Polydopamine and polynorepinephrine as functional interfaces in electrochemical glucose biosensors

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

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

The growing demand for rapid, reliable, and decentralized diagnostic tools has significantly accelerated the development of point-of-care testing (POCT) systems for glucose monitoring. In this context, hybrid nanostructures have emerged as versatile platforms enabling enhanced analytical performance, improved stability, and facile integration into miniaturized sensing devices. This work explores the design and application of catecholamine-based hybrid nanomaterials, including polydopamine (PDA) and polynorepinephrine (PNE).

Catecholamine-derived polymers are of particular interest due to their bioinspired adhesive properties, rich surface chemistry, and ability to form conformal coatings on a wide range of substrates. Their structure, inspired by mussel adhesive proteins, provides abundant functional groups (e.g., catechol and amine moieties) that enable efficient immobilization of biomolecules such as glucose oxidase, as well as strong interactions with inorganic nanomaterials. In the present research, PDA- and PNE-based hybrid systems were engineered by combining organic polymer matrices with nanostructured components, including metal nanoparticles and carbon-based nanomaterials, to create synergistic sensing interfaces.

The influence of these hybrid architectures on key biosensor performance parameters was systematically investigated. Special attention was given to the limit of detection (LOD), limit of quantification (LOQ), sensitivity, and selectivity in complex sample matrices. The incorporation of catecholamine-based layers was found to significantly enhance enzyme immobilization efficiency and electron transfer kinetics, leading to improved signal-to-noise ratios and lower detection limits. Furthermore, hybridization with conductive nanomaterials contributed to increased sensitivity and broader linear detection ranges, which are critical for accurate glucose monitoring across physiologically relevant concentrations.

The presented results demonstrate that hybrid nanostructures based on polydopamine and polynorepinephrine constitute highly promising platforms for effective glucose biosensors. Their tunable physicochemical properties, combined with ease of fabrication and compatibility with scalable processes, make them particularly attractive for integration into portable and user-friendly POCT devices. This work contributes to the advancement of nanomaterial-enabled diagnostics and provides insights into the design of high-performance biosensing interfaces for clinical and personalized healthcare applications.

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