Talanta 225 (2021) 121964

Contents lists available at ScienceDirect

Talanta

journal homepage: www.elsevier.com/locate/talanta

DNA-targeted formation and catalytic reactions of DNAzymes for label-free ratiometric electrochemiluminescence biosensing

Jingjing Jiang, Xuezhong Du *

Key Laboratory of Mesoscopic Chemistry (Ministry of Education), State Key Laboratory of Coordination Chemistry, Collaborative Innovation Center of Chemistry for Life Sciences, and School of Chemistry and Chemical Engineering, Nanjing University, Nanjing, 210093, People's Republic of China

ARTICLE INFO

Keywords:
CdS quantum Dots
DNA detection
Electrochemiluminescence
G-quadruplex/hemin DNAzymes
Luminol

ABSTRACT

A label-free ratiometric electrochemiluminescence (ECL) sensing strategy for the sensitive detection of target DNA (T-DNA) was proposed on the basis of G-quadruplex/hemin-regulated ECL emissions of CdS quantum dots (QDs) and luminol with their common coreactant of H_2O_2. The ECL biosensor was constructed through stepwise assemblies of CdS QDs and hairpin DNA (H-DNA) on a glassy carbon electrode, and subsequent introduction of T-DNA resulted in the development of G-quadruplex/hemin DNAzymes via the specific recognition of T-DNA and H-DNA in the presence of hemin and K^+ ions. The formed DNAzymes not only prompted the catalytic oxidation of hydroquinone followed by deposition of insoluble oxidation oligomers on the electrode surface to attenuate the cathodic ECL emission of CdS QDs but also triggered the catalytic oxidation of luminol to enhance the anodic ECL emission. The label-free ratiometric ECL biosensor for the detection of T-DNA showed a wide response range from 1 to 10,000 fM (10^{-15} M) with a low detection limit of 0.2 fM and exhibited excellent selectivity against mismatched base sequences. This work provides a reliable and sensitive sensing platform for the detection of targets in analytical community by means of rational design of DNA sequences.

1. Introduction

DNA biosensing is crucially important for the quantitative analyses of a variety of biomarkers of diseases and has a wide range of applications in clinical diagnosis, gene therapy, and pathogen monitoring [1–5]. Owing to the ever increasing requirements of biological assays, several techniques including fluorescence [6,7], electrochemistry [8,9], chemiluminescence [10], and electrochemiluminescence (ECL) [11,12], have been exploited for DNA detection. In particular, ECL technique has attracted much attention in analytical community because of its low background and high sensitivity [13–16].

The detection mechanism of conventional ECL methods usually depends on resonance energy transfer [17,18], generation/consumption of coreactants [19,20], and steric hindrance in the course of bio-recognition events [21,22]. In most cases, target molecules are usually labeled with the ECL responses from single emitters, so that environmental variations, such as solution pH and coreactant concentration, may give rise to false errors. Ratiometric ECL analyses can eliminate most of the false errors via the normalization of environmental changes [23,24] and attract tremendous research interest recently. Cheng et al. presented a ratiometric ECL sensing approach based on CdS quantum dots (QDs), luminol−gold nanocomposites, and cyanine dye as the cathodic and anodic ECL emitters and quenchers, respectively, for the detection of Mg^{2+} ions in HeLa cell extract [25]. Zhang et al. combined CdS nanocrystals and luminol−platinum nanocomposites to design a dual-potential ratiometric ECL biosensor for the sensitive detection of mp53 oncogene [26]. For the two ratiometric ECL sensing platforms, dye molecules and metal nanoparticles were used to label DNA for the quenching of ECL signals via resonance energy transfer, which were involved in the complex processes for separation and purification and might lead to the deactivation of DNA. Thus, it is urgent to develop a label-free ratiometric ECL biosensor for the sensitive detection of targets.

Deoxyribozymes, also called DNAzymes, are catalytically active oligonucleotides. DNAzymes can catalyze many specific chemical reactions similar to proteases. Among various DNAzymes, G-quadruplex/hemin complexes have received considerable attention recently, because of their advantages of low cost, ease of labeling, and high thermal stability [27,28]. G-quadruplex is a guanine-rich nucleic acid sequence and can couple with hemin to form G-quadruplex/hemin DNAzyme via the coordination interaction between the π–π conjugate system in G-quadruplex and the iron ion in hemin [29–31]. As

* Corresponding author.
E-mail address: xzdu@nju.edu.cn (X. Du).

https://doi.org/10.1016/j.talanta.2020.121964
Received 1 November 2020; Received in revised form 26 November 2020; Accepted 30 November 2020