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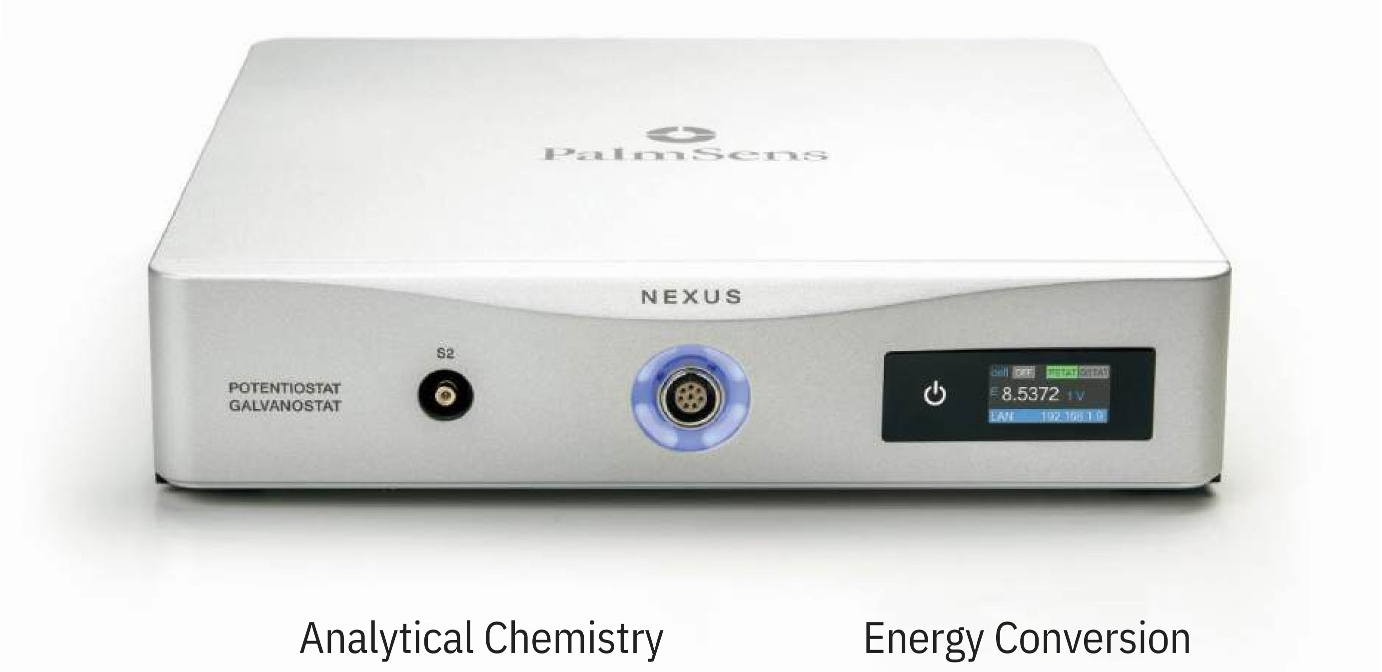
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Day 1

14 November 2025

Sensing of Bacterial Adhesion on Micro- and Nanostructured Surfaces

Vladislav Genevskiy[1,2,3], Khurram Usman[3], Elsa Westerlund[4], Per-Ola Önnervik[4], Maryam Mostajeran[4], Marius Dagys[5], and Sergey Shleev[1,2,†]

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This tutorial examines cutting-edge micro- and nanostructured strategies to detect and prevent bacterial adhesion. Bacterial infections—driven by virtually universal surface affinity and rising nosocomial rates—pose a growing threat to global health, as biofilms readily form in moist environments like wounds and the urinary tract. On invasive medical devices, *i.e.*, long-term implants (*e.g.*, prostheses, pacemakers) and indwelling devices (*e.g.*, cardiovascular cannulas, endotracheal tubes, and urinary catheters), biofilm development often necessitates painful, costly replacement or surgical intervention [1].

We begin by critiquing current biofilm diagnostics—namely invasive sampling, lengthy culture times, and expensive molecular assays—and then introduce real-time, *in situ* electrochemical methods (amperometry, voltammetry, and impedance spectroscopy) for rapid, non-destructive infection monitoring. We also weigh the advantages and limitations of potentiometric, wireless sensing of bacterial adhesion (Fig. 1a and 1b) [2].

Next, we introduce nanoimprint lithography—a low-cost, versatile micro/nanofabrication method ideal for high-throughput manufacturing [3]. It enables patterning of any kind of material in a desired layout—even on sharp edges and curved surfaces—which gives it an advantage over traditional techniques, especially in biomedical applications requiring ergonomic, flexible designs (Fig. 1c).

Then we contrast conventional chemical coatings—including polymers, metal ions, antibiotics, and peptides, which often suffer from cytotoxicity, instability, and uncontrolled release—with bioinspired mechano-bactericidal surfaces (Fig. 1d). Precision-engineered nano-textures provide durable, drug-free anti-biofouling performance, offering a scalable, proactive solution for infection control in indwelling medical devices, especially urinary catheters that remain in place for just days or weeks.

The tutorial's centerpiece is a dual-function catheter insert: high-resolution, "cicada–wing–inspired" nanopatterns imprinted on biocompatible polyurethane to mechanically rupture *E. coli* membranes, combined with miniaturized gold/Ag┃AgCl electrodes for potentiometric, Bluetooth-enabled wireless detection of early biofilm formation in human urine (Fig. 1e and 1f).

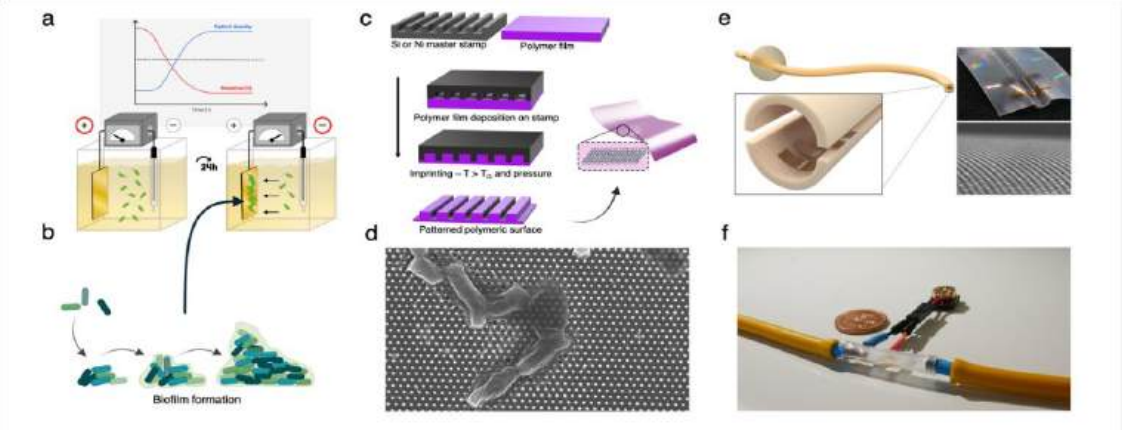

Figure 1. Development and integration of an antimicrobial, biofilm-sensing catheter insert.

Acknowledgments

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References

[1] C Arciola, D. Campoccia, L. Montanaro, *Nature Reviews* **16**, 397 (2018).
[2] V. Genevskiy, V. Chaturvedi, K. Thulin, K. Usman, E. Westerlund, P.-O. Önnervik, M. Mostajeran, and S. Shleev, *ChemElectroChem* **12**, e202400691 (2025).
[3] Y. Ofir, I. Moran, C. Subramani, K. Carter, V. Rotello, *Advanced Materials* **22**, 3608 (2010).

Electrochemical fingerprinting for medical and food research

Aleksandra Tobolska[†]**, Klaudia Głowacz, Katarzyna Biernat, Aleksandra Kędzierska, Wojciech Wróblewski, Nina E. Wezynfeld, Patrycja-Ciosek Skibińska**

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Electrochemical fingerprinting has emerged as a powerful approach for the rapid, low-cost analysis of complex samples [1–3]. Instead of focusing on individual analytes, this method captures the overall electrochemical response, forming a unique "chemical signature" and interprets it using multivariate statistical tools such as Principal Component Analysis (PCA) and Partial Least Squares Discriminant Analysis (PLS-DA). This strategy offers a fast and information-rich alternative for quality assessment, authenticity verification, and comparative analysis across various fields.

In this lecture, the fundamental principles behind electrochemical fingerprinting will be introduced and discussed in their practical implementation using voltammetric techniques. Drawing from both the literature and the work of our research team, selected case studies from two domains will be presented: electrochemical profiling of metal-peptide complexes relevant to medical diagnostics, particularly for recognizing biomarkers associated with Alzheimer's disease, as well as detecting biologically relevant anions [4,5], and real-world samples from the food industry, including tea beverages, fruit extracts, and dietary supplements.

These examples will illustrate that electrochemical fingerprints, when analyzed through chemometric modeling, allow for the detection of subtle chemical differences and group-related trends that often are difficult to trace applying classical analytical methods focused on respective, single analytes. The talk will also reflect on the strengths and limitations of this approach and highlight its potential as a versatile analytical strategy for both research and practical applications.

Figure 1: Applications of Electrochemical Fingerprinting in food and medical analysis.

Acknowledgments

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References

[1] R. Arita, N. Morita, K. Takemura, W. Iwasaki, S. Ueda, S, *Diam. Relat. Mater*. **144**, 110951 (2024).
[2] Y. Tan, M. Luo, C. Xu, J. Wang, X. Wang, L. Jiang, J. Yang, *Anal. Chem*. **97**, 21, 11016-11025 (2025).
[3] G. Moro, H. Barich, K. Driesen, N. Felipe Montiel, L. Neven, C. Domingues Mendonça, S. Thiruvottriyur Shanmugam, E. Daems, K. De Wael, *Anal. Bioanal. Chem*. **412**, 5955–5968 (2020).
[4] A. Tobolska, K. Biernat, N.E. Wezynfeld, W. Wróblewski, P. Ciosek-Skibińska, Proc. *IEEE Sensors* (2024).
[5] A. Tobolska, A. Goluch, P. Ciosek-Skibińska, K. Głowacz, N.E. Wezynfeld, W. Wróblewski, *Talanta* **291**, 127799 (2025).

Miniaturized cell for spectroelectrochemistry at the liquid-liquid interface

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Ion-transfer voltammetry at the interface between two immiscible electrolyte solutions (ITIES) offers an alternative approach to studying interactions between ionophores and ions. It can yield more straightforward data compared to ion-selective electrodes, which often have their sensitivity and selectivity influenced by factors such as the type of plasticizer, lipophilic salt, and the component ratios in the membrane. However, standard ITIES configurations are typically custom-built or demand specialized apparatus.

