High performance non-enzymatic glucose sensor based on nickel hydroxide modified nitrogen-incorporated nanodiamond

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Monitoring of glucose is extremely important for biotechnology, food industry and clinical diagnostics. Various nonenzymatic sensors have been fabricated by using carbon materials like glassy carbon, carbon paste, carbon nanotubes and diamond, because of low cost, widespread availability and outstanding resistance to fouling. The diamond-based sensors exhibit low background signal and high stability but have relatively poor sensitivity [1,2]. In contrast, highly sensitive sensors based on nickel-modified electrodes have been proposed, but they need to be scanned to higher potentials to be effective, had high reaction potential to prevent interfering signal, and some showed narrow linear range [3-6]. In this study, nickel hydroxide modified nitrogen incorporated nanodiamond (NND) electrode has been prepared and applied to the detection of glucose with highly enhanced sensitivity.

The NND electrode was fabricated by plasma-enhanced chemical vapor deposition followed by deposition of the nickel hydroxide catalyst. Then, the sensor was fabricated by e-beam evaporation of a thin Ni film on NND followed by the growth of $Ni(OH)_2$ using an electrochemical process. This approach provides strong adhesion between nickel hydroxide and NND, allowing excellent charge transfer reversibility and chemical/mechanical stability. Cyclic voltammetry (CV) and amperometry were used in a three-electrode cell configuration for glucose detection in alkaline solutions, with and without interfering species including ascorbic acid (AA), uric acid (UA) and acetaminophen (AC). The modified NND was successfully able to detect glucose with high signal/background ratio. Owing to its characteristic nanostructure, the best sensor fabricated from 150 nm Ni deposition showed two wide response ranges, namely, 0.02–1 mM and 1–9 mM, with sensitivities of 3.20 and 1.41 mA mM^{-1} cm^{-2}, respectively, and a detection limit of 1.2 μM (S/N = 3). This sensor also showed good long-term stability as well as high selectivity in the presence of AA, UA, and AC. This finding reveals the possibility of exploiting the NND as an electrochemical biosensor platform where high performance addressable sensor array could be built.

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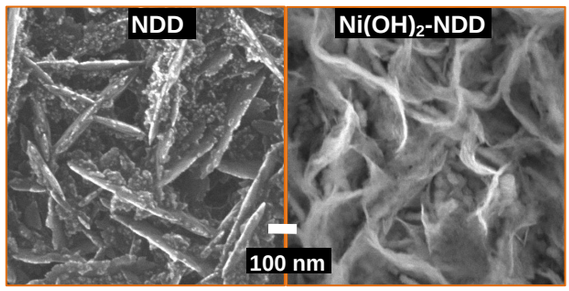

Fig. 1 FESEM images of NND and $Ni(OH)_2$ modified NND electrodes.

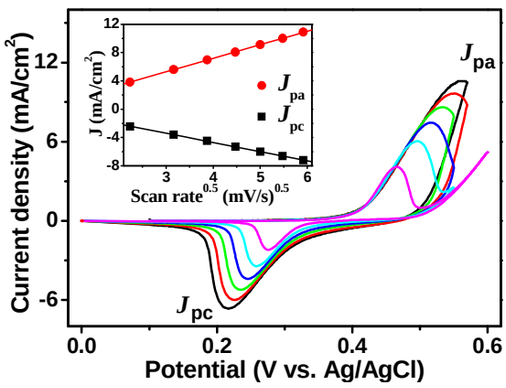

Fig. 2 Cyclic voltammograms of 500 μM glucose obtained with the optimized $Ni(OH)_2$-NND electrode in 0.5 M NaOH solution at scan rates of 5, 10, 15, 20, 25, 30 mV/s. Inset: the plot of the peak current densities versus the square root of scan rate.

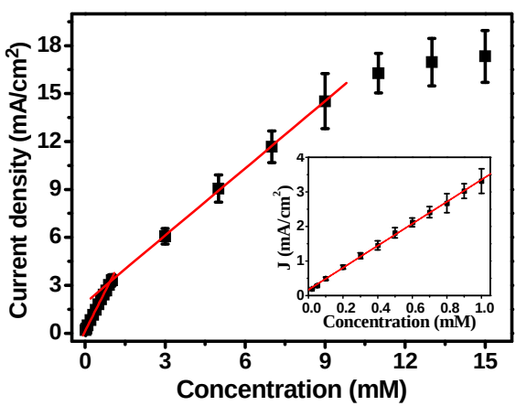

Fig. 3 Calibration curve of the optimized $Ni(OH)_2$-NND electrode. Inset: An expanded view of the calibration curve in the lower detection range of 0.02–1.0 mM.