Polydiacetylene (PDA) as tool for the development of biosensors to apply in analytical field

Abstract

Polydiacetylene (PDA) is a conjugated polymer that has unique chromatic properties. Usually it is found in the bilayer form, both as vesicles as layered films. When polymerized by UV radiation, this structure exhibits blue color, and under certain stimuli that changes the carbon chain structure, there occurs a rapid colorimetric transition in response, which represents a great potential in the biosensors field.

Keywords: polydiacetylene, biosensor, detection, analytical devices

Abbreviations: PDA, polydiacetylene; DA, diacetylene monomers

Introduction

The demand for new sensing technologies for detection of target compounds has significantly increased in recent years in order to improve methods of selection and identification. Numerous technologies have been developed, since many fields need to develop a rapid, sensitive and specific method of detection suitable for monitoring and control. Thereby, biosensors techniques have gained a crucial importance in several areas of application, from the detection of biological warfare agents to pathogenic microorganisms in food.1

Polydiacetylene (PDA) has attracted relevant scientific and technological interest due to its unique chromatic properties and its ability to auto-arrange in vesicles form or layered films. The PDA is a conjugated polymer that exhibits a colorimetric response observed when external perturbations, as heat, mechanical stress, solvent and others disturbance affect the PDA reorganization. Because that, a structural transformations from planar to non-planar form occurs in the PDA chain, resulting in rapid blue-to-red transitions for 520–700nm. This color transition is perceptible even on naked eye, but also by a spectrophotometer for qualitative and quantitative analyses.2 Therefore, this macromolecule is a strong candidate for sensor devices. The colorimetric detection systems using PDA have been used widely in biosensors, which present many advantages: a simple and rapid detection system, easy recognition through color change, and label-free detection.3

Assembling of PDA biosensor and mechanism of PDA color change

PDA production is generally developed by a topochemical reaction mechanism.4 Basically, the PDA formation occurs by dispersion of amphiphilic long chain molecules, known as diacetylene monomers (DA), and then it is stored at low temperature.5,6 After that, the irradiation of UV light or γ-radiation above PDA dispersion lead to topotactic photopolymerization and result in a metastable structure in the form of film or vesicles with blue color.7 This light absorption (around 650nm) occurs by electrons displacement within a Π-conjugated linear structure, corresponding to a Π-Π* transition.8 The color transition from blue to red (around 550nm) occurs by the conformation change of the structure conjugated due to an external stimuli, causing it to absorb and reflect light at different wavelengths.9

Considerable studies approach PDA application by the fact of being sensing and stress-responsive. On the other hand, the use of molecules with particular properties allows the development of a huge diversity of structures to be applied as biosensors. Among the possible PDA applications, there are the control of new production techniques, the manipulation of the carbonic structure conformation, the head of the functional group and the interaction or reaction of PDA with other molecules. The control of colorimetric transition, sensitivity and specificity of PDA-based biosensors grows exponentially by the interaction of molecules such as polymers, cations, bacteriophages, antibodies, etc.9–11

Potential PDA application

Oliveira et al.12 addressed that PDA associated with lysine can be employed as a simple biosensor to detect molecules released from Salmonella. The study approach that Salmonella could induce amino acid decarboxylases enzymes producing cadaverine. Cadaverine is a basic amine, which promotes a typical reaction initialized by nitrogen nucleophilic attack in an electrophile, like the carboxylic acid of the PDA causing the chromatic blue–red transition.

In other work, Oliveira et al.13 embedded the PDA compound in methylcellulose base to produce an intelligent packaging. For a specific color modification, bio-recognition tools were covalently linked with PDA. The broad-spectrum virulent phage (PVP-SE1) was used as bio-recognition element to detect Salmonella cells and induced the PDA color change (Figure 1). A series of experiments were performed to monitor colorimetric response. Chromatic immunoassay could be significant in increasing potential applications of PDA intelligent packaging.
Wang et al.\textsuperscript{14} presented a facile “lock–key” strategy, based on rapid and specific detection of plasma lysophosphatidic acid (LPA, an early stage biomarker) with polydiacetylenes (PDAs)-based probe, for the early diagnosis of ovarian cancer. The strategy relies on specifically inserting LPA “key” into the PDAs “lock” through the synergistic electrostatic and hydrophobic interactions between them, leading to conformation transition of the PDA backbone with a concomitant blue-to-red color change. The level of LPA could be quantified in plasma samples from both mouse xenograft tumor models and patients with ovarian cancer. Impressively, this approach can be introduced into a portable point-of-care device to successfully distinguish the blood samples of patients with ovarian cancer from those of healthy people, with 100% accuracy.

Zhang et al.\textsuperscript{15} combined micropatterned paper devices (PPDs) with PDA probes for double-stranded DNA detection (dsDNA). The device was produced on paper by wax-screen-printing. PDA vesicles were functionalized with amine, added in paper chambers and incorporated with 100% accuracy.

Figure 1 Color transition of PDA vesicles incorporated with phage PVP-SE1. A) Blue color: without bacteria; B) pink (or red) color: with S Enteritidis; C) purple color: with E coli ATCC 10536; d) purple color: with S. aureus ATCC 25923.

Conflict of interest

The author declares that there is no conflict of interest.

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