In this study, we developed a miniaturized version of a conventional electrochemical cell featuring a macro-scale liquid/liquid interface (see Fig. 1). Unlike traditional setups that require 5–15 mL of each phase, our design uses only 150–200 µL. Thanks to the large interface and symmetrical diffusion, this compact system enables straightforward data interpretation and direct comparison with previously published results. It retains the benefits of a standard electrochemical cell while avoiding the limitations associated with micro-ITIES. The device is assembled using commonly available lab items, such as a glass spectrophotometric cuvette and a Pasteur pipette. Like the standard cell, it is transparent, making it possible to observe unusual phenomena at the interface—such as deposit formation, bubble generation, or micro-emulsions. The system setup fits within a cuvette, making it suitable for spectroelectrochemical experiments, which increases the possibility of conducting research other than electrochemical.

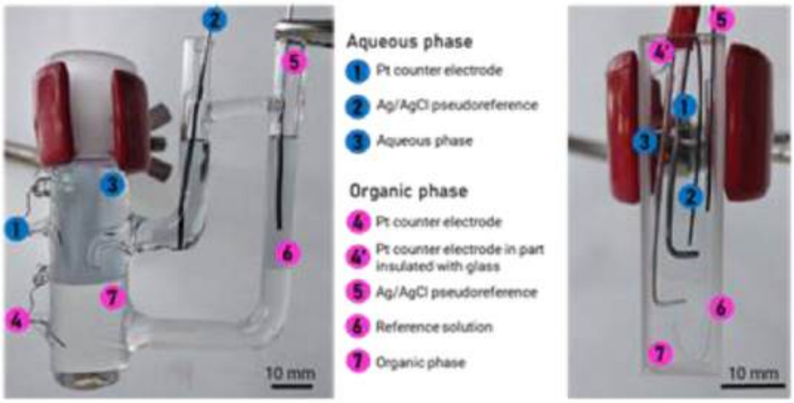

Figure 1: A photograph showing the standard cell (on the left) and the miniaturized cell (on the right) for electrochemistry at the liquid-liquid interface. In the miniaturized version, the counter electrode from the organic phase extends through the aqueous phase, requiring glass insulation. All other components of the cell are consistent with the design of the standard, larger cel.

Acknowledgments

Authors would like to thank National Science Centre Poland (NCN) Sonata 2020/39/D/ST4/02256 project

References

[1] Durka M, Durka K, Luliński S, Witkowska Nery E. Screening of organoboron compounds as potential ionophores in a miniaturized ITIES cell. ChemRxiv. 2024; doi:10.26434/chemrxiv-2024-jncnf

Day 2

15 November 2025

Plasmonic Single-Molecule Affinity Detection at 10^{-20} Molar

Eleonora Macchia[1], Cinzia Di Franco[2], Cecilia Scandurra[3], Lucia Sarcina[3], Matteo Piscitelli[4], Michele Catacchio[1], Mariapia Caputo[1], Paolo Bollella[3], Gaetano Scamarcio[4,5], Luisa Torsi[3,†]

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DNA can be readily amplified through replication, enabling the detection of a single-target copy. A comparable performance for proteins in immunoassays has yet to be fully assessed. Surface-plasmon-resonance (SPR) serves as a probe capable of performing assays at concentrations typically around 10^{-9} molar. In this study, plasmonic single-molecule assays for both proteins and DNA are demonstrated, achieving limits-of-detections (LODs) as low as 10^{-20} molar (1 ± 1 molecule in 0.1 mL), even in human serum, in 1 h. This represents an improvement in typical SPR LODs by eleven orders-of-magnitude. The single-molecule SPR assay is achieved with a millimeter-wide surface functionalized with a physisorbed biolayer comprising trillions of recognition-elements (antibodies or protein–probe complexes) which undergo an acidic or alkaline pH-conditioning [1]. Potentiometric and surface-probing imaging experiments reveal the phenomenon underlying this extraordinary performance enhancement. The data suggest an unexplored amplification process within the biomaterial, where pH-conditioning, driving the biolayer in a metastable state, induces a self-propagating aggregation of partially misfolded proteins, following single-affinity binding. This process triggers an electrostatic rearrangement, resulting in the displacement of a charge equivalent to 1.5e per 10^2 recognition elements. Such findings open new opportunities for reliable SPR-based biosensing at the physical detection limits, with promising applications in point-of-care plasmonic systems.

References

[1] E. Macchia, C. Di Franco, C. Scandurra, L. Sarcina, M. Piscitelli, et al., Advance Materials, 2025, vol.37, 2418610.

Nanomaterials based amplifications in electronic biosensors

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Novel strategies for on-chip integrated nanoelectronic devices inspired the development of a new generation of biosensors, employing inorganic and organic materials. The main element of such biosensors is the semiconductor (e.g. in field effect transistors) or metal (in electrochemical, chemiresistive or impedimetric sensors) transducer, with the radically miniaturized sensing area down to the several nanometers. Merging such nanodevices with the biological species, e.g. cells or molecules of similar nanosizes, offers the remarkable increase in the biosensor sensitivity.

We envision that hierarchical integration of the nanomaterials into the sensing devices will support further amplification of the sensing signal. Earlier we demonstrated that linear assembly of gold nanoparticles increases the sensitivity of the plasmonic resonance shift to the biomolecular binding, compared to the single particles. After successful fabrication of the silicon based nanoscopic FETs and template assisted arrays of the plasmonic nanoparticles for the biosensor applications, merging of these technologies for the realization of the clinically relevant use case is realized. Combining the optical and electronic components in the biosensing device requires to use the scenario, where each of them results in the maximal signal change. We demonstrate that the optoelectronic characterization of the Nanoparticles featured FET devices can support the signal modulation in the device upon binding the biomolecules.

Figure 1: Merging of the plasmonic nanoparticles with the FET biosensor for the amplified response.

Selective Recognition of Enantiomers/Isomers at Molecularly Encoded Metal Surfaces

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The molecular recognition of enantiomers or isomers is of utmost importance in various sectors, including sensing and synthesis of pharmaceuticals. To date, the development of concepts allowing chiral and molecular recognition is still a great challenge in terms of achieving a reliable discrimination of one enantiomer or conformation with respect to the other. Recently, we have successfully developed a series of chiral imprinted metals with mesoporous features by electrodeposition of metals in the simultaneous presence of lyotropic liquid crystalline surfactants and various chiral compounds such as the enantiomers of 3,4-dihydroxyphenylalanine (DOPA), mandelic acid, and phenylethanol[1-5]. The discrimination between two corresponding enantiomers has been clearly observed using Differential Pulse Voltammetry (DPV) even after removal of the chiral templates. In addition, to further improve the efficiency of chiral imprinted metals for chiral recognition in terms of their stability, a chiral encoded Pt-Ir alloy has been obtained by co-electrodeposition of Pt and Ir in the presence of a liquid crystal phase and chiral templates. Interestingly, again a very high discrimination between two enantiomers is observed, even after applying highly positive potentials. To extend the range of applications of these designer materials, they have also been used as selective materials imprinted with different isomers to discriminate between Cannabidiol (CBD) and Tetrahydrocannabinol (THC). We report here the first example of a molecular-encoded platinum-iridium (Pt/Ir) alloy, used as a sensing layer for the selective detection of cannabinoids, including cannabidiol (CBD) and tetrahydrocannabinol (THC). To design these molecular-imprinted electrodes, an electrodeposition technique was applied, using CBD or THC model molecules as templates in the simultaneous presence of a lyotropic liquid crystal structure of non-ionic surfactants. After the complete removal of all templates, mesoporous structures containing molecular recognition sites for these two cannabinoids were obtained. The efficiency of the molecular discrimination between CBD and THC model compounds has been studied with differential pulse voltammetry (DPV), revealing a highly selective recognition of these two isomers with detection limits of 10 µM. Most importantly, the nanostructured materials can also be employed for analyzing real cannabis oil samples and the sensors can be reused several times[1]. These findings open up promising perspectives in the general frame of the electroanalysis of various types of molecules ranging from chiral compounds to complex molecules such as THC and CBD at molecularly encoded metal surfaces.

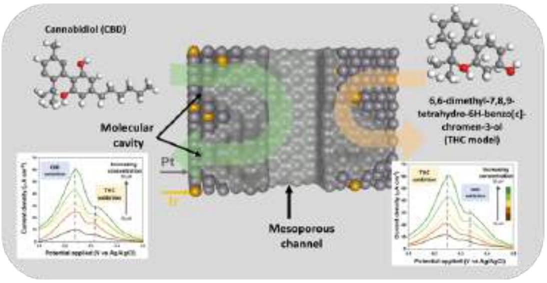

Figure 1. Schematic illustration of CBD and THC recognition on Pt/Ir alloy.

Acknowledgments

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References

[1] W. Nunthakitgoson, N. Kaewwan, S. Butcha, M. Ketkaew, A. Kuhn, and C. Wattanakit, submitted, (2025)
[2] S. Supattra, B. Suwankaisorn, K. Yomthong, W. Srisuwanno, S. Klinyod, A. Kuhn, and C. Wattanakit, *Chem. Eur. J.*, 29, e2023020 (2023).
[3] S. Butcha, V. Lapeyre, C. Wattanakit, and A. Kuhn, *Chem. Sci* 13, 2339 (2022).
[4] S. Butcha, S. Assavapanumat, S. Ittisanronnachai, V. Lapeyre, C. Wattanakit, and A. Kuhn, *Nat. Comm*, 12, 1314 (2021).
[5] S. Assavapanumat, M. Ketkaew, A. Kuhn, and C.Wattanakit, *J. Am. Chem. Soc.* 141, 47, 18870-18876 (2019).

Extended-Gate-Type Organic Field-Effect Transistors with Self-Assembled Monolayers for Chemical Sensing Applications

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Real samples contain abundant chemical species playing crucial roles in environmental assessments, food analysis, and diagnosis fields. Conventionally, large-sized analytical instruments have been widely applied to real-sample analysis owing to their accuracy. However, the applicability of such a well-established instrumental approach is still a concern in on-site analysis because of the complicated detection principle that requires trained personnel and time-consuming operation. Herein, the presenter introduces an approach for the development of chemical sensor devices based on organic field-effect transistors (OFETs). OFETs are electronic devices showing switching characteristics by applying voltages [1][2]. Owing to the inherent amplification ability, OFETs functionalized with appropriate molecular recognition materials allow sensitive analyte detection over conventional electrochemical sensing methods [3]. Meanwhile, organic semiconductive layers of OFETs are unstable against water, which poses applications for chemical sensing in aqueous media [4]. Thus, an extended-gate structure has been employed to obtain stable signals upon detecting analytes on the gate electrode [5].

