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Abstract

Electrochemical Performance of WS_2-CNT Core–Shell Heterostructures for the Detection of Vitamin B_2 †

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Abstract: In this study, a novel electrochemical sensor was developed for the quantitative determination of riboflavin. The tungsten disulfide (WS_2) layer was deposited on carbon nanotubes (CNTs) by atomic layer deposition (ALD), forming a CNTs-WS_2 core–shell heterostructure. This material was used to modify the commercial screen-printed carbon electrode in order to enhance its electrocatalytic activity toward the detection of vitamin B_2. Cyclic voltammetry was performed as a preliminary test in the presence of riboflavin. In addition to this, an extensive electrochemical study was performed using differential pulse voltammetry, demonstrating that modified the CNTs-WS_2/SPCE sensor display superior electrochemical performance compared with bare SPCE. The sensor exhibits a linear response in the concentration range from 0 μM to 45 μM, with remarkably enhanced sensitivity (9 $\mu A \mu M^{-1} cm^{-2}$) compared with the bare electrode, with a limit of detection (LOD) of 1.24 μM. This enhancement is attributed to the conformal growth of the WS2 flakes on the CNTs and the high surface area offered by these flakes.

Keywords: atomic layer deposition; tungsten disulfide; carbon nanotubes; electrochemical sensor; riboflavin

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1. Introduction

Transition metals dichalcogenides (TMDs) have been investigated as sensing layers in electrochemical sensors to detect various analytes such as biomolecules [1], gases [2], and heavy metal ions [3]. Among the compounds of this family, tungsten disulfide (WS2) presents a layered structure that makes it attractive for various applications. WS2 has been investigated as a sensing material in electrochemical sensors due to its unique properties. Carbon nanotubes (CNTs) have also been used in electrochemical sensors due to their excellent electrical conductivity, high surface area, and biocompatibility [4]; CNTs can be combined with WS2 to develop CNTs-WS2 heterostructures with improved electrochemical performances.

In this respect, here, we investigate the CNTs-WS2 heterostructure for the detection of riboflavin (vitamin B_2), a water-soluble vitamin essential for human health. It is involved in many metabolic processes in the body, including the metabolism of carbohydrates, fats, and proteins. Riboflavin is important for maintaining healthy skin, hair, and nails, and is also needed for the production of red blood cells [5]. The improved sensor performances of the CNTs-WS2 heterostructure are related to the synergy between the WS2 layer, which provides the active sites for target analyte adsorption, and the CNTs, which provide excellent electron transport properties.

2. Materials and Methods

Carbon nanotubes (CNTs) were functionalized as follows: 10 mg of dried powder (80 °C overnight) was dispersed in 2 mL ethanol by ultrasonication (30 min) and drop-cast on an Al foil for ALD-WS2 deposition. WS2 films were deposited in the ALD system at 300 °C, using BTBMW (maintained at 80 °C) and H2S as precursors.

3. Discussion

The good electroanalytical performance of the developed CNTs-WS2/SPCE sensor is summarized in Figure 1a, showing the large current variation during the differential pulse voltammetry (DPV) analysis of a solution containing different concentrations of RF, from 0 to 45 μM. Figure 1b shows the corresponding calibration curve, plotting the peak current as a function of the analyte concentration. The sensitivity of 9 $\mu A \mu M^{-1} cm^{-2}$ was computed from a linear fit of the data (red line) and resulted in a limit of detection of 1.24 μM.

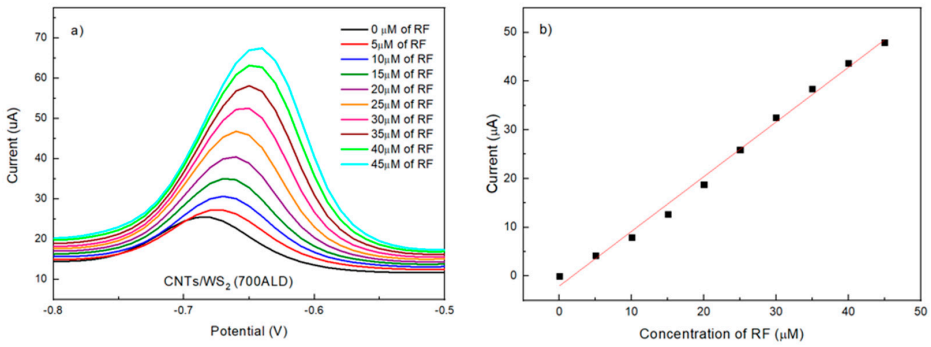

Figure 1. (**a**) DPV of CNTs-WS2/SPCE in 0.1 M PBS in the presence of different RF concentrations, (**b**) calibration curve corresponding to the DPV test. (The red line corresponds to the linear fit of the calibration curve).

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