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Highly sensitive glucose sensor based on monodisperse palladium nickel/activated carbon nanocomposites

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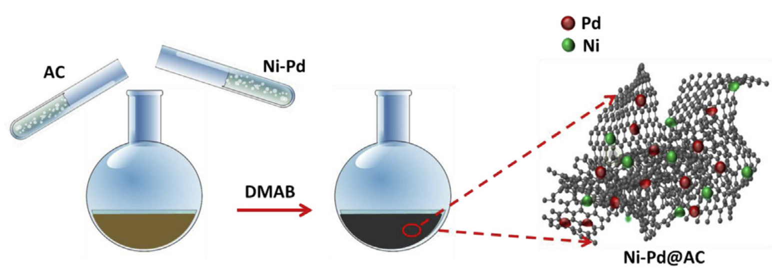
HIGHLIGHTS

- An easy and facile synthesis of highly monodisperse novel PtNi@AC nanocomposites.
- The surface of the AC layers appeared effectively and stabilized the metal nanoparticles dimensionally.
- Rapid, Sensitive, and Reusable Detection of Glucose by novel nanocomposites.
- The excellent electrochemical sensing properties of monodisperse PtNi@AC nanocomposites.
- Thanks to the ultrasmall sizes, monodispersity and high Pt and Ni % surface of novel materials.

GRAPHICAL ABSTRACT



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ABSTRACT

Glucose enzyme biosensors have been used for a variety of applications such as medical diagnosis, bioprocess engineering, beverage industry and environmental scanning etc. and there is still a growing interest in glucose sensors. For this purpose, addressed herein, as a novel glucose sensor, highly sensitive activated carbon (AC) decorated monodisperse nickel and palladium alloy nanocomposites modified glassy carbon electrode (Ni-Pd@AC/GCE NCs) have been synthesized by in-situ reduction technique. Raman Spectroscopy (RS), X-ray Photoelectron Spectroscopy (XPS), X-ray Diffraction (XRD), Transmission Electron Microscopy (TEM), cyclic voltammetry (CV) and chronoamperometry (CA) were used for the characterization of the prepared non-enzymatic glucose sensor. The characteristic sensor properties of the Ni-Pd@AC/GCE electrode were compared with Ni-Pd NCs/GCE, Ni@AC/GCE and Pd@AC/GCE and the results demonstrate that the AC is very effective in the enhancement of the electrocatalytic properties of sensor. In addition, the Ni-Pd@AC/GCE nanocomposites showed a very low detection limit of 0.014 μM, a wide linear range of 0.01 mM−1 mM and a very high sensitivity of 90 mA mM^{-1} cm^{-2}. Furthermore, the recommended sensor offer the various advantageous such as facile preparation, fast response time, high selectivity and sensitivity. Lastly, monodisperse Ni-Pd@AC/GCE was utilized to detect glucose in real sample species.

1. Introduction

Diabetes has turn into one of the important illness that negatively influences the life of many people. The blood glucose level is

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the very important in the early diagnostic and treatment of diabetes and should not be lower or higher than the range of 4.4–6.6 mM [1–11]. Therefore many methods such as electrochemical [2–11] and spectrophotometric [3] etc have been utilized to determine the glucose level in different samples. Among these methods, the electrochemical methods are promising because of their high sensitivity, simplicity, selectivity and performance. Electrochemical glucose sensors were divided into two groups as enzymatic and nonenzymatic sensors [3]. For glucose determination, enzymatic glucose sensors have been widely utilized due to their sensitivity and selectivity but they have many disadvantageous such as immobilization problems between the electrode and the enzyme, instability, high cost etc [1–11]. Unlike enzymatic sensors, non-enzymatic glucose sensors have lots of benefits like being high sensitivity, long-term stability for the glucose detection. For instance, metals like Ni, Co, In, Ru, Au and Cu; metal oxides like Co_3O_4, NiO(OH), RuO_2; and different metal combinations or composites like Cu-Pd, Pt-Au, Ni-Cr have been utilized for the detection of glucose [1–11]. Besides, carbon-based materials like active carbon (AC), graphene and multi-walled carbon nanotube (MWCNT) have unique properties, for example, fabulous electrical conductibility, large surface area, great chemical stability and critical mechanical quality. Therefore, they have influenced scientists for various scientific investigations [12–43]. Due to those important properties such as good chemical stability, excellent conductivity, high adsorption capacity and large surface-to-volume ratio, activated carbon (AC) are thought as one of the best alternatives for the preparation of electrocatalytic nanomaterials. These features of ACs allow faster electron exchange with metal nanoparticles and anode surface. For this reason, this work is focused on the use of sensor prepared with activated carbon (AC)-supported Ni-Pd nanoparticles on a glassy carbon electrode to increase electroactivity against glucose. Furthermore, the suggested novel Ni-Pd@AC nanocomposites were investigated for stability, reusability, selectivity, accuracy, linear range, sensitivity and limit detection limit (LOD) as a non-enzymatic electrochemical glucose sensor. Finally, it was shown that novel Ni-Pd@AC/GCE nanocomposites were tested in human blood serum sample as sensors.