Biological materials such as enzymes and antibodies have been employed owing to their favorable specificities to analytes based on the lock-and-key recognition principle. However, detectable analyte structures are limited by a library of these biological materials. Therefore, synthetic receptors based on molecular recognition chemistry are promising approaches in the design of recognition sites. Among them, supramolecular receptors have been vigorously developed in molecular recognition fields. In particular, the cross-reactivity can be applied to simultaneous detection by using pattern recognition methods [4]. Cross-reactive supramolecular receptors are easily modified as self-assembled monolayers (SAMs) on the gate electrode of the OFET [6-8]. This presentation will introduce the design strategy of OFET-based chemical sensors and actual sensing performance in real samples.

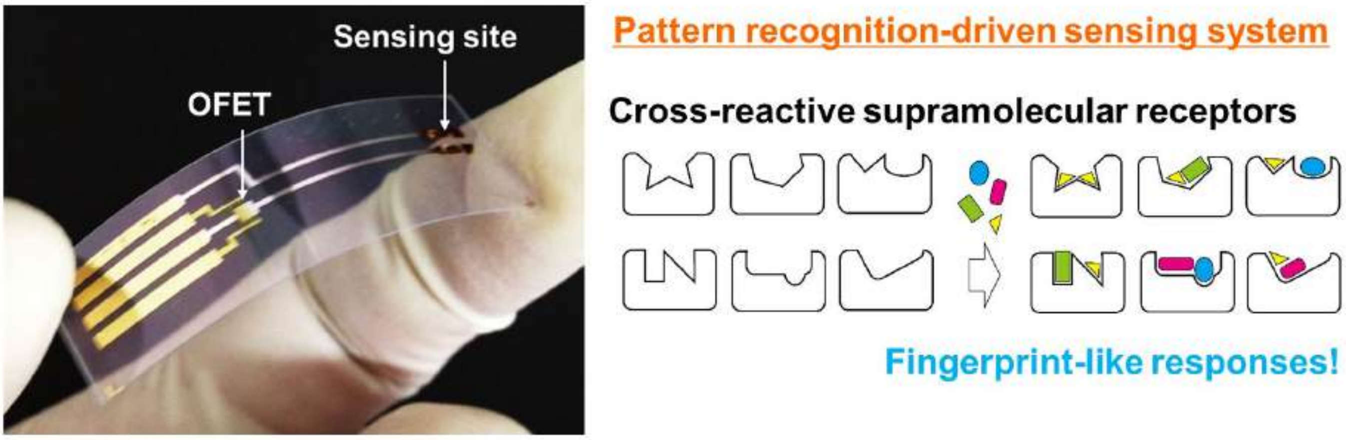

Figure 1: Conceptual figure of an extended-gate-type OFET device functionalized with cross-reactive supramolecular receptors for pattern recognition-driven chemical sensing.

Acknowledgments

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References

[1] T. Minami et al., *ACS Sens.* **4**, 2571 (2019) (**Invited Review and Cover**).
[2] T. Minami et al., *ACS Appl. Mater. Interfaces.* **17**, 31165 (2025) (**Invited Review and Cover**).
[3] T. Minami et al., *Sens. Actuators B Chem.* **382**, 133458 (2023) (**Invited Paper**).
[4] T. Minami et al., *Coord. Chem. Rev.* **429**, 213607 (2021) (**Invited Review**).
[5] Z. Bao et al., *Proc. Natl. Acad. Sci. U. S. A.* **105**, 12134 (2008).
[6] L. Baraban et al., *Next Nanotechnol*. **3**, 100025 (2023).
[7] T. Minami et al., *J. Mater. Chem. C* **9**, 11690 (2021) (**Invited Paper and Cover**).
[8] T. Minami et al., *ACS Appl. Mater. Interfaces* **14**, 22903 (2022) (**Invited Paper and Cover**).
[9] T. Minami et al., *Chem. Commun.* **60**, 9930 (2024) (**Invited Paper and Cover**).

Electrical wiring of enzymes with minimal cytochromes

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Cytochromes are essential electron-transfer proteins that drive critical redox reactions in biological systems. In this presentation, I delve into the innovative application of minimal cytochromes—compact proteins with short peptide sequences—sourced from magnetotactic and electroactive bacteria. These streamlined cytochromes serve as highly efficient electron shuttles.

Inspired by nature's own designs, particularly the enzymes cellobiose dehydrogenase and pyranose dehydrogenase, we have engineered genetic fusions of these minimal cytochromes with various enzymes. This fusion significantly boosts enzymatic activity and enhances electron transfer to electrodes.

Throughout my talk, I will showcase a range of applications developed in our lab, where cytochromes are tethered to proteins and enzymes. These hybrid systems exhibit unique properties that advance biosensing, biocatalysis, and microbial electron transfer. By highlighting these developments, we aim to deepen our understanding of biological electron transfer strategies and unlock new possibilities in biotechnology.

Local Investigations of Electrochemical Reactions for Biotechnological Applications

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The interface of redox proteins with electrode materials allows us to address fundamental biological questions and make use of such biological elements in the fabrication of electrode architectures for different biotechnological applications. Redox enzymes are highly active and selective biological catalysts, performing catalytic conversions with high yields under mild conditions, such as aqueous solutions, near-neutral pH, and ambient temperature and pressure. Therefore, they are widely studied in combination with electrodes targeting different applications. Among others, relevant examples include the implementation of biofuel cells for clean energy generation and sensing applications, and the development of novel catalytic materials used in bioelectrosynthesis aiming at the conversion of surplus residues into valuable products. In addition, the photosynthetic reactions enabled by light-activated protein complexes show an exceptionally high quantum yield, close to 100%, for the photon-to-electron conversion. As a result, there is a great interest in the study and coupling of photosynthetic elements with electrode materials for the fabrication of semi-artificial biodevices that will enable the conversion of solar light energy into electrical power and the synthesis of valuable products.

As it will be shown, we can fabricate various functional bioelectrodes consisting of electrically conductive materials and integrate isolated enzymes or photosynthetic elements for diverse applications. Taking advantage of relatively simple but powerful electrochemical characterization tools, the biohybrid materials are investigated to assess performance and electrochemical reactions at the biotic/abiotic interface, aiming at appropriate immobilization strategies and a productive interaction between the biological entities and the electrode surface. The possibility of performing electrochemical characterizations at the microscale allows direct local analysis with higher spatial and temporal resolution. Therefore, the use of miniaturized electrochemical probes offers important advantages for analytical purposes. Since the probe has a substantially smaller size compared to the investigated sample, the analysis is carried out with a rather low substrate consumption, which ensures minimal invasiveness and avoids possible interferences during the measurement. In addition, the small size of the sensor helps to increase mass transport rates and allows sample characterization and the measurement of catalytic reactions under operando conditions. Examples will be shown highlighting the possibility of performing electrochemical characterizations at the microscale when using micro(bio)sensors for direct local analysis.

Acknowledgments

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Potential and applications of multifunctional nanoparticles with enzyme-like activities

Lorico Delos Santos Lapitan Jr[1], Kinga Westphal[1], Jan Górniaszek[1,2], Paweł Stańczak[1,2], Monika Śmigielska[1,2], Marcin Drozd[1,2], Ilona Grabowska-Jadach[2], Areta Czerwińska[2], Katarzyna Tokarska[1], Kamil Żukowski[1], Elżbieta Malinowska[1,2], Mariusz Pietrzak[1,2,†]

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Hybrid (multi-component) nanoparticles enable the combination of multiple desirable properties and functionalities within a single structure [1]. Such nanoparticles can be used in bioanalytics and combined anticancer therapies (including photothermal and chemodynamic ones). This presentation will show research into the development of modern multifunctional nanoplatforms (characterized with interesting optical properties, catalytic activity, and ease of further functionalization) utilizing superparamagnetic cores, and present the characterization of such particles and their potential applications, also in microfluidic bioanalytical cartridges developed using polyester films technology. The advantages of proposed approaches will be discussed and the most promising nanoparticles pointed out.

Acknowledgments

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References

[1] P. Ivanova, M. Drozd, K. Michrowski, S.Karoń, M. Mazurkiewicz-Pawlicka, M. Pietrzak, Au-X (X=Pt/Ru)-decorated magnetic nanocubes as bifunctional nanozyme labels in colorimetric, magnetically-enhanced, one-step sandwich CRP immunoassay, Biosensors and Bioelectronics, 237, 2023, 115511

Tailored Ru-Complex Grafted Nanofilms for Light-Voltage Driven Systems

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Photocatalysis and photoelectrocatalysis offer promising routes for solar energy conversion and sustainable chemical transformations. However, in most cases, the catalyst is in homogeneous phase (solution), limiting its recyclability, stability, and integration into devices. Developing robust, surface-bound alternatives is essential for enabling more durable and scalable light-driven systems. In this context, constructing well-defined photoelectrocatalytic interfaces remains a major challenge, particularly when precise control over film structure and composition is required to maximize the catalyst efficiency (increasing TurnOver and minimizing overvoltage).

Polypyridine Ruthenium complexes exhibit remarkable photophysical and redox properties, making them prime candidates for light-voltage-driven applications[1].

In this work, we demonstrate an innovative approach to design photoelectrocatalytic interfaces through the electrografting of bis-terpyridine ruthenium complex $[Ru(tpy)(tpy\text{-}ph\text{-}N_2^+)]^{3+}$ onto carbon surfaces. Through mono- or co-grafting of diazonium salts we achieve fine-tuning of the film's thickness, composition, and chemical architecture at the molecular level. This approach offers a powerful means to tailor the electronic, steric, and conformational properties of the resulting films.

To achieve a more comprehensive picture of the film organization and to understand the precise structure-property relationships, we employe a multi-technique investigation. The dynamic of the layer grafting is investigated by Electrochemical quartz crystal microbalance (EQCM) whereas Atomic Force Microscopy (AFM) revealed its morphology (roughness and thickness). UV-vis spectroelctrochemistry[2] is used to monitor the optical changes of the Ru complex film associated to its redox activity, enabling a better understanding of the interfacial reactivity. While this work is still under investigation, preliminary results indicate that the optical properties of the films are strongly influenced by the density and distribution of the grafted moieties. Modulating such properties will lead to a control over the photoelectrocatalytic performance of the surface.[4] This study contributes to advancing molecular-level engineering of light-sensitive interfaces, paving the way for future applications in sustainable catalysis.

