast response time and reliable results for glucose detection which increased the affordability of such tests in remote areas. In addition, the comparative results confirmed that single-walled carbon nanotubes modified electrodes can be exploited for better amplification signal as compared to multi-walled carbon nanotubes.

1. Introduction

Carbon nanomaterials such as graphene, carbon nanotubes (single walled and multi walled), fullerene, reduced graphene oxide and their hybrids are often considered as exciting platform for sensing applications [1–3]. Moreover, carbon nanomaterials are considered over other nanomaterials for electrochemical sensing due to their remarkably high aspect ratio, good electrical conductance; they show good resistance towards surface accumulation of unwanted materials, and increasing electron transfer process [4–8]. Amongst the class of carbon nanomaterials available today, carbon nanotubes are the most unique and novel material. Carbon nanotubes, including both single walled (SWCNT) and multi walled (MWCNT), show exceptionally good properties in electrical, mechanical and thermal applications [9–14]. MWCNT are simply few numbers of sheets of graphene rolled up together to form tubular hollow structures whereas the single walled as the name suggests are a single graphene sheet rolled up together. The structure and properties of CNTs are determined by the atomic arrangement taking place during rolling up of graphene sheets, length and diameter of nanotubes [15–18]. Though the CNTs have proved to be advantageous for glucose detection in the past few years, but a comparative study of different types of CNTs for amperometric glucose sensing is still unknown for application in portable diagnosis.

Patients need to frequently test their glucose levels in order to avoid emergencies of severe diabetic conditions and for an effective treatment to control their sugar levels. Therefore, the development of simple, easy to use, highly sensitive and most importantly low cost glucose monitoring device with an exceptional selectivity and detection range is a major subject of concern today [19,20]. Biosensors have been used for a wide variety of applications like sensing pathogenic viruses, vitamins, drugs and many more [21–25]. However, there are significant challenges in fabrication of highly stable having enhanced sensitivity and low cost biosensors based for glucose detection. There has been a recent increased demand in providing efficient and highly selective sensing of glucose in areas of clinical diagnosis. A quicker diagnosis and determination of the severity of the condition can be achieved from moving from conventional clinical glucose testing towards point of care testing, just next to the patient's bed side or even at home. In this work, we aim to develop a low cost, portable glucose monitoring device for point of care testing, to be used by patients themselves or by a person

* Corresponding authors at: Amity University, Noida, India.
E-mail addresses: jnmalhotra@amity.edu (J. Narang), amathur@amity.edu (A. Mathur).

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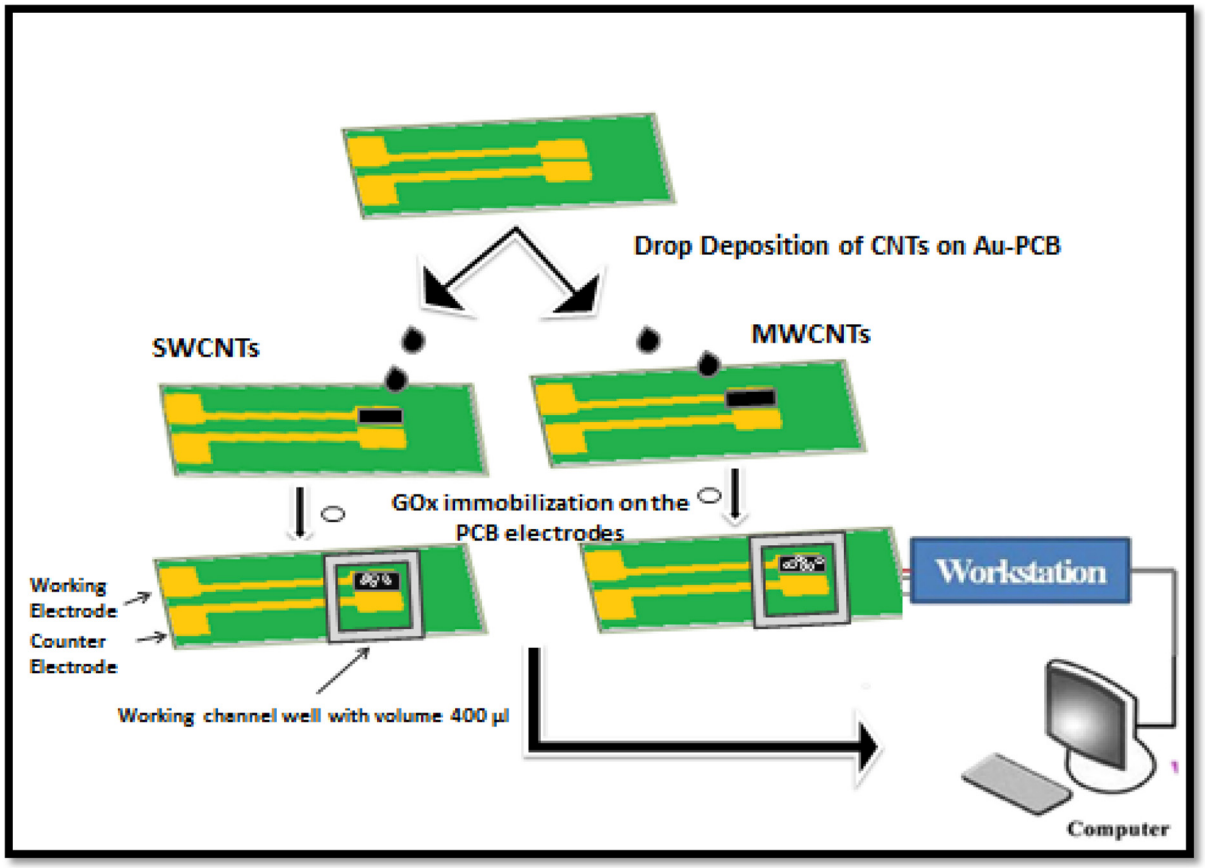

