UNIVERSITI TEKNOLOGI MARA

MODIFICATION OF SCREEN-PRINTED CARBON ELECTRODE (SPCE) WITH GOLD NANOSTRUCTURES FOR ELECTROCHEMICAL DETECTION OF NICOTINE

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ABSTRACT

The determination of nicotine, a highly addictive compound found in tobacco products, requires reliable and sensitive analytical methods. Screen-printed carbon electrodes (SPCEs) have emerged as a cost-effective and portable platform for nicotine detection. Aside, the low active surface area of the carbon electrode in SPCE poses challenges in detecting trace amounts of samples. Hence, the sensitivity and selectivity of SPCEs for nicotine detection can be improved by electrodepositing gold nanostructures on SPCE. Nonetheless, the electrochemical performance of the electrode is usually affected by the morphological structure of the gold (Au) and the major challenge in producing gold nanostructures revolves around controlling their size, shape and stability. Therefore, this study aimed to develop a modified screen-printed carbon electrode (SPCE) with gold nanostructures (AuNS) using three different electrodeposition approaches namely deposition at low overpotential by cyclic voltammogram to produce gold nanoparticles (AuNP), electrodeposition using hydrogen bubble dynamic template (at hydrogen evolution reaction) to produce gold with the dendritic network (AuDS) and dealloying of gold-copper (Au-Cu) alloy to produce nanoporous gold (NPG) electrode. The modified electrodes were evaluated for their electrocatalytic performance and stability in the electrochemical detection of nicotine. By manipulating deposition parameters such as deposition cycle for the first approach, deposition potential for the second approach, and dealloying cycle for the third approach, different surface morphologies of AuNS, including nanoparticles, nanodendrites, and nanoporous structures were obtained. The optimum conditions for electrodeposition of the AuNS electrode with the highest electrochemically active surface area (ECSA) and electrocatalytic properties were produced from the second approach by applying a constant potential at -1.1V for 15 minutes, resulting in the formation of Au dendritic networks (AuDS-(-1.1V)). The AuDS-(-1.1V) electrode exhibited the highest ECSA (4.45 cm^2) and a roughness factor (40.46). The EDX analysis confirmed that most of the SPCE surface was successfully coated with Au using all electrodeposition approaches. Furthermore, the AuDS-(-1.1V) electrode demonstrated enhanced electrochemical performance for nicotine detection compared to the unmodified SPCE, achieving a limit of detection of 0.065 µM. These findings highlight the potential of the AuDS-(-1.1V) modified SPCE as a promising electrode that could be potentially used as sensitive and selective electrochemical sensing material for detection of nicotine.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

Nicotine (S)-3-(1-methylpyrrolidin-2-yl) pyridine (NIC) is a toxic compound found in purine alkaloids, constituting approximately 2-8% of tobacco plants such as Nicotiana genus species including N. Tabacum, N. Rustica, and N. Glauca (El-Ramady et al., 2015; Kowalcze & Jakubowska, 2020; Marsh et al., 2004; Rahim et al., 2018a; Scharenberg et al., 2019). It is characterized as an oily, hygroscopic, colourless pale-yellow liquid that readily dissolves in water at room temperature (Hannisdal et al., 2007). When consumed, NIC is rapidly absorbed by the human body and directly affects the nervous system. Its frequent intake can result in various harmful diseases and health effects, including elevated blood pressure and heart rate, impaired healing processes, and vascular disorders (Dushna et al., 2022; Wang et al., 2009; Wu et al., 2009). Furthermore, it has been associated with the development of lung, nasal, kidney, stomach, bladder, and colon cancers (Banerjee et al., 2012; Yu et al., 2013). However, it is worth noting that NIC has also shown potential therapeutic effects in treating Alzheimers and Parkinsons diseases (Nop et al., 2021; Suto & Zacharias, 2004). Conventional methods for detecting nicotine, such as gas chromatography, high-performance liquid chromatography (HPLC), and immunoassays, while widely used, come with certain drawbacks. These techniques often require sophisticated equipment and trained personnel, making them relatively expensive and less accessible. Additionally, these methods might not always distinguish between nicotine and its metabolites, potentially leading to less precise measurements and requiring further analysis for accurate results.

Recent advances in nanomaterials open all sorts of possibilities for advancing nicotine electrochemical detection. Nanomaterials have been widely used as a medium of signal amplification to improve the detection limit of electrochemical sensors. Saljooqi et al., (2020) used graphene oxide nanosheet decorated by gold nanoparticles and polythiophene for nicotine sensing in biological samples and cigarettes, revealing remarkable selectivity and specificity at picomolar (pM) concentrations. Karthika et al.,