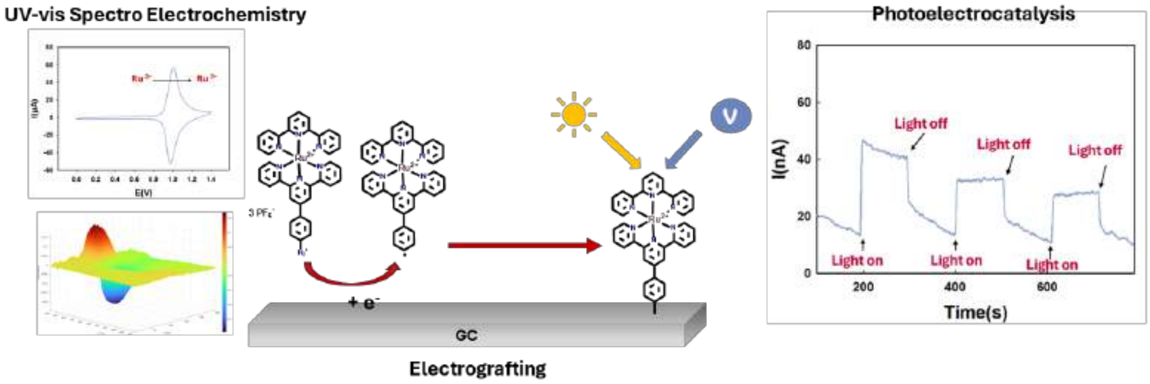

Figure 1: Overview of the multi-technique approach used to investigate the photoelectrocatalytic behavior of the organic nanofilms

References

[1] J. J. Concepcion, M.-K. Tsai, J. T. Muckerman, et T. J. Meyer, *J. Am. Chem.* 132, 1545-1557, **2010**.
[2] L. Pichereau, C. Gautier, et T. Breton, *J. Mater. Chem. C*, 10, 7111-7118, **2022**.
[3] J. D. Knoll, B. A. Albani, et C. Turro, *Acc. Chem. Res.*, 48, 2280-2287, **2015**
[4] N. Kaveevivitchai, L. Kohler, R. Zong, M. El Ojaimi, N. Mehta, et R. P. Thummel, *Inorg. Chem.*, 52, 10615-10622, **2013**.

Electrochemical detection of a narrow therapeutic range drug using aptasensors with the application of carbon surfaces

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Drugs with a narrow therapeutic range are medicines for which the therapeutic dose and the toxic dose are relatively close to each other. One such drug is vancomycin, an intravenous antibiotic used to treat severe staphylococcal and streptococcal infections that are resistant to beta-lactam antibiotics. An overdose of vancomycin can lead to hearing loss, kidney damage, and even death. Therefore, it is important to monitor the concentration of this antibiotic in the blood. Currently used techniques, such as HPLC-MS or immunoassays do not allow for accurate monitoring of vancomycin concentrations [1,2]. The solution may be the use of electrochemical biosensors.

The aim of the study was to develop an electrochemical aptasensor based on carbon transducers (GCE, EPPG, miniature screen-printed electrodes) for the detection of vancomycin. Techniques such as cyclic voltammetry, square wave voltammetry, electrochemical impedance spectroscopy, and chronocoulometry were used in the study. In order to immobilize the aptamers, sequences with terminal anthracene or pyrene groups were employed, which allowed tethering through π-π interactions between carbon surface and aromatic anchor groups conjugated to aptamer 5' end [3]. Calibration curves were prepared to confirm the usefulness of the developed biosensors in the drug therapeutic range. The selectivity of the receptor layer was also checked and tests were carried out in human serum. Moreover, the studies were conducted on the influence of the use of a blocking agent in the form of a compound containing an aromatic ring (2-phenoxyethanol).

Acknowledgments

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References

[1] Dauphin-Ducharme P, Yang K, Arroyo-Currás N, et al, *ACS Sens*. **4**, 10 (2019)
[2] Mu F, Zhou X, Fan F, Chen Z, Shi G., *Anal Chim Acta*., **1151**~~,~~ (2021)
[3] N. Arroyo-Currás, *ACS Sens*., **9**, 5 (2024)

The Immobilisation of Enzymes on Electrodes: Appplications in Catalysis

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Electrochemical methods are of interest in the controlled immobilisation of enzymes for a range of applications. The use of enzymes in biocatalysis is of interest as an alternative means of performing redox reactions in place of conventional reagents, while the development of biofuel cells is of interest in medical applications. Electrodes can be used as supports for the immobilization of enzymes in a precisely controlled manner with the degree of spatial control dictated by the area of the working electrode. Here we describe recent work on the application of electrochemical methods to for use in the development of biocatalytic reactors and of biofuel cells.

Modified liquid-liquid interfaces for SERS spectroelectrochemistry

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Gold nanoparticles (AuNPs) assemblies have been formed at liquid-liquid interfaces to serve as substrates for Surface Enhanced Raman Spectroscopy (SERS). Plasmonic soft interfaces provide opportunities to create highly reproducible, scalable and low-cost SERS substrate with high Raman enhancement factor. We have investigated the use of AuNP films floating at liquid-liquid interface, highlighting the impact of interfacial polarization on the Raman signal.

SERS of several organic ions were recorded at varying interfacial potential differences (methylene blue, tolmetin, norfloxacin). Using Raman 2D correlation analysis, we will show how the potential difference impacts the SERS signal of the targeted molecules and how the chemical environment contributes to the SERS signal.

“Smart” next-generation microbial biosensors: integration of genetic and nanotechnological engineering for diagnostics and environmental monitoring

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Modern medical diagnostics, research in the field of environmental safety and food safety are largely based on the use of components and properties of living things of the molecular level [1]. Such urgent problems as quality control of drinking water and food resources, the creation of reliable and express methods of diagnosis and treatment, often cannot be solved by traditional approaches. There is an urgent need to develop and implement fundamentally new methods and technologies based on highly specific enzymes obtained from traditional microbial sources or recombinant microorganisms.

In recent years, microbial biosensors based on whole cells have become one of the most interesting analytical systems due to the low cost of biosensor elements, high operational stability and specificity. The main advantage of using microbial cells as bioselective elements of biosensors is their ability to undergo genetic modifications by mutation or recombinant DNA technology, as well as to serve as an economical source of intracellular enzymes. However, the main limitation is the potential loss of the number of plasmids, which affects the overall performance. In this context, a promising direction is the development of "smart" microbial biosensors - analytical systems of a new generation, built on the basis of recombinant microorganisms enriched with natural enzymes and artificial enzyme-like nanomaterials – nanozymes. Unlike classical biosensors, "smart" microbial biosensors combine high sensitivity and selectivity of natural enzymes with the stability and multifunctionality of nanomaterials; are able to work in real samples – in particular, in wastewater or in food and beverages; open up prospects not only for diagnostics or environmental monitoring, but also for detoxification of harmful substances and generation of bioenergy in microbial fuel cells [2].

To construct an amperometric "smart" sensor, the yeast (*Saccharomyces cerevisiae*, *Ogataea polymorpha,* and *Komagataella phaffii*) or bacterial (*Corynebacterium glutamicum*) cells were additionally enriched with the target enzymes (formaldehyde dehydrogenase, glycerol dehydrogenase methylamine oxidase or creatinine deiminase) and nanozymes possessing diaphorase-like or peroxidase-like activities by combining three ways of genetic and nanotechnological engineering: on the genetic level – by overexpression of the corresponding gene coding for target enzyme in recombinant yeast cells; under nanotechnological approaches – by the additional loading of the cells with the purified target enzyme, co-immobilized with nanomimetics, *i.e.*, nCdTe, nCu, nCeAu or nMoAuCo. These engineered cells were successfully used for the construction of “smart” biosensors, biofuel cells and bioreactors for detection and bioremediation of toxic formaldehyde, methylamine, creatinine, glycerol in soap stocks, wastewater food products and biological fluids.

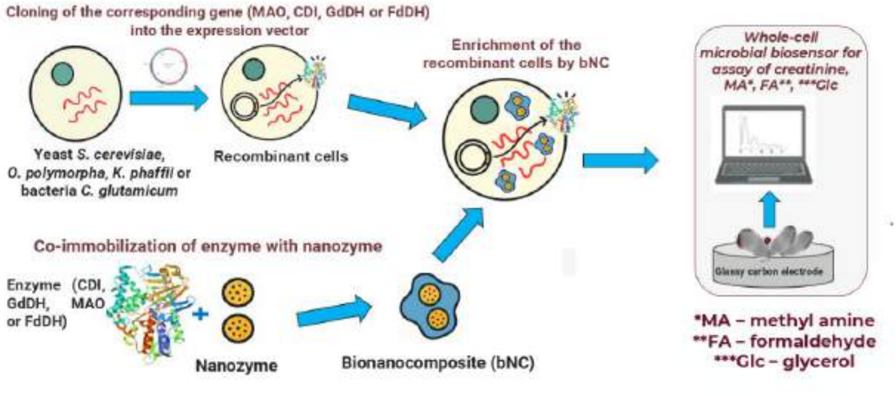

Figure 1: General scheme for construction of “smart” next-generation microbial biosensors.

Acknowledgments

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References

[1] Gu Chengcheng, P. Gai and F. Li, *Nano Energy* **93**, 106806 (2022)
[2] A. Ali, H. Shaukat, S. Bibi, W.A. Altabey, M. Noori and S.A. Kouritem *Energy Strat. Rev.* **49**, 101124 (2023)

Triazabutadienes for the Immobilization of Electrodes with Biomolecules

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We have been developing triazabutadiene molecules as a tool to enable light-activated covalent grafting of biomolecules onto electrode surfaces (Figure 1).[1] This talk will describe the synthetic development of our toolkit of molecules and their application in new biosensors.[2], [3], [4] We are able to graft to wide range of surfaces, including off the shelf silicon wafers. The stability of the immobilization is particularly useful is enabling us to apply Fourier transform voltammetry to interrogate our modified electrode surfaces.[5]

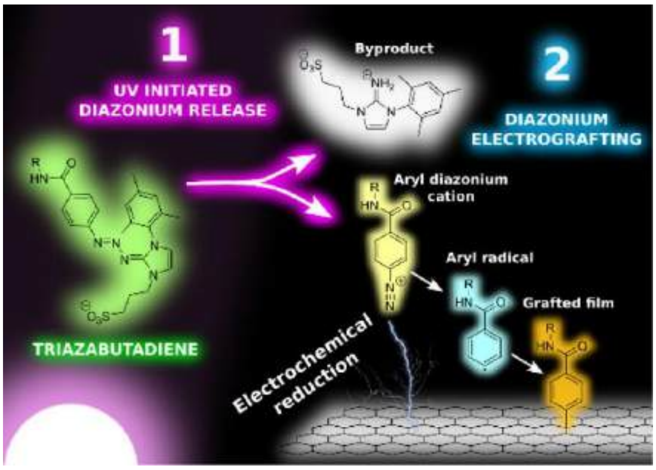

Figure 1: Light-driven electrografting of a triazabutadiene.

