GRAPHENE-BASED NON-ENZYMATIC ELECTRODES FOR SWEAT GLUCOSE MONITORING APPLICATIONS

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Wearable biosensors have been gaining significant attention in recent years for enabling non-invasive, real-time monitoring of physiological parameters. Among various biofluids, sweat has emerged as a promising medium for continuous glucose monitoring due to its non-invasive collection, ease of access, and rich biochemical composition. Blood sampling is conventionally the standard method for glucose measurement, but its invasive nature limits frequent monitoring and affects patient comfort. This has driven interest in sweat-based electrochemical sensors, which offer a practical and user-friendly alternative by allowing continuous glucose tracking without repeated skin penetration.

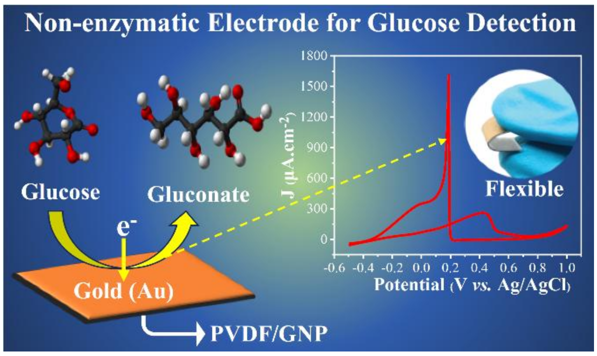

Fig. 1 - Graphical abstract for this research work

Sweat-based electrochemical glucose sensors present a practical, painless, and non-invasive alternative to conventional finger-prick blood tests used in diabetes management [1]. These sensors are generally classified into two types: enzymatic and non-enzymatic, each employing a different approach for glucose detection. Enzymatic sensors utilize glucose oxidase (GO_x) to catalyze oxidation reactions that produce an electrical signal. However, their performance can be hindered by issues such as enzyme degradation, limited stability, and high manufacturing costs. In contrast, non-enzymatic sensors detect glucose through direct oxidation at the electrode surface, removing the need for biological components (i.e., GO_x). Nevertheless, achieving high sensitivity and selectivity with this method depends on the careful design of electrode materials. Specifically, the fabrication of an effective non-enzymatic sensor requires two key elements: (1) a conductive substrate and (2) an electrooxidation catalyst for glucose detection.

This research introduces a novel, non-enzymatic, flexible graphene-based polymeric electrode for glucose detection, as illustrated in the graphical abstract. The electrode is fabricated using a simple, cost-effective solution casting method. It is composed of polyvinylidene fluoride (PVDF) polymer, selected for its excellent chemical stability and biocompatibility, and is incorporated with graphene nanoplatelets (GNPs). The GNPs provide several advantages, including low-cost production, a high aspect ratio, a lightweight structure, ease of processability, and enhanced electrical and mechanical properties. The resulting PVDF/GNP nanocomposite combines flexibility with high electrical conductivity [2]. To further improve its electrochemical performance, a thin gold (Au) layer is sputter-coated onto the composite, chosen for its high catalytic activity and low oxidation potential, thereby facilitating the development of sensitive, energy-efficient electrodes.

Cyclic voltammetry (CV) results demonstrate a consistent increase in peak current density values at approximately 0.15 V as glucose concentrations rise, as shown in Fig. 2a. This peak corresponds to the direct oxidation of glucose during the reverse scan, which was specifically chosen to assess the electrode's electrocatalytic performance with respect to glucose concentration. Calibration is performed by plotting the cathodic reoxidation peak current density at 0.15 V against glucose concentration, yielding a linear relationship given by J = 172.29C + 3.58, where J represents peak current density ($\mu A \cdot cm^{-2}$) and C denotes glucose concentration (mM). The results show a sensitivity of 172.29 and a correlation coefficient (R^2) of 0.99, as depicted in Fig. 2b. This linear behavior suggests that the oxidation process is controlled by adsorption, with rapid electron transfer kinetics. These findings highlight the strong potential of this electrode for emerging wearable glucose monitoring devices.

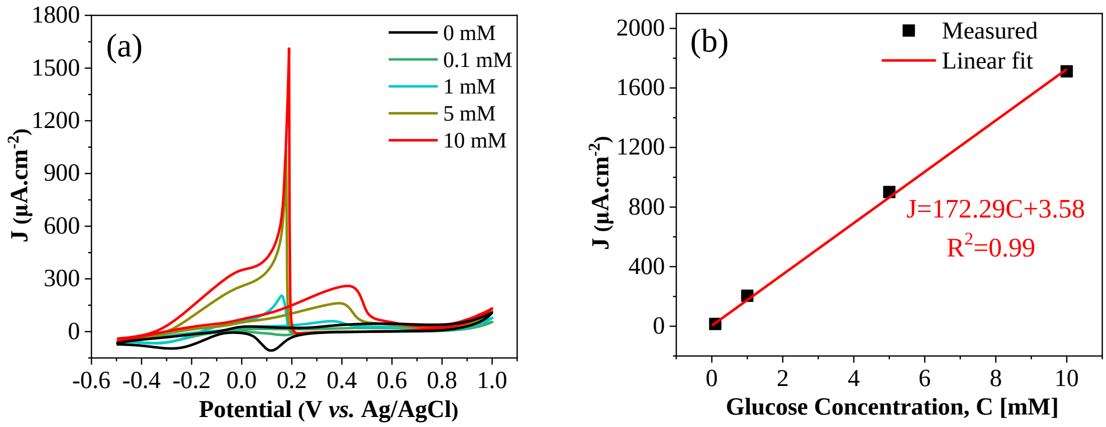

Figure 2. (a) Cyclic voltammograms of the PVDF/GNP/Au-based polymeric nanocomposite electrode at different glucose concentrations and (b) Current density versus glucose concentration acquired at potential of 0.15V [3].

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References:

[1] F. Gao et al., "Wearable and flexible electrochemical sensors for sweat analysis: a review," Dec. 01, 2023, Springer Nature. doi: 10.1038/s41378-022-00443-6.

[2] Hossein Cheraghi Bidsorkhi, Lavanya Rani Ballam, Alessandro G. D'Aloia, Alessio Tamburrano, Giovanni De Bellis, and Maria Sabrina Sarto. "Flexible graphene based polymeric electrodes for low energy applications." In 2020 IEEE 20th International Conference on Nanotechnology (IEEE-nano), pp. 263-266. IEEE, 2020.

[3] Lavanya Rani Ballam, Hossein Cheraghi Bidsorkhi, Marco Fortunato, Alessandro Giuseppe D'Aloia, and Maria Sabrina Sarto, "Flexible and Enzyme-free Graphene-PVDF-Au electrode for Glucose Detection in Sweat", selected as contributed paper, In procedings of 2025 IEEE 25th International Conference on Nanotechnology (IEEE-NANO 2025).