New competitive electrochemical aptasensor for the detection of cancer biomarker using 2D WSe_2/ MAX phase (Ti_3AlC_2) nanocomposite modified screen printed carbon electrode

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Abstract

Ovarian cancer is one of the most lethal gynecological malignancies, with the majority of cases diagnosed at an advanced stage, significantly limiting treatment options and reducing survival rates. Therefore, early detection is crucial for improving patient outcomes. CA125 is a well-established tumor marker commonly used for the detection and monitoring of ovarian cancer progression. This study aims to develop a highly sensitive competitive electrochemical aptasensor for the detection of CA125. A 2D WSe_2/MAX phase (75:25 %w/w) nanocomposite was utilized to modify the surface of a screen-printed carbon electrode (SPCE), enhancing the electroactive surface area to improve electron transfer and providing a specific site for protein immobilization. Thymol blue (TMB) was deposited onto the modified SPCE, serving as an internal redox probe. Subsequently, the CA125 antigen was immobilized on the electrode surface, followed by blocking nonspecific binding sites with BSA, to obtain a BSA/CA125/TB/2D WSe_2/MAX phase/SPCE sensing platform. The detection process began with the pre-incubation of a specific CA125 aptamer with the target solution to form an aptamer-antigen complex. Subsequently, the remaining unbound aptamers were introduced onto the sensing platform, enabling the indirect quantification of CA125. Under optimal conditions, the proposed aptasensor exhibited a good linear relationship between the electrochemical response and the logarithmic concentration of CA125 across a wide range (0.10 – 100.0 ng/mL). These findings highlight the potential of the developed aptasensor for accurate and rapid CA125 detection. Furthermore, the selectivity, stability, reproducibility, and real-sample analysis will be further investigated to validate its practical applicability.

Introduction

Ovarian cancer (CA125)

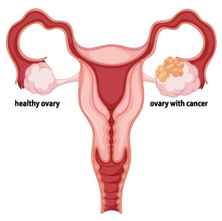


Fig. 1 Ovarian cancer

Ovarian cancer is a leading cause of gynecological cancer deaths, with most cases diagnosed at an advanced stage. CA125, with a cut-off value of 35 U/mL, is the gold standard biomarker for diagnosis, monitoring, and assessing treatment response[1].

Biosensor

Biosensor technology facilitates rapid, precise, and cost-efficient biomarker detection, with electrochemical biosensors demonstrating exceptional sensitivity and selectivity[2].

Materials

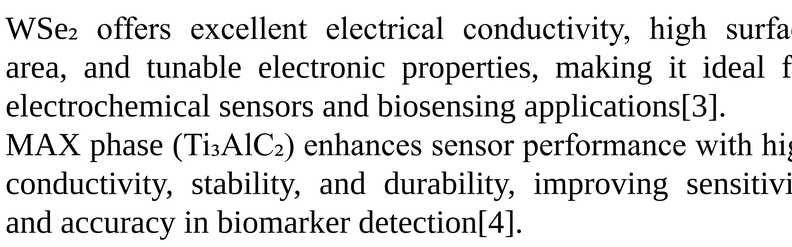
- WSe_2 offers excellent electrical conductivity, high surface area, and tunable electronic properties, making it ideal for electrochemical sensors and biosensing applications[3].
- MAX phase (Ti_3AlC_2) enhances sensor performance with high conductivity, stability, and durability, improving sensitivity and accuracy in biomarker detection[4].

Objective

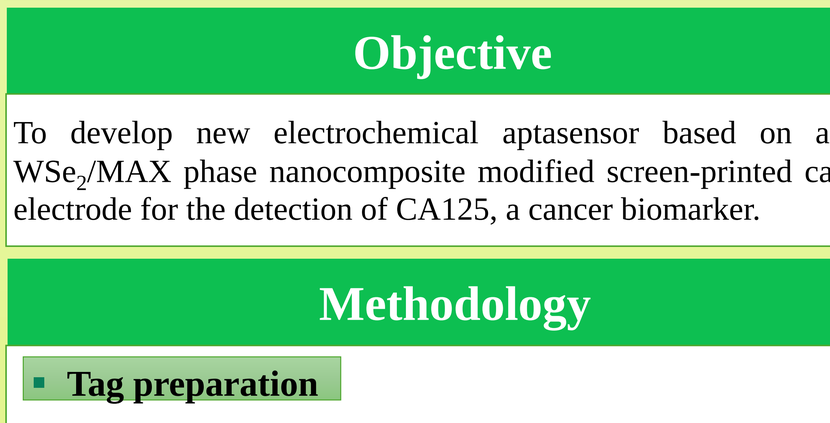
To develop new electrochemical aptasensor based on a 2D WSe_2/MAX phase nanocomposite modified screen-printed carbon electrode for the detection of CA125, a cancer biomarker.