Acknowledgments

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References

[1] Yates NDJ, Hudson L, Schwabe O, Parkin A. Langmuir. 2025 Mar 25;41(11):7386-7395.
[2] Yates NDJ, Hatton NE, Fascione MA, Parkin A. Chembiochem. 2023 Aug 15;24(16):e202300313.
[3] Yates NDJ, Miles CG, Spicer CD, Fascione MA, Parkin A. Bioconjug Chem. 2024 Jan 17;35(1):22-27.
[4] Hewson AR, Lloyd-Laney HO, Keenan T, Richards SJ, Gibson MI, Linclau B, Signoret N, Fascione MA, Parkin A. Chem Sci. 2024 Sep 13;15(39):16086-95.
[5] Baranska NG, Jones B, Dowsett MR, Rhodes C, Elton DM, Zhang J, Bond AM, Gavaghan D, Lloyd-Laney HO, Parkin A. ACS Meas Sci Au. 2024 May 7;4(4):418-431.

Structure–Performance Insights into Hyper-Crosslinked Polymer Catalysts for the Oxygen Reduction Reaction

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The oxygen reduction reaction (ORR) is a pivotal process in energy conversion technologies such as fuel cells and metal–air batteries. However, the reliance on precious metal catalysts, particularly platinum-based materials, has hindered the large-scale implementation of these systems due to high costs and limited durability.[1] This work addresses the critical need for sustainable and cost-effective electrocatalysts by exploring a new class of phthalocyanine-based hyper-crosslinked polymers (HCPs) tailored for ORR electrocatalysis.

We report the synthesis of two distinct HCPs via a Friedel–Crafts alkylation strategy [2], using metalated (cobalt) and metal-free phthalocyanine precursors. This design enables a systematic investigation of the central metal atom effect on ORR performance, while maintaining a persistent polymer backbone. It also provides a unique opportunity to compare the role of molecular structure, and porosity within a controlled framework. Both materials exhibit high surface areas (>1000 m^2g^{-1}) and interconnected porous networks, facilitating O_2 transport and charge mobility.

Electrochemical analysis revealed that the insertion of cobalt into phthalocyanine ring increases onset potential, and current density. Still metal-free HCP also demonstrated appreciable ORR activity. This is attributed to the nitrogen-rich framework, and microporous structure of the polymer. These structural features likely promote oxygen adsorption and facilitate electron transfer, highlighting the intrinsic electrocatalytic potential of the polymer framework, even in the absence of a metal center. Tafel slope analysis and rotating ring-disk electrode (RRDE) experiments allowed to quantify the number of electrons transferred per oxygen molecule.

These findings underscore the importance of structure–function relationships in organic electrocatalysts and highlight phthalocyanine-derived HCPs as a promising platform for developing next-generation, low-cost, and metal-efficient ORR catalysts. This comparative strategy not only advances the understanding of non-precious metal ORR electrocatalysts but also opens avenues for rational design of hybrid materials where polymeric backbones play a synergistic role with or without metal centers.

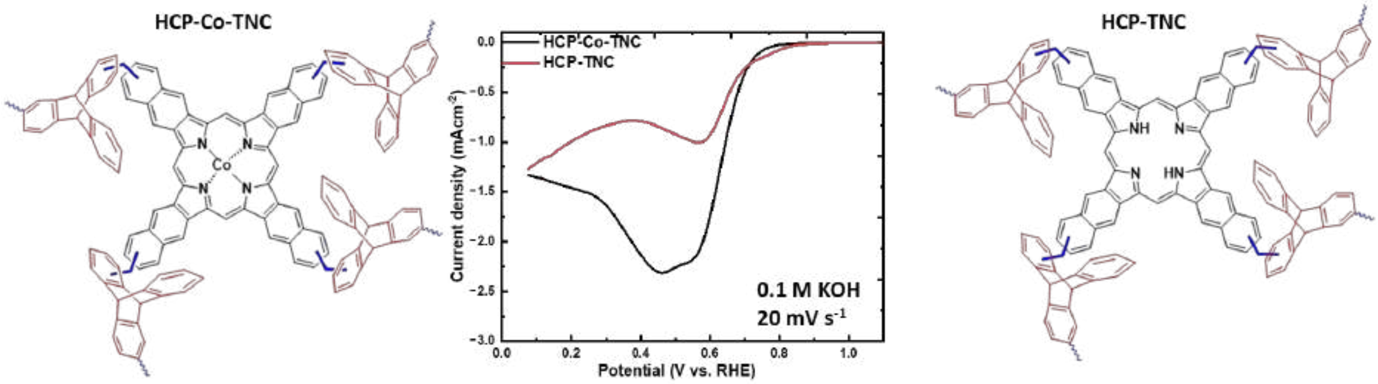

Figure 1: Schematic representation of phthalocyanine-based HCPs and linear sweep voltammograms obtained with glassy carbon disc modified with HCPs in 0.1 M KOH at 20 mVs^{-1} in the Oxygen. Hg/HgO used as a reference and Pt wire as a counter electrode.

Acknowledgments

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References

[1] Dai, L., Xue, Y., Qu, L., Choi, H.J. and Baek, J.B., *Chemical Reviews* **11**, 4823-4892 (2015).
[2] Tan, L. and Tan, B., *Chemical Society Reviews* **46**, 3322-3356 (2017).

Electrochemical actuation of pristine carbon fibers

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Structures that can be stimulated to change shape have potential for various applications,[1] but they often require processing and modification.[2] We propose a simple and straightforward actuation strategy based on bipolar electrochemistry,[3] which drives asymmetric reactions at the surface grooves of pristine carbon fibers.

In the first set of proof-of-principle experiments, a free-standing carbon fiber is polarized in a closed bipolar cell to trigger asymmetric benzoquinone/hydroquinone redox reactions in two distinct compartments. Ion transfer occurs beyond a specific threshold potential, and the part of the fiber involved in the anodic reaction exhibits reversible directional motion.

Elemental surface characterization of the polarized carbon fiber suggests that the deflection results from the intercalation and deintercalation of ions accompanying the oxidation and reduction of the fiber. Simultaneous local ionic adsorption and desorption at the surface contribute to the observed motion.

The extent of fiber deflection is determined by the length of the segment exposed to the electrochemical reduction reaction in the opposite compartment of the closed bipolar cell, while the direction of motion is governed by the groove orientation. Effective bending was achieved by optimizing both fiber alignment and stimulus parameters.

The actuation of two parallel fibers oriented in opposite directions produces a microtweezer-like motion.[4] We anticipate that these findings will enrich the toolbox for research in soft robotics and micromechanics.

References

[1] [Kong, L., Chen, W. Advanced Materials 26, 1025–1043 (2014).
[2] Melvin, A.A., Gupta, B., Tieriekhov, K., Nogala, W., Garrigue, P., Reculusa, S., Kuhn, A. *Advanced Functional Materials* **31**, 2101171 (2021).
[3] Loget, G., Zigah, D., Bouffier, L., Sojic, N., Kuhn, A. *Accounts of Chemical Research* **46**, 2513 (2013).
[4] Johnson, K. C., Clemmens, E., Mahmoud, H., Kirkpatrick, R., Vizcarra, J. C., Thomas, W.E. *Journal of Biological Engineering* **11**, 47 (2017).

Lessons learnt from DNA immobilization on Au surfaces for sensing in the clinical field

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DNA is arguably the most versatile molecule. It is the genetic molecule, but it also carries conformational information that can be used for sensing purposes. By two main distinct mechanisms, DNA can bind other nucleic acid sequences (hybridization) but also any other molecule – from small molecules to biomolecules – and even whole cells by shape and chemical complementarity. DNA can be thus considered a broad-spectrum receptor. Indeed, DNA can bind complementary strands in genosensing but also can fold into intricate secondary and, more importantly, 3D structures, to bind different molecules (aptamers).

Both health monitoring and disease diagnosis rely in a large extent on analytical methods providing evidence of biomarkers alteration. Nucleic acid sequences, proteins, and peptides are typical targets that can be recognized by DNA. Non-coding RNA reveals to be relevant biomarkers of several diseases because of up- or downregulation in pathological states [1]. Protein and peptides can be advantageously recognized by aptamers, which can complement antibodies-based analytical methods and beat them when more specific binding is required because their obtention can be more easily directed toward specific regions of the target [2].

In most countries, the budget dedicated to clinical analyses is constantly growing due to advances in the understanding of molecular mechanisms and the universalization of healthcare. This trend underscores the need for cost-effective diagnostic devices that can be used not only in clinical settings but also at patients' homes, enabling decentralized testing. DNA-based biosensors are promising for this purpose, especially the electrochemical ones because they can be easily miniaturized and are highly sensitive. Gold is one of the most widely used electrode materials due to its stability and ease of modification. In this keynote, we will examine different DNA immobilization methods, and the appropriateness for some specific applications such as point of care and health monitoring. Their advantages and disadvantages will be discussed along with potential solutions and unsolved issues that need to be addressed.

Acknowledgments

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References

[1] R. Miranda-Castro, N. de-los-Santos-Álvarez, M.J. Lobo-Castañón, *Analytical and Bioanalytical Chemistry* **411**:4265 (2019).

[2] A. Díaz-Fernández, R. Lorenzo-Gómez, R. Miranda-Castro, N. de-los-Santos-Álvarez, M.J. Lobo-Castañón, *Analytica Chimica Acta*, **1124**, 1 (2020).

Oxygen reduction reaction electrocatalysis on non-metallated hypercrosslinked polymers

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The design of non-metallic catalysts for the oxygen reduction reaction (ORR) is increasingly important in the context of sustainable energy technologies, such as fuel cells and metal-air batteries [1] or electrochemical H_2O_2 generation [2]. The high cost and limited availability of platinum-based catalysts have driven the search for alternative non-metallic materials. In this context, easily synthesized hypercrosslinked polymers (HCPs [3]), a promising class of porous organic polymers, offer a combination of high ORR activity, low cost, and environmental friendliness.

An example of a promising HCP is the TPBA polymer, derived from triphenylbenzene (TPB) and triphenylamine (TPA), synthesized via Friedel-Crafts or Scholl coupling using $FeCl_3$ or $AlCl_3$ as catalysts, respectively. The advantage of this method is its simplicity and the lack of need for high temperatures or expensive precursors, and it yields materials with a highly porous, three-dimensional structure, enabling efficient oxygen adsorption and transport to active sites. This structural feature facilitates ORR in an alkaline solution [4].

