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Advanced DNA-Biomacromolecule Sensor: Enhancing Sensitivity in Clinical Cancer Sample Detection

John Paulisen*

Department of Radiation Oncology, University of Memphis, Memphis, Italy

Abstract

An ultrasensitive DNA-biomacromolecule system or technology has the capability to detect and analyze DNA molecules with exceptional sensitivity. DNA, serving as the fundamental genetic material in living organisms, holds critical significance in numerous biological processes and finds extensive applications in diagnostics and research. Ultrasensitive DNA-biomacromolecule technologies are specifically engineered to identify and quantify minute amounts of DNA molecules within a given sample. Employing diverse detection methodologies such as fluorescence, electrochemical sensing, nanopore sequencing, or amplification techniques like polymerase chain reaction, these technologies enable scientists to achieve remarkably precise and sensitive detection of DNA molecules, even when present in exceedingly low concentrations.

Keywords: DNA-biomacromolecule • Macromolecule • Ultrasensitive DNA

Introduction

Ultrasensitive DNA detection plays a pivotal role in molecular diagnostics, facilitating the identification of diseases, genetic disorders, and infectious agents. By pinpointing specific DNA sequences linked to particular conditions, it supports early disease detection and personalized medicine initiatives. Moreover, DNA analysis serves as a cornerstone in forensic investigations, assisting in suspect identification and establishing genetic relationships with exceptional accuracy. Ultrasensitive DNA technologies excel in extracting and analyzing DNA from minute biological samples, thereby enhancing the precision and dependability of forensic analyses. Additionally, DNA-based monitoring techniques are leveraged to evaluate the presence and abundance of diverse organisms in environmental samples. These ultrasensitive DNA-biomacromolecule technologies empower the detection of rare or low-abundance species, thereby enriching biodiversity studies and ecological research endeavours [1].

Literature Review

Detecting and analyzing DNA mutations or abnormalities associated with cancer is paramount for unraveling the molecular underpinnings of the disease and devising targeted therapies. Ultrasensitive DNA technologies play a crucial role in identifying rare mutations or circulating tumor DNA, thereby facilitating early cancer diagnosis and monitoring treatment efficacy. DNA analysis forms an integral component of drug development and clinical trials, enabling the quantification of drug target genes, assessment of treatment effectiveness, and monitoring for drug-resistant mutations. In the realm of disease detection, particularly cancer, the importance of diagnostic testing of biological macromolecules cannot be overstated. Nonetheless, achieving sensitive detection of macromolecules via interface-based sensing methods poses challenges, given their limited surface area and significant steric hindrance. Introducing the "biphasic replacement" electrochemical aptamer-based sensing technique, this approach substitutes the capture reaction of the biomacromolecule with a small diameter of single-stranded DNA attached to the interface. Demonstrating the ultrasensitive detection of luteinizing hormone with a detection of the BRE-AB sensor showcases promising potential for sensitive molecular detection in clinical settings [2].

Discussion

The aptamer-target LH binding mechanism is investigated using Molecular Dynamics simulations. In addition, it has been established that the BRE-AB sensor exhibits superior sensing capabilities in both undiluted plasma and whole blood. The BRE-AB sensor successfully quantifies the LH concentrations in 40 clinical samples, revealing that breast cancer patients have higher LH expression. Additionally, the sensor's simplicity, low cost, and ease of regeneration and reuse point to its potential use in biological macromolecule diagnostics at the point of care. Depicts the BRE-AB system's signaling mechanism. There is a solution reaction and an interface reaction in the BRE-AB system. Prehybridized aptamer/signal duplexes were in the solution phase without a target, and only a few free signal probes with the redox indicator methylene blue were able to enter the interface. The steady state of the anchored helper probes on the interface continued in the meantime. It formed more stable aptamer/target complexes by binding specifically to the aptamer and releasing signal probes from aptamer/signal duplexes following the addition of target biomacromolecules. The helper probes, which were anchored to the surface of the gold electrode using Au–S chemistry, enter the interface and then hybridize with the released signal probes. As a result, the MB indicators are able to get within easy reach of the gold surface, accelerating electron transfer significantly [3-6].

Conclusion

This study introduces a Biphasic Replacement E-AB (BRE-AB) sensing platform designed for highly sensitive detection of biomacromolecules at the picomolar level. The sensor offers notable advantages, including ultrahigh sensitivity, excellent regenerability, and reusability, all achieved through a straightforward and cost-effective fabrication process. Remarkably, the BRE-AB sensor exhibits a remarkable detection limit even in whole blood samples. MD simulation findings suggest that electrostatic interaction, hydrogen bonding, and the alkyl hydrophobic effect are the predominant forces driving Luteinizing Hormone (LH) binding to the aptamer. We propose that the BRE-AB sensor holds promise for the analysis and detection of various

***Address for Correspondence:** John Paulisen, Department of Radiation Oncology, University of Memphis, Memphis, Italy, E-mail: senpauli@gmail.com*

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target molecules, facilitated by well-designed probe sequences informed by theoretical simulations and free energy predictions. This study underscores the potential of the BRE-AB sensor for early cancer diagnosis and positions it as a promising candidate for macromolecular detection applications.

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Conflict of Interest

No potential conflict of interest was reported by the authors.

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