Methodology

Tag preparation



Aptasensor preparation



Results and discussions

Characterization of materials

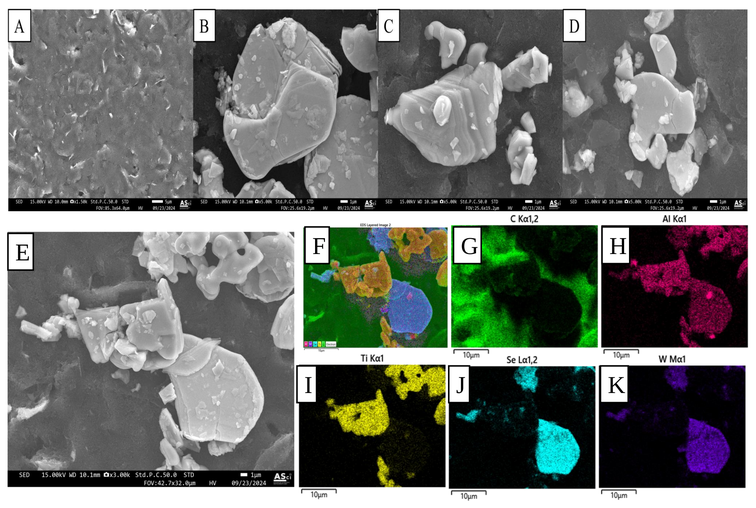


Fig. 2 SEM images of (A) bare SPCE and SPCE modified with (B) WSe_2, (C) MAX phase, and (D) WSe_2/MAX phase nanocomposite. Elemental mapping of SPCE modified with the WSe_2/MAX phase nanocomposite (E-K).

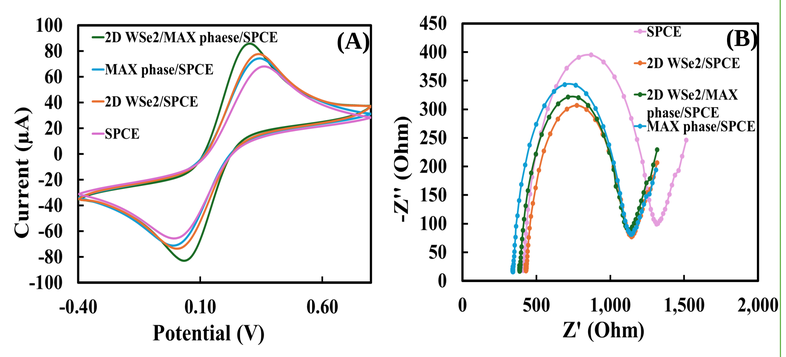
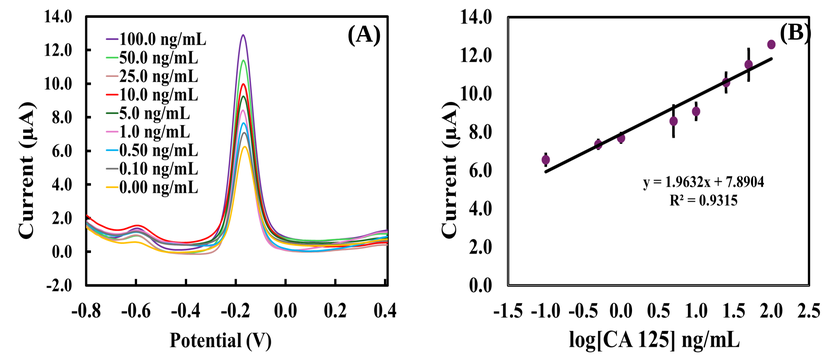


Fig. 3 (A) CV and (B) EIS curves of bare SPCE and modified SPCEs with the different materials.