For electrochemical experiments, HCP particles were immobilized in Nafion® film at a glassy carbon electrode. Voltammetric and chronoamperometric experiments were performed in acidic and alkaline solutions in static and hydrodynamic (rotating disk electrode (RDE) and rotating ring-disk electrode (RRDE)) conditions. They confirmed the catalytic capability of HCPs and the 2-electron pathway of ORR. The influence of the Lewis acid catalysts on the TBPA morphology and ORR efficiency was observed and validated using scanning electron microscopy (SEM) and textural properties. Clearly, the replacement of $FeCl_3$ by $AlCl_3$ during synthesis results in a different pore size distribution. DFT calculations allowed for the estimation of the probable TBPA structure and its interaction with dioxygen.

Our research demonstrates that HCPs are promising catalysts with potential for further optimization and application in energy conversion technologies.

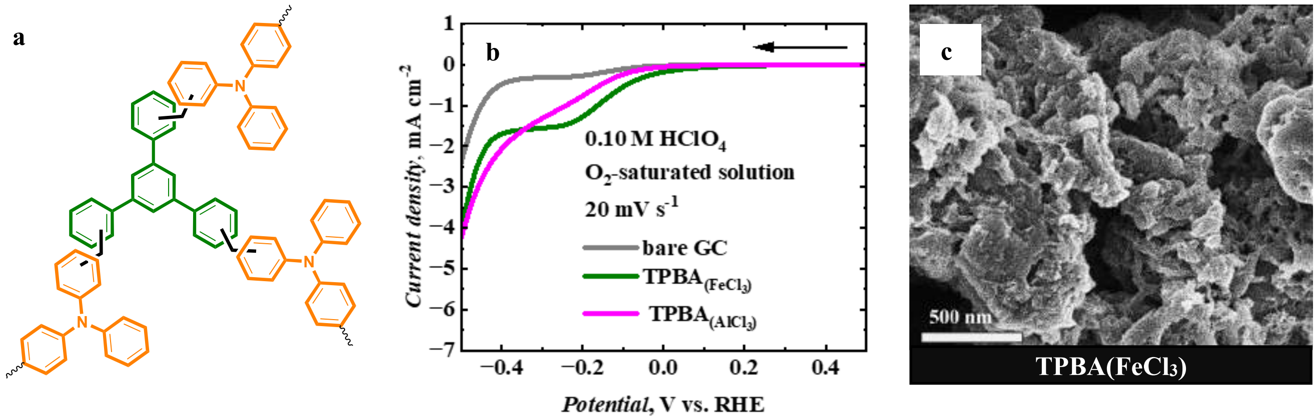

Figure 1: (a) Scheme of TPBA; (b) LSV curves obtained with bare GC electrode and modified with TPBA polymer synthesized with different catalysts of unmodified substrate, TPBA($FeCl_3$), and TPBA($AlCl_3$) on GC; (c) SEM images of TPBA($FeCl_3$).

Acknowledgments

This research was financially supported by the National Science Center (Poland) through Grant Opus 27 Nr DEC-2024/53/B/ST4/01997 (MO).

References

[1] Y. Zhao, et al., *Chem. Rev.* **123** 6257-6358 (2023).
[2] Y. Ke et al. *ChemSusChem*. **18**: e202401952 (2025).
[3] Y. Gu et al. *Adv. Funct. Mater.* **31**: 2008265 (2021).
[4] S. Razzaque et al., *Electrochem. Commun.* **167**, 107800. (2024).

Ergonomic 3D-Printed Electrochemical Platform: Design and Functionalization

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Additive manufacturing (AD) is recognized for its transformative approach to fabricating electrochemical platforms. Its ability to combine structural design flexibility with rapid prototyping offers significant advantages for customizable and accessible sensing technologies. Nevertheless, complete systems in which all components are 3D printed and optimized for electrochemical performance remain relatively underdeveloped.

In this work, we manufactured a fully 3D printed electrochemical sensing platform in which the electrodes and an ergonomic measurement cell were fabricated via fused deposition modeling (FDM) (see Figure 1). Carbon black/poly(lactic acid) (CB/PLA) filament was employed for the electrodes, while the cell body was printed from standard PLA. To improve electrochemical performance, all electrodes (working, counter, and reference) underwent a combined activation procedure involving dichloromethane treatment followed by sequential anodic and cathodic polarization. A tailored surface modification strategy was applied to auxiliary electrodes: the reference electrode was coated with electrodeposited silver and AgCl to stabilize its potential, while the counter electrode was modified with platinum particles. It was found that the surface coverage of the modified electrodes was not uniform and the metallic deposits outprinted the distribution of the electrode catalytic sites. Nevertheless, proposed solutions offered a cost-effective replacement for commercial components. The structure and surface properties of the printed elements were examined using complementary techniques, such as voltammetry, chronoamperometry, electrochemical impedance spectroscopy, scanning electron microscopy, optical profilometry, attenuated total reflectance Fourier–transform infrared spectroscopy, laser–induced breakdown spectroscopy, and wetting analysis. System performance was first verified with ferrocenemethanol as a model redox probe and then applied to the determination of paracetamol. The platform achieved a detection limit of 0.38 µM and a quantification limit of 1.26 µM. Successful analysis of pharmaceutical tablets by the standard addition method demonstrated the applicability of the proposed low-cost and fully 3D-printed device for quantitative measurements in complex matrices [1]

Figure 1: Electrochemical cell with incorporated electrodes, fabricated using FDM.

Acknowledgments

The project was financially supported by the National Science Center (NCN) in Krakow, Poland (Grant no. 2022/47/D/ST5/02523)

References

[1] G. Kowalski, K. Kwaczyński, L. Poltorak, *Talanta* **296**, 128467 (2026).

Day 3

16 November 2025

Fighting antibiotic resistance : Synthetic antibodies target and inhibit efflux pump membrane transporter of ESKAPE bacteria

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Antimicrobial resistance is a major current health challenge. Gram-negative bacteria from the ESKAPE group (*E. faecium, S. aureus, K. pneumoniae, A. baumannii, P. aeruginosa, Enterobacter sp.*) thereby have the highest resistance indices [1]. One of the main mechanisms of resistance is overexpression of efflux pumps, which expel antibiotics from bacteria cells [2]. We report molecularly imprinted polymer (MIP) [3] nanogels obtained by solid-phase synthesis on an immobilized epitope peptide [4] able to target and inhibit an *E. coli* efflux pump. MIPs were characterized for their specificity and affinity through batch binding assays, and using flow cytometry and confocal microscopy on *E. coli* cells. They were able to inhibit the efflux pump resulting in increased antibiotic efficiency.

Acknowledgments

The authors acknowledge financial support from the French National Research Agency ANR (Natural-Arsenal project). K. Haupt acknowledges financial support from Institut Universitaire de France.

References

[1] J. Denissen et al. (2022) Prevalence of ESKAPE pathogens in the environment: Antibiotic resistance status, community-acquired infection and risk to human health. *Int. J. Hyg. Environ. Health* 244, 114006.
[2] X. Wen, A. M. Langevin, M. J. Dunlop. Antibiotic export by efflux pumps affects growth of neighboring bacteria. *Sci. Rep*. 8, 1–9, 2018.
[3] B. Tse Sum Bui, T. Auroy, K. Haupt (2022) Fighting Antibiotic-Resistant Bacteria: Promising Strategies Orchestrated by Molecularly Imprinted Polymers. *Angew. Chem. Int. Ed.* 61, e202106493.
[4] B. Tse Sum Bui, A. Mier, K. Haupt (2023) Molecularly imprinted polymers as synthetic antibodies for protein recognition: The next generation. *Small* 19, 2206453.

Controlled Radical Polymerization to Design Molecularly Imprinted Polymers: Thin Films and Nanoparticles

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Free radical polymerization (FRP) still is the most popular way when synthesizing molecularly imprinted polymers [1]. Though rather straightforward in principle, it has its limitations especially regarding batch-to-batch reproducibility [2]. If electropolymerization is not an option, one aims at replacing the free radical process with controlled radical polymerization, for instance reversible-addition-fragmentation chain-transfer (RAFT) polymerization, where adding a so-called RAFT agent slows down the overall polymerization process and, in turn, yields more homogeneous chain length distributions. This has already led to some MIP applications of the process [3]. For chemical sensing, the approach leads to very apprciable results both when aiming at MIP thin films and synthesizing MIP nanoparticles through solid phase synthesis.

In contrast to FRP, RAFT polymerization easily allows for generating polymer thin films directly in situ on the surfaces of sensor devices. When immobilizing a raft agent on the gold electrodes of a quartz crystal microbalance (QCM) and choosing the proper linker for that purpose, it is possible to control the layer height of acrylate-based films by controlling the polymerization time (see Figure 1). We could demonstrate that one can use metal and oxide nanoparticles as templates to generate sensor layers that selectively re-incorporate their respective target particle. The mass-sensitive QCM signal in such cases depends on all three fundamental particle properties: diameter, density (i.e.: composition of the core), and stabilizer shell. The latter plays the largest role for in determining the interactions between the sensor layer and the respective analyte particle. Size exclusion, also works very well (include data). Of course, when assessing the absolute sensor responses, one needs to consider the different masses of different particle types.

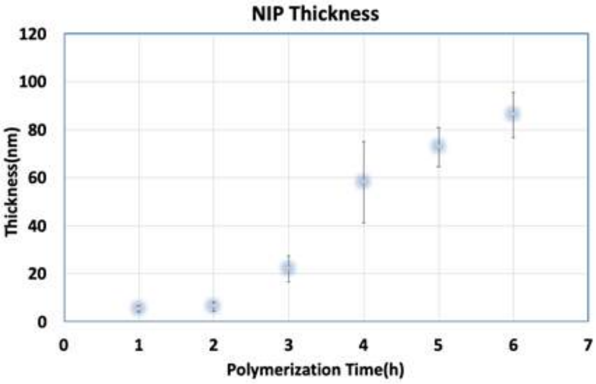

Figure 1: RAFT polymer layer height as a function of polymerization time

RAFT also improves MIP nanoparticles (nanoMIPs) that result from solid phase synthesis [4] and represent antibody mimics, e.g. targeting insulin. Combining solid-phase imprinting with RAFT leads to very homogenous nanoparticle distributions: The resulting nanoMIPs are on average 30±0.07 nm in diameter, whereas FRP leads to 44±14 nm. Particles are not only smaller, but also lead to larger sensor effects: compared to FRP, the specific response of RAFT-based nanoMIP towards insulin is about 1.5 times higher, whcih further corroborates how feasible the approach is.

