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Electrochemical DNA sensors based on electropolymerized materials

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ABSTRACT

The use of electropolymerized materials in the DNA sensors is reviewed with particular emphasis on their functions and specific interactions with DNA and oligonucleotides. Polyaniline, pollypyrrole, polythiophenes and polymeric forms of phenazines play significant role in the immobilization and signal transduction of DNA sensors for the detection of hybridization events, DNA–protein and other specific interactions on the sensor surface. The mechanism of electropolymerization and the influence of oligonucleotides are also considered for various types of polymers. The DNA sensor performance is classified in accordance with the biological targets and composition of the surface layer.

1. Introduction

The interest to the development of DNA sensors has dramatically increased in the past decades [1,2]. This is mainly due to the great significance of DNA analysis in many areas related to human health, e.g., diagnostics of pathological microorganisms and viruses, genetic mutations, new drug discovery, especially in oncology, food technology, etc. [3,4]. Besides conventional techniques intended for the detection of specific genes based on direct sequencing or DNA hybridization, there is an urgent demand for developing compact, sensitive and inexpensive measurement devices for such purposes. They fill the gap between the sophisticated approaches to the DNA assay requiring complex specialized equipment and qualified personnel [5], and the requirements for the point-of-care diagnostics and field application [6]. Biosensor technologies are most suitable for such goals because of the broad possibilities of tuning their assembly and biorecognition elements and meeting specific requirements, e.g., simplified data readout, exclusion of the sample pre-treatment and autonomous operation [7,8].

From the early 1990-s, the DNA bioassay technologies utilizing radioactive or fluorescent labels exerted a serious influence on genomics and proteomics applications, specifically for the human genome project [9,10]. They were inspired by the appropriate protocols successfully elaborated in molecular biology starting from in 1970-s. Being very sensitive and effective in encoding primary nucleotide sequence, the appropriate devices called DNA sensor arrays have some drawbacks, e.g., the use of hazardous chemicals for their manufacture, the multi-step analysis protocol, the limitations of labeling and DNA probe stability, and the precision of oligonucleotides tagging and positioning on a solid support [11]. This complicated their routine application especially for a limited number of samples or in field conditions. The development of more simple and rather cheap DNA sensors instead of sensor arrays made it possible to extend their application area to the detection of low-molecular compounds specifically interacting with DNAs and the DNA damage caused by antitumor drugs, reactive oxygen species or some genotoxicants [12]. Such DNA sensors are certainly less productive and efficient in mass screening of a great number of samples, but they were found rather suitable for future applications in local doctor's offices or portable alarm systems directed to single use of the biosensors or a very modest number of assays per day/sensor.

The development of rather simple and inexpensive DNA sensors does not presume the application of radiolabels or lasers in readout systems. Even though the cost of appropriate detection systems has been dramatically decayed to date, they are still rather sizeable and complicated in manufacture and use. Meanwhile, electrochemical transducers have had privilege because of the possibility to use conventional measurement techniques, well elaborated backgrounds of signal transduction and user friendly design [13]. At the beginning, the intrinsic electroactivity of guanine restudies was used in electrochemical DNA sensors [14,15] but at present main attention is focused on the application of mediators and labels which alter the redox signals in hybridization events or to any other changes resulting from the interaction of the DNA probes with the analyte molecules [16]. The efficiency of such measurement protocols which are derived from the appropriate immunoassay techniques significantly depend on the way DNA is connected with the electrode. Direct electron transfer in accordance with Marcus Eq. (1) [17] requires an

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