2. Experimental

2.1. Preparation of monodisperse Ni-Pd@AC NCs

In the preparation of Ni-Pd@AC nanocomposites (NCs), AC was used for both reduction and stabilization. At the beginning, before addition of AC (2.5 mmol), Ni (acac) (0.25 mmol in 25 mL H_2O) and $PdCl_2$ (0.25 mmol in 25 mL H_2O) were mixed each other in ultrasonic conditions. After that, the refluxing of the resulting mixture was performed at 90 °C for 2 h. It was then cooled to room temperature and the color of the nickel-palladium nanocomposites dispersed by AC was observed to be brownish black by the addition of 1.0 mmol of DMAB with good stability and homogeneity. All reactions were implemented in a nitrogen gas atmosphere.

3. Results and discussion

3.1. Material characterization

After the preparation of Ni-Pd@AC nanocomposites (NCs), the prepared nanocomposites have been characterized by TEM, RS, XRD, XPS etc. As shown in Fig. 1(a) and b, Ni-Pd nanomaterials are monodispersely distributed on the surface of decorated ACs. In addition, TEM results showed that the mean particle size was measured as 3.72 ± 0.42 nm. Furthermore, the geometric structure

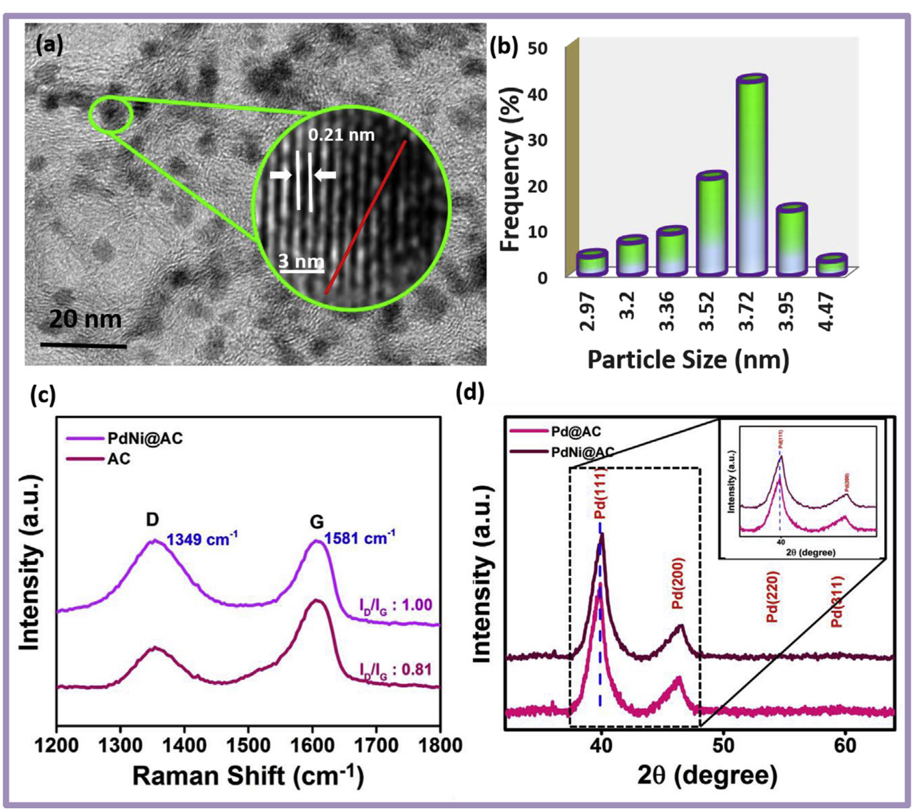

Fig. 1. (a) Transition electron micrograph and HR-TEM image, (b) Particle size histogram, (c) The Raman spectra (d) The XRD of Ni-Pd@AC NCs.