SAPOKAZI TIMAKWE

PROJECT: An electrochemical sensor for insulin, based on bimetallic oxide nanoclay composites.

Insulin is a possible marker for diabetes mellitus (DM), which is a highly prevalent metabolic condition due to insulin resistance and insufficiency, resulting in vision loss, kidney failure, cardiac arrest, heart disease, obesity, stroke and dementia, if it is not detected or managed on time. Numerous methods incorporating immunoassays, chromatography and optical have been developed to assist with the identification of insulin. However, these necessitate costly and complex equipment, radioactive reagents and technical knowledge, and are time demanding: hence, the development of an electrochemical sensor fabricated with bimetallic oxide functionalised nanoclay.

Nanoclays are used due to their low cost, easy availability, mineral-rich content, ability to resist elevated temperatures, high surface area, good intercalation properties, increased stability, and because they are environmentally friendly. However, due to their poor conductivity, bimetallic oxide nanoparticles will be used to enhance the conductivity of the nanoclay. The sensor will be user-friendly, inexpensive and rapid; and will be validated and employed in artificial biological fluids containing insulin.

Background and Rationale

Insulin is a polypeptide hormone that is essential for cells to absorb glucose for use in the process of metabolism. Its concentrations in fasting human serum are typically below 30 $\mu IUmL^{-1}$, however, if the system struggles to generate enough insulin or properly utilise the generated insulin, an elevated fasting level of insulin could signal insulin resistance, which develops into conditions like diabetes and insulinoma. A report issued by the South African Medical Research Council on World Diabetes Day on the 14th of November 2022, revealed that diabetes was reported in 2018 as the leading cause of fatalities for women and ranks second for both men and women in South Africa, and is still a major concern world worldwide, with about 4.2 million individuals living with diabetes in South Africa. Approximately 45.4% of them have not received a diagnosis. Also, the International Diabetes Federation (IDF)

estimates that 2.8% of the population had diabetes in 2000 and this is expected to reach 4.4% in 2023. As a result, insulin tracking is crucial for clinical evaluation which would improve the management of diabetes. Hence, the study suggests a development of a user-friendly electrochemical sensor for insulin built on the modification of the electrode with nanomaterial. It will be validated and employed in artificial biological fluids containing insulin.

Objectives

The study's objectives include synthesis and variation of molar ratio of bimetallic oxide nanoparticles; functionalisation of the nanoclay using the synthesised bimetallic oxides; characterisation of all the synthesised material with spectroscopic techniques (FTIR, X-ray, TEM, SAED, SEM-Image J); characterisation of the film and non-film with electrochemical techniques (CV, DPV, EIS, SWV); modification of the glassy carbon and screen-printed electrodes; optimisation of the sensor method (step potential, modulation amplitude, modulation time, interval time, scan rate); validation of the developed sensor (repeatability, reproducibility, stability) and Application of the sensor in spiked artificial biological fluids

Procedure:

The bimetallic oxide nanoparticles will be synthesised and characterised with spectroscopic and electrochemical techniques. These will be used for functionalising the nanoclay, forming bimetallic oxide nanoclay composites. The synthesised composites will be applied in sensor fabrication by electrode modification. The sensor procedure will be optimised by varying different parameters including step potential; modulation amplitude; modulation time and interval time. This will be followed by the use of the optimum conditions to perform various standards (calibration graph, analytical parameters, detection limits, linear range, sensitivity). The sensor will then be validated in the aspect of selectivity by detecting insulin in the presence of interferences, including its repeatability and reproducibility and stability, followed by its application in spiked artificial biological fluids without the use of human and animal sampling.

Timeline

Work	Period
Literature review, formulation of the research topic, proposal writing, designed methods.	February 2023-May 20 23
Synthesis and characterisation of metallic oxide nanoparticles, bimetallic oxide nanoparticles and nanoclay composites. Article writing.	October 2023- February 2024
Fabrication of the sensor using GCE and Carbon screen printed, optimisation, detection, validation and application, Article writing.	March 2024-November 2024
Dissertation write-up and submission, article writing	February 2025-October 2025

Results or preliminary data

Spectroscopic and Electrochemical characterisation of metallic oxide nanoparticles

The synthesised metal oxides were characterised with Fourier-transform infrared spectroscopy (FTIR) and represented in figure 1 (A). The metal oxides exhibit similar functional groups which are as a result of the hydroxide reducing agent used in the synthesis of both oxides, confirming successful formation of oxides. Figure 1 (B) represents the electrochemical behaviour of the metal oxides at glassy carbon electrode (GCE), where the current increases with increased scan rates.

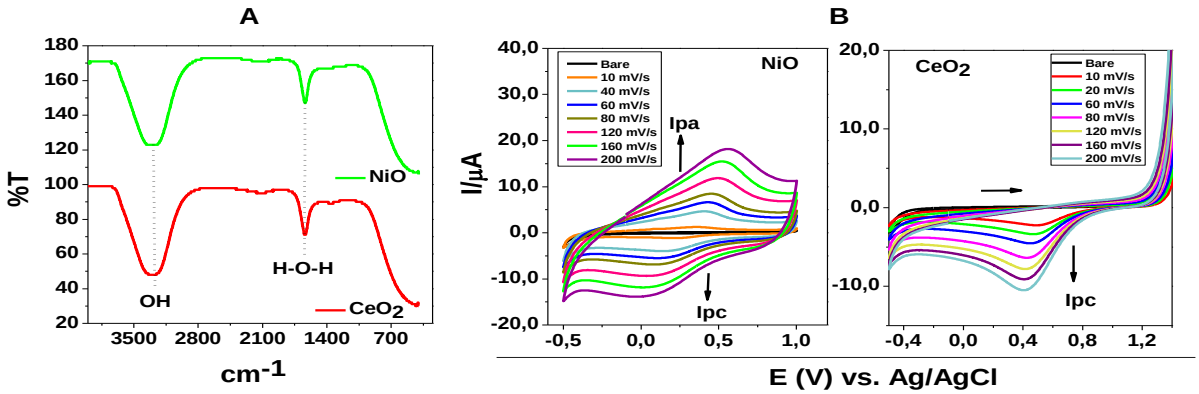

Figure 1: FTIR spectra (A) and Cyclic voltammograms (B) of metallic oxide nanoparticles at GCE in 0.1 M HCl