One-step preparation of silver–polyaniline nanotube composite for non-enzymatic hydrogen peroxide detection

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A modified glassy carbon electrode with silver nanoparticles–polyaniline nanotubes (AgNPs–PANI) composite is used as a non-enzymatic nanobiosensor for detecting hydrogen peroxide (H₂O₂). The electrocatalytic activity for the reduction was strongly affected by the concentration of silver ammonia solution in the nanocomposites, with the best electrocatalytic activity observed for the composite of 6:1 volume ratios of PANI to Ag(NH₃)₂OH (0.04 M). Field emission scanning electron microscope images and their size distribution diagrams indicated that using the silver ammonia complex instead of silver nitrate caused uniform distribution of nanometer-sized silver nanoparticles with a narrow size distribution in the composite. The corresponding calibration curve for the current response showed a linear detection range of 0.1–90 mM (R² = 0.9986), while the limit of detection was estimated to be 0.2 µM at the signal to noise ratio of 3.

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1. Introduction

In the past decade, the detection of hydrogen peroxide (H₂O₂) has received considerable attention due to its important role in the chemical, pharmaceutical, biochemical, and various other fields [1,2]. Many different methods have been developed for detecting H₂O₂, such as spectrophotometry [3,4], titrmetry [5], chemiluminescence [6], chromatography [7], spectrofluorometry [8], and electrochemistry [9–12]. The electrochemical enzymatic sensors have been extremely used in determination of H₂O₂ due to their high sensitivity and their good selectivity. Horseradish peroxizide and hemoglobin enzymes have been mostly used for preparation of modified enzymatic electrodes and for amperometric determination of H₂O₂ [4]. The most inevitable disadvantage of a modified electrode was chemical and thermal instability which is inevitable part of the intrinsic nature of the enzymes. This disadvantage has diverted the recent studies to direct detection of H₂O₂ by using enzymeless electrodes. Accordingly, the studies on the materials for direct detection of H₂O₂ could develop new generation of enzyme less sensors.

The one dimensional (1D) nanomaterials like nanowires [13], nanofibers [14–16], nanotubes [17–19], nanorods [20], and core–shell [21–23] have attracted intense in chemistry because of their particular sizes and morphologies. The nanomaterial properties depend on their shape, size, and dimension. In particular, these kind of nanoscale-sized and high surface area materials have been widely used for sensors and biosensors [24–27]. Furthermore, conductive polymers like polypyrrole and polyaniline (PANI) have received considerable interest in the last few years because of their applications as sensor and biosensors and due to their polymer chain structure, high conductivity, environmental stability, and low cost. Particularly, the PANI nanotubes (PANINTs) have shown encouraging results for application in biosensors due to their high conductivity and high surface area [28,29]. Previous articles have indicated that the noble metal nanoparticles have important applications in different electrochemical devices such as sensors. Moreover, the synthesis of the nanoscale composites with noble metals and conductive polymers as electrochemical sensors has been greatly developed [30–32]. Among the noble metals, silver, platinum, and gold play an important role in fabrication of the nanoscale sensors [33–35]. Silver nanoparticles (AgNPs) show good sensitivity for detecting H₂O₂ [36–40]. Past articles have reported that composites of polymers and noble metals have shown more promising results for detecting H₂O₂ in comparison with AgNPs. The physical and chemical properties of these composites are completely dependent to the size and morphology [41–43,40]. The homogenous distribution of nanometer-sized silver nanoparticles in PANINTs matrix could be achieved using silver ammonia complex as the precursor, instead of silver nitrate which is mostly used [44]. By using optimized amount of silver ammonia complex, small
previously reported. The characterization response of the proposed amperometric biosensor shows lower results in comparison to most of the articles [45,55–61].

The effect of common interfering species on PANINTs–AgNPs modified electrode was studied. Fig. 9 shows the amperometric response of the modified electrode towards the addition of 1 mM H$_2$O$_2$ and this is followed by glucose, glycine, and ascorbic acid into 0.2 M phosphate buffer solution (pH 6.5). As seen, these interfering substances responded to very weak signals which demonstrate that this modified electrode has a good selectivity towards H$_2$O$_2$.

To check the reliability of the prepared sensor, the lens cleaning solution was used in order to detect H$_2$O$_2$. The standard addition technique was used to determine the H$_2$O$_2$ in the solution of lens cleaning samples. Before measuring the current response, PBS (pH 6.5) was used to dilute the samples and then, with using standard addition method, H$_2$O$_2$ solutions were added to the cell. Table 4 shows the obtained data (four times) and the recovery values of all samples. The relative standard deviation (RSD) values and measured recoveries confirm that the prepared sensor has potential performances for determination H$_2$O$_2$ in a certain concentration range.

4. Conclusion

Silver-nanoparticle (AgNP)–polyaniline nanotubes (PANINTs) were successfully synthesized through a one-step method without using any extra acid, reducing agent, and template. It was defined that the silver ammonia complex was the key component to achieve well-distributed AgNPs with small and narrow size distribution in the composite. The AgNPs–PANINTs modified electrode offers a direct electrochemical response as a non-enzymatic sensor for determination of H$_2$O$_2$. The observed long stability, high sensitivity and low LOD of the obtained nanobiosensor have demonstrated that the AgNPs–PANINTs nanocomposite is an effective non-enzymatic H$_2$O$_2$ sensor. Therefore, it demonstrates a new pattern of direct H$_2$O$_2$ detection by non-enzymatic amperometric biosensor.

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