References

[1] B.T.S. Bui and K. Haupt, *Analytical and Bioanalytical Chemistry* **398**, 2481 (2010).
[2] C. Unger and P.A. Lieberzeit, *Reactive and Functional Polymers* **161**, 104855 (2021).
[3] E. Parula, O. Soppera, K. Haupt, C. Gonzato, *ACS Applied Polymer Materials* **10**, 4769 (2021)
[4] F. Canfarotta, A. Poma, A. Guerreiro, S. Piletsky, *Nature Protocols* **11**, 445 (2017).

Biomimetic sensors for medical diagnostics of lung diseases and intestinal disorders

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In this presentation, we focus on two medical applications of molecularly imprinted polymers (MIPs) that are serving as selective receptors for molecular biomarkers related to lung diseases and intestinal disorders. While these two themes appear only loosely related, they demonstrate nicely that electro-polymerization is a highly flexible approach for MIP synthesis. Using task-specific electrode structures, MIP-type receptors can fit diverse purposes, allowing also analytical measurements in complex matrices which are hard to study with certain natural receptors.

Within the Remedia project [1], we have developed an impedimetric sensor system for the quantitative analysis of molecular biomarkers in exhaled breath condensate (EBC). EBC samples are obtained non-invasively by exhaling through a condenser unit which samples typically 1.5 mL of EBC in only 5 minutes of tidal breathing [2]. The selected biomarkers for cystic-fibrosis patients are hexanal and 3-nitrotyrosine (3-NT); for patients with chronic obstructive pulmonary disease (COPD), the corresponding biomarker is the protein neutrophil elastase (NE). To measure these three biomarkers in parallel, we have developed electrode arrays with four sensing spots, consisting each of a concentric electrode couple (disk and ring). The sensor spots were functionalized with a sol-gel MIP for hexanal and an electro-polymerized polypyrrole-polydopamine MIP in case of 3-NT. This copolymer forms already at low voltages so that the integrity of the 3-NT template molecules is not affected. The sensor spot for detecting NE was functionalized with an NE-binding aptamer and the fourth spot was coated with non-imprinted copolymer to quantify non-specific adsorption of non-target molecules. On each sensor spot, the receptor layer was deposited on both electrodes (disk and ring) so that there was no formal distinction between working- and counter electrode. By impedimetric detection, we reached for each marker (hexanal, 3-NT, NE) detection limits below 100 pM, i.e. below the physiological range, and upper detection limits exceeding pathophysiological concentrations. Concluding this part, we will present data on EBC samples from healthy volunteers and COPD patients who underwent a medical study that followed the evolution of biomarker concentrations over the course of twelve days.

The second part addresses the trajectory towards a catheter-based impedimetric sensor that will eventually serve as a tool in the diagnosis of the irritable bowel syndrome (IBS) and the follow-up of therapies. The biomarker here is histamine as an indicator for food intolerances and chronic inflammations, which are possible causes of IBS. As a considerable complication, the histamine needs to be quantified inside the duodenum, which can best be reached with nasogastric catheter. This requires however a small size of the sensor probe, and the best solution are gold microwires, coated with polypyrrole MIPs; the current catheter design has six such microelectrodes in the tip: One couple serves for histamine detection, a second couple corrects the data for electrode fouling, and a third couple may serve for detecting an additional biomarker. So far, we could show that the MIPs are insensitive to competitor molecules (e.g. histidine), that their binding efficiency is widely independent on pH, and that the prototype catheter can measure histamine levels up to ca. 1 µM in real intestinal fluid [3]. The catheter sensor is currently further tested and optimized to fulfill all regulatory requirements and first studies on healthy volunteers, regarding tolerability of the procedure, will follow shortly. Intestinal biosensing comes with considerable challenges; however, the final application is expectedly less invasive for patients than the currently used procedure of taking biopsies from the intestinal mucosa.

Acknowledgments

The work on lung biomarkers was funded by the European Union through the H2020 project REMEDIA (Impact of Exposome on the Course of Lung Diseases), grant no. 874753. Regarding the catheter-based sensor, we acknowledge funding by the Research Foundation Flanders FWO for the project "Catheter-based sensors for the intestinal detection of molecular biomarkers in the context of functional bowel disorders", grant G0A6821N.

References

[1] M. Benjdir, É. Audureau, A. Beresniak, P. Coll, R. Epaud *et al., Environmental Epidemiology* **5** (4), e165 (2021).
[2] M. Khorshid, S. Bakhshi Sichani, D. L. Barbosa Estrada *et al.*, *Advanced Sensor Research* **3** (7) 2400020 (2024).
[3] G. Wackers, P. Cornelis, T. Putzeys, M. Peeters, J. Tack, F. Troost, T. Doll *et al.*, *ACS Sensors* **6** (1), 100-110 (2020).

Molecularly Imprinted Polymer-Decorated Ruthenium Oxide Electrode for Rapid Electrochemical Detection of Clinically Relevant Proteins

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The use of molecularly imprinted polymers (MIPs) as biomimetic receptors in sensing devices presents a promising strategy to overcome the limitations of biological recognition elements, such as instability under thermal and pH variations and limited shelf life. Molecular imprinting creates specific cavities within a polymeric network that mimic the size, conformation, and chemical properties of target molecules, enabling high specificity and efficient binding. Integrating MIPs with electrochemical transducers offers a powerful approach for developing portable sensors with real-time monitoring capabilities, user-friendliness, low cost, and high sensitivity [1]. A direct sensing strategy that eliminates the need for external redox probes further enhances sensor performance by better mimicking complex sample environments and reducing interpretation errors.

Ruthenium oxide (RuO_2) electrodes, known for their excellent electrochemical properties, have received limited attention in molecular imprinting applications. Here I present a study conducted by my research group demonstrating the synergy between a MIP layer and a RuO_2 electrode in an electrochemical sensor designed for the direct detection of disease biomarkers in biological samples. In this sensor configuration, RuO_2 functions both as the electrode transducer and as an integrated redox probe, enabling signal measurement directly in the analyte solution [2,3]. Protein biomarkers, including brain-derived neurotrophic factor (BDNF) and growth factor X, were selected as target analytes. Following optimization of template elution, rebinding time, and MIP layer thickness, the sensors exhibited effective performance within relevant analytical ranges in serum samples. Furthermore, the sensors demonstrated high reusability, maintaining consistent performance across multiple rebinding–regeneration cycles.

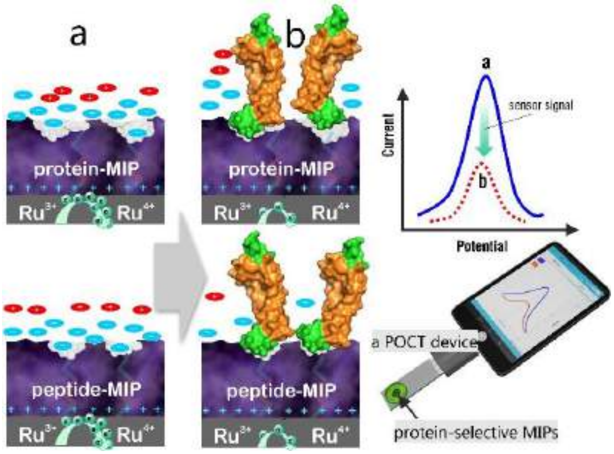

Figure 1: Schematic representation of the principle of protein detection using a MIP-decorated ruthenium oxide electrode.

Acknowledgments

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References

[1] A.G. Ayankojo, J. Reut, V. Syritski, *Biosensors* **14** (2024) 71. https://doi.org/10.3390/bios14020071.
[2] V.B. Chau Nguyen, J. Reut, A.G. Ayankojo, V. Syritski, *Talanta* **287** (2025) 127580. https://doi.org/10.1016/j.talanta.2025.127580.
[3] A.G. Ayankojo, J. Reut, R. Boroznjak, V. Syritski, *Sensors and Actuators B: Chemical* **429** (2025) 137301. https://doi.org/10.1016/j.snb.2025.137301.

Designing Gold Nanocluster Interfaces for Tailored Electrocatalytic Outcomes

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Atomically precise metal nanoclusters (NCs), particularly $Au_{25}(SR)_{18}$ (AuNCs), are highly valuable in nanotechnology due to their unique quantum-size-related properties, defined stoichiometry, and discrete energy levels. This presentation explores the fundamental properties and diverse electrocatalytic and bio-hybrid applications of gold and gold-platinum clusters, emphasizing the crucial role of precise structural control and spatial organization on electrode surfaces.

We demonstrate that controlling the organization of $Au_{25}(SR)_{18}$ clusters is paramount for optimizing their performance in the electrochemical CO_2 reduction reaction. Utilizing the Langmuir–Schaefer (L-S) method enables the fabrication of well-ordered two-dimensional (2D) assemblies on highly oriented pyrolytic graphite (HOPG) electrodes. We found that deposition at low surface pressures (10 mN/m) maximizes the catalytic efficiency, as proper dispersion minimizes aggregation, which otherwise buries active sites and decreases normalized activity. The inherent low activity of gold clusters toward the competing hydrogen evolution reaction (HER) facilitates high selectivity for CO_2 conversion.

Beyond surface catalysis, AuNCs are exceptional electron relays in bio-hybrid systems. Introducing neutral $Au_{25}(SR)_{18}$ clusters into the outer leaflet of an insulating lipid bilayer (DPPTE/DOPC) on a gold electrode dramatically increases the electron transfer (ET) rate constant. This effect, observed even at concentrations as low as 0.01 mol%, proves that AuNCs function as "remote gold electrodes," restoring the reversibility of fast electrochemical probes across the barrier layer [1].

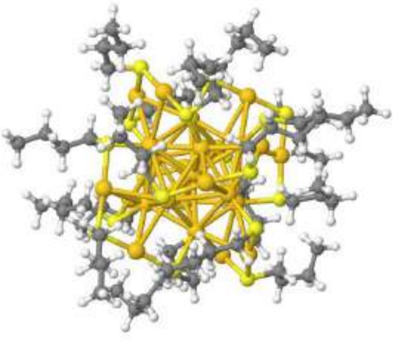

Figure 1: The structure of $Au_{25}(SC_4H_9)_{18}$.

Furthermore, the structural modification of the core, specifically doping with platinum to form $Au_{24}Pt(SR)_{18}$ clusters, yields unique electrocatalytic properties. Thes clusters exhibit a strong electrocatalytic effect for the conversion (oxidation and reduction) of hydrogen peroxide (H_2O_2). This enhanced activity, attributed to the interaction between the central Pt atom and the delocalized electron system of the gold core, permits the quantitative determination of in H_2O_2 aqueous solutions with high accuracy, suggesting potential as single-use sensors for biological analysis [2].

These studies confirm that the functionality of gold nanoclusters and their doped variants is highly tunable through precise control of both their composition and, crucially, their spatial organization at the interface.