Analytical performance of developed aptasensor



Optimization of fabrication conditions

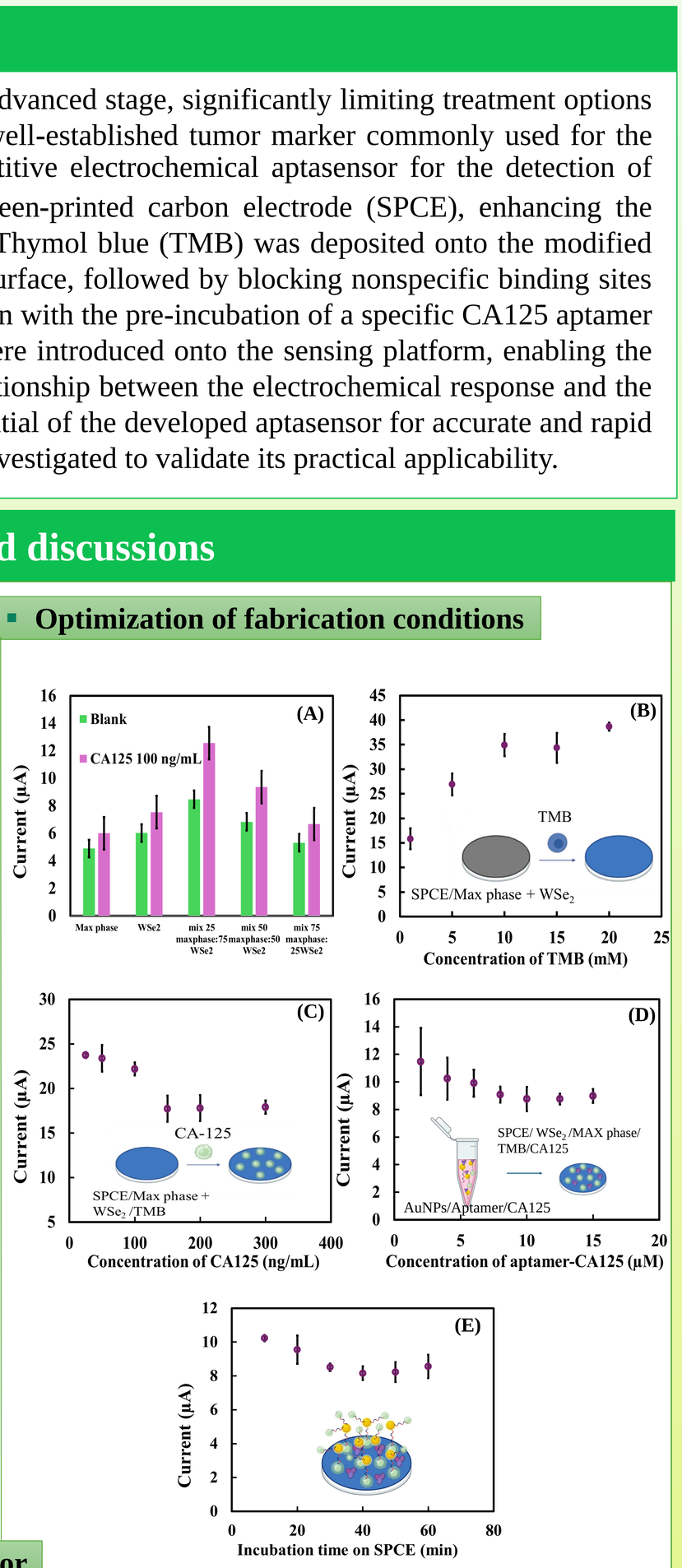


Fig. 4 (A) current response between blank, target detection. Current responses of modified SPCEs after each immobilization step for the aptasensor (B-D) and Current responses of the developed aptasensor with different bio-interaction times for aptamer-CA125 complex formation on electrode surface(E).

Fig. 5 (A) The differential pulse voltammetry (DPV) peak signals of CA125 at varying concentrations and (B) Calibration curves illustrating the electrochemical response of CA125

Conclusions

- A novel competitive electrochemical aptasensor for CA125 detection was successfully developed using a WSe_2/MAX phase nanocomposite-modified SPCE.
- The optimal WSe_2/MAX phase nanocomposite composition was determined to be 75:25% w/w, providing superior electron transfer properties and facilitating high electrochemical performance.
- The developed aptasensor exhibited a linear detection range of 0.10–100 ng/mL and a low limit of detection (LOD) of 0.40 ng/mL, demonstrating high sensitivity for CA125 quantification.
- The proposed aptasensor presents significant potential for biomarker analysis and early-stage clinical diagnostics, with future work focusing on selectivity, stability, reproducibility, and real-sample validation to confirm its practical applicability.

Acknowledgement

Department of Chemistry, Faculty of Science, Chiang Mai University.

References

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