Fig. 1. Schematic representation of the fabrication of Au-PCB electrodes.

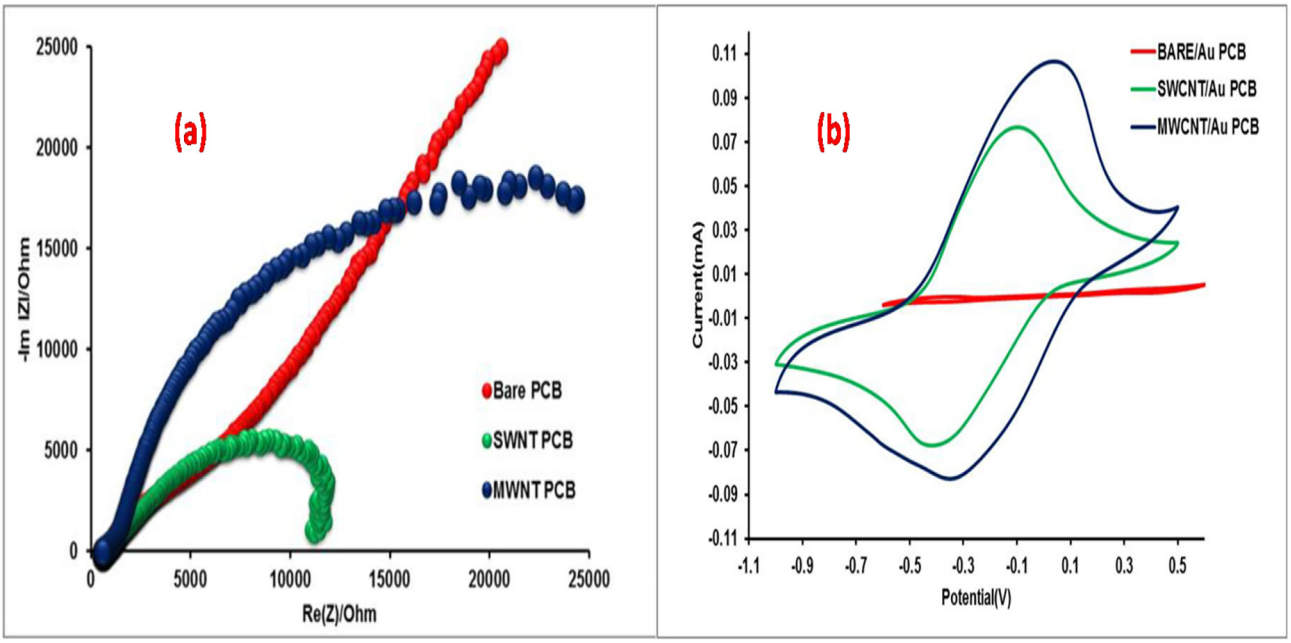

Fig. 2. (a): Nyquist plots at bare PCB, SWCNT/Au-PCB and MWCNT/Au-PCB in 5 mM $[Fe(CN)_6]^{3-}$ with a frequency range of 0.1 Hz–100 KHz and amplitude at 10 mV. (b): Cyclic voltammograms of bare PCB, SWCNT/Au-PCB and MWCNT/Au-PCB in the Potential range − 1.0 to + 0.5 V at scan rate of 100 mV s^{-1} in 5 mM $K_3Fe(CN)_6$.

next to them. There have been works on electrochemical detection of glucose using carbon nanomaterials however, to the best of our knowledge; none of them have described the comparative analysis of SWCNTs and MWCNTs for the detection of glucose [26–28]. Therefore, the present work focuses on the comparative study between SWCNT and MWCNT deposited gold printed circuit board (Au-PCB) electrodes, all containing immobilized GOx (glucose oxidase) to detect different concentration of glucose present in real samples.