FACULTY OF CHEMISTRY

DEPARTMENT OF PHYSICAL CHEMISTRY AND TECHNOLOGY OF POLYMERS

Conducting polymer coatings exhibiting bacteria-responsive antibacterial properties-synthesis, structure, and mutual interactions

Powłoki z polimerów przewodzących wykazujące właściwości antybakteryjne reagujące na obecność bakterii-synteza, struktura i wzajemne oddziaływania

mgr. Abdullah

Supervisor: dr hab. inż. Katarzyna Krukiewicz, prof. PŚ

Gliwice 2026

Abstract

Conducting polymers have reversible redox activity, ionic transport, electrical conductivity, and the capacity to accommodate biologically active substances. These characteristics make them suitable for microbial electrochemical systems, but they also pose a challenging interface design problem. The electrode should facilitate bacterial adhesion, cell viability, and extracellular electron transfer in bioelectronic applications. On the other hand, in medical applications, the same tendency toward surface colonization must be suppressed before a mature biofilm is established. This dissertation examines both directions and develops a set of surface engineering strategies for controlling the interaction between PEDOT-based coatings and bacterial cells.

The first part of the work established the scientific basis for electrically conducting biohybrids by reviewing immobilization strategies, bacterial electron-transfer pathways, and the role of conducting polymers in linking biological and electronic charge transport. Two subsequent studies focused on improving the performance of PEDOT:PSS as a microbial electrode. Functionalization with organic compounds identified glucose as a particularly effective modifier, increasing *Shewanella oneidensis* MR-1 biofilm formation and cell viability while improving charge transfer between bacteria and the electrode. Modification with biologically relevant metal salts showed that calcium produced a favourable combination of roughness, wettability, cell viability, biofilm formation, and charge storage, whereas barium shifted the same material toward an antibacterial response.

The antibacterial part of the thesis investigated poly(3,4-ethylenedioxythiophene) (PEDOT) electropolymerized in the presence of dodecyltrimethylammonium bromide (DTAB). DTAB acted as a surfactant, dopant, structure-directing agent, and antibacterial component. The resulting PEDOT@DTAB coating stored substantially more charge than pristine PEDOT and inhibited biofilm formation by both *S. oneidensis* and *Pseudomonas aeruginosa*. Electrical stimulation accelerated DTAB release, demonstrating that the redox activity of the polymer could be used to regulate antibacterial release from the coating.

The major contribution of the dissertation was the development of a ceftazidime (CAZ)-loaded PEDOT coating that linked antibiotic release to bacterial redox activity. Ceftazidime was incorporated during electropolymerization without compromising the charge-storage capability of PEDOT. Passive leakage remained low, whereas external electrical stimulation and interaction with electroactive bacteria produced substantially higher release. *S. oneidensis*

and *P. aeruginosa* produced distinct electrochemical and spectroscopic responses, consistent with their different extracellular electron-transfer mechanisms. The coating reduced bacterial viability at the material interface, retained antibiofilm activity during prolonged incubation, and remained compatible with human dermal fibroblasts.

Taken together, the studies showed that PEDOT-based coatings could be designed either to support electroactive biofilms or to respond to bacterial colonization with localized antibacterial activity. The results provided a coherent foundation for future infection-responsive coatings for catheters, implants, wound dressings, and related bioelectronic devices.