Electrochemical Platforms Based On Catecholamine-Inspired Polymers For Detection Of Diverse Analytes

Maria Kuznowicz[1,2], Artur Jędrzak[2], Teofil Jesionowski[2]

[1]Poznan University of Technology, Interdisciplinary Centre for Ecotechnology, PL-60965 Poznan, Poland
[2]Institute of Chemical Technology and Engineering, Faculty of Chemical Technology, Poznan University of Technology, Berdychowo 4, PL–60965 Poznan, Poland

The development of electrochemical diagnostic systems is increasingly driven by the need for sensitive, robust, and adaptable analytical tools capable of operating under complex conditions. However, many conventional electrochemical platforms still rely on rigid electrode materials and simplified surface modifications, which limit their performance and long-term usability. Common challenges include high overpotentials, insufficient selectivity, surface fouling, and poor control over interfacial processes. These issues are particularly evident in the detection of biologically relevant analytes such as nicotinamide adenine dinucleotide (NADH) and glucose, where efficient electron transfer and stable surface functionality are critical.

In this work, we propose a new class of electrochemical platforms based on biopolymer-derived nanomaterials, which serve as key functional components of the sensing interface. Special emphasis is placed on catecholamine-inspired polymers, including poly(caffeic acid) which act as versatile building blocks for the fabrication of hybrid nanostructures. These biopolymer-based materials offer a unique combination of properties, such as intrinsic bioaffinity, redox activity, strong adhesion to various substrates, and the presence of multiple functional groups enabling further modification. As a result, they provide an effective route toward the rational design of electrochemical interfaces with controlled physicochemical characteristics.

The presented platforms are constructed by integrating biopolymer nanolayers with conductive nanomaterials and catalytic components, forming hierarchical structures that enhance both electron transfer and surface accessibility. Unlike traditional electrode coatings, biopolymer-based nanostructures allow for precise tuning of interfacial properties without the need for harsh chemical treatments or complex fabrication procedures. Their ability to mediate interactions between the electrode surface and target analytes plays a crucial role in improving analytical performance.

Importantly, the obtained results clearly demonstrate that biopolymer-based nanomaterials play an active electrochemical role in enhancing sensor performance, rather than serving merely as passive coatings. Their intrinsic redox activity and ability to facilitate charge transfer significantly improve electron transfer kinetics, leading to increased current responses and lower detection limits. At the same time, their antifouling properties and strong interfacial adhesion contribute to improved operational stability and repeatability of the measurements. As a consequence, the developed platforms exhibit superior analytical parameters compared to conventional systems, confirming that the rational integration of biopolymer nanomaterials directly translates into more efficient, sensitive, and reliable electrochemical (bio)sensors.

Funding

This work was supported by a subsidy from the Polish Minister of Science and Higher Education. Additionally, this work received funding from the Interdisciplinary Centre for Ecotechnology at Poznan University of Technology.