Acknowledgments

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References

[1] A. Wieckowska, E. Jablonowska, M. Jaskolowski, R. Bilewicz, *J. Electroanal. Chem.* **932,** 117261 (2023).
[2] K. Zdunek, A. Więckowska, *J. Electroanal. Chem.* **984,** 119009 (2025).

Smart electrode surfaces for sensing contaminants of environmental concern

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Preventive monitoring of chemical pollution is a challenge, since methodologies and mechanisms for real-time analysis and fast screening of potentially contaminated sites are very expensive and cumbersome. Currently, real-time monitoring of chemicals (organics, inorganic substances, heavy metals, oil) in the water matrices are mostly done in lab settings and/or using time and money consuming techniques. In this context, electrochemical (bio)sensors are promising systems when on-site analysis is needed for a rapid decision-making. Indeed, main advantages in using electrochemical systems consist of simplicity of use, portability and low-cost of the instrumentation, and the ability to limit the use of tedious sample pre-treatment procedures, especially if coupled to lab-on-a-chip platforms. However, electrochemical sensors can also face limitations: presence of electrochemically active interferences in the sample, weak long-term stability, and troublesome electron-transfer pathways.

The development of innovative smart electrode surfaces, decorated with natural or biomimetic architectures, is an interesting research topic for next-generation electrochemical sensing, to face the complex chemical-physical behavior of novel hazardous molecules, improve electron transfer and minimize fouling effects.

In this perspective, different approaches on electrode surface modifications and challenging strategies to develop innovative electrochemical (bio)sensors will be here illustrated. In-depth studies of the electron transfer mechanisms and electrochemical kinetics related to the recognition reaction were carried out to magnify the analytical performance of the developed (bio)sensors.

Acknowledgments

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References

[1] Quadrini L., Orlandini S., Laschi S., Ciccone C., Catelani F., Palchetti I., Talanta, 2025, 289, 12775
[2] Laschi S., Sfragano P.S., Tadini-Buoninsegni F., Guigues N., Palchetti I., Analyst, 2024, 149(16), 4239–4249

Spark Discharge-Based Activation and Nanomaterial Modification of Electrochemical Sensors

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Simultaneous electrode activation and nanomaterial modification can be achieved using a spark discharge technique. This method involves bringing a source electrode made of a conductive material (e.g., metal or carbon) into close proximity with the target electrode and applying a high DC voltage (800–1200 V) between them. The applied voltage causes dielectric breakdown of the surrounding atmosphere (typically air), resulting in a spark that vaporizes small amounts of the electrode materials into micro-plasma. This micro-plasma, composed of vaporized and potentially oxidized species (via reaction with atmospheric oxygen), rapidly cools to form nanoparticles that deposit onto the electrode surface. This spark discharge modification process enables the fabrication of highly sensitive electrochemical sensors and is especially suitable for single-use, mass-producible electrode platforms such as screen-printed electrodes (SPEs), carbon fiber microelectrodes (CFMEs), and 3D-printed electrodes. To date, we have successfully demonstrated the analytical utility of SPEs modified with Bi [1, 2], Cu / Ni / CuNi alloys [3], Sn [4], Au [5], carbon [6] etc., and CFME surfaces with Pt [7] and Ni [8]. Pilot studies also show effective activation of 3D-printed electrodes fabricated from conductive carbon-based filaments [9, 10]. As highlighted in these studies, the method is extremely simple (no chemical solutions are required), environmentally friendly (involving no toxic chemicals and producing only trace amounts of nanomaterials), and fast (from ten seconds to several minutes). Technical implementations include manual sparking, 3D positioner-assisted "spot" and "linear" modes, and energy-controlled discharge procedures.

References

[1] [1]D. Riman, A. Avgeropoulos, J. Hrbac, M.I. Prodromidis, *Electrochim Acta* **165**, 410 (2015).
[2] D. Riman, D. Jirovsky, J. Hrbac, M.I. Prodromidis, *Electrochem Commun* **50**, 20 (2015).
[3] D. Riman, K. Spyrou, A.E. Karantzalis, J. Hrbac, M.I. Prodromidis, *Talanta* **165**, 466 (2017).
[4] M.G. Trachioti, J. Hrbac, M.I. Prodromidis, *Sensor Actuat B-Chem* **260**, 1076, 83 (2018).
[5] M.G. Trachioti, E.I. Tzianni, D. Riman, J. Jurmanova, M.I. Prodromidis, J. Hrbac, *Electrochim Acta* **304**, 292 (2019).
[6] M.G. Trachioti, D. Hemzal, J. Hrbac, M.I. Prodromidis, *Sensor Actuat B-Chem* 310, 127871 (2020).
[7] Z. Bartosova, D. Riman, V. Halouzka, J. Vostalova, V. Simanek, J. Hrbac, et al., *Anal Chim Acta* **935**, 82 (2016).
[8] Z. Belbasi, J. Petr, J. Sevcik, D. Jirovsky, J. Hrbac, *Acs Omega* **9,** 5038 (2024).
[9] J.F. Hernandez-Rodriguez, M.G. Trachioti, J. Hrbac, D. Rojas, A. Escarpa, M.I. Prodromidis, Spark-Discharge-Activated 3D-Printed Electrochemical Sensors, *Anal Chem* **96,** 10127 (2024).
[10] M. Mertiri, J. Hrbac, M. Prodromidis, A. Economou, C. Kokkinos, *Appl Mater Today* **39**, 102289 (2024).

Molecularly imprinted polymer (MIP) nanogels for specific capture of Vascular Endothelial Growth Factor

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Vascular Endothelial Growth Factor or VEGF is a secreted protein which, upon binding to its designated receptor VEGFR, plays an important role to form new blood vessels during embryonic development, wound healing, and vascular permeability. VEGF is found to be a key mediator of tumor-associated neo-angiogenesis and progression. Angiogenesis is regulated by pro- and anti- angiogenic modulators. During tumor progression, the angiogenesis process is turned on by upregulation of pro-angiogenic factors, such as VEGF which is indeed found overexpressed in most human cancers. This process of new blood vessel proliferation is fundamental for tumor growth, invasion, and metastasis formation since these tumoral mass growth is limited by nutrient requests [1]. Indeed, the formation of new blood vessels that bring oxygen and nutrients inside the new tumor results in sustaining the progression and growth of tumoral mass. VEGF is therefore an important drug target. The purpose of this project is to rely on molecular imprinting technology generate synthetic antibodies (molecularly imprinted polymers, MIPs) able to bind and sequester VEGF and thus to impar its associated angiogenic pathway. MIPs are 3D polymer networks with cavities generated by the use of molecular templates. The cavities are complementary in terms of size, shape, and position of chemical groups to the template molecule [2]. In this project, MIPs are synthetized as polyacrylamide nanogels by relying on solid-phase synthesis.[3] Physicochemical characterization of polyacrylamide nanogels was conducted, as well as the assessment of the affinity and selectivity properties of MIPs with respect to the selected target, VEGF.

Acknowledgments

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References

[1] M. Kowanetz, N. Ferrara, Clinical Cancer Research 12, 5018-5022 (2006).

[2] K. Haupt, P.X. Medina Rangel, B. Tse Sum Bui, Chemical Reviews 120, 9554-9582 (2020).

[3] S. Ambrosini, S. Beyazit, K. Haupt, B. Tse Sum Bui, Chemical Communications 49, 6746-6748 (2013).

Molecularly Imprinted Hydrogels for Protein Recognition

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Molecular imprinted polymers (MIPs) are biomimetic receptors synthesized from the co-polymerization of a functional monomer and cross-linker around the template.[1] MIPs have been studied for the purification and recognition of proteins, however, designing and synthesizing MIPs with high binding and specificity for macromolecules is still challenging.[2] In this study, we take hemoglobin (Hb) as a model protein, a hemoprotein contained in red blood cells responsible for oxygen transport.[3]

Here we design and optimize a method for the preparation of MIPs in the form of molecularly imprinted hydrogel (MIH) for Hb relying on bulk protein imprinting. Morphological analysis reveals the MIH having a more structured porous network compared to a more uniform morphology for the corresponding non-imprinted hydrogel (NIH). The adsorption ability and selectivity were assessed by measuring the absorbance after incubating the MIH in Hb and in a mixture containing Hb and other major protein competitors. Preliminary results show that high concentrations of other proteins did not interfere with the absorbance values presenting proof that the MIH has good selectivity towards Hb.

Acknowledgments

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References

[1] Tse Sum Bui, B., Mier, A., & Haupt, K. *Small*, **19(13)**, 2206453 (2023).
[2] K. Haupt, P. X. Medina Rangel, T. B. Bui, *Chemical Reviews* **120**, 9554-9582 (2020).
[3] K. Wang, X. Bian, M. Zheng, P. Liu, L. Lin, X. Tan, *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* **263**, 120-138 (2021).

Electroassisted in situ metalation of multicopper oxidases

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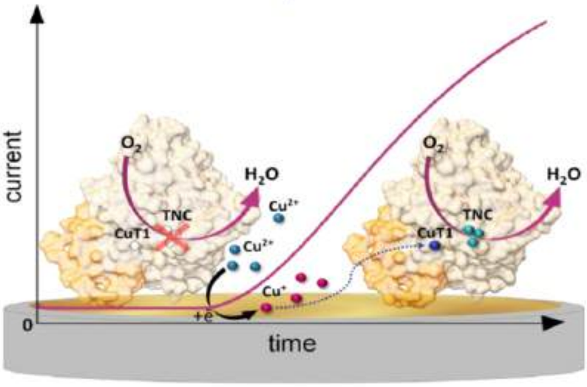
The family of multicopper oxidases (MCOs) encompasses a large number of enzymes, including well known laccases or bilirubin oxidases. Four copper sites form their active center: a Cu-T1, where substrates oxidize and a trinuclear copper cluster, where bound O_2 is reduced to water. Copper efflux oxidases (CueOs) belong to the MCO family [1]. A methionine-rich (Met-rich) domain that covers the CuT1 site, is one characteristic of CueOs. We recently studied its impact on cuprous oxidase activity of Escherichia coli CueO, and demonstrated that the Met-rich domain acts as a facilitator of Cu^+ recruitment from the strongly copper chelated forms [2][3]. The impact of the Met-rich domain on O_2 reduction was also studied [4]. It was demonstrated that the bulky Met-rich domain decreases the interfacial electron transfer rate. The electrochemical experiments also highlighted a continuous increase in the catalytic signal with time.

In this work, we will discuss the origin of this increase in catalytic current. We will demonstrate that this activation process is link to full metalation of the protein immobilized on the electrode surface by electrogenerated $Cu^{+.}$ Thanks to in silico analysis, we will propose that a conserved histidine residue ligand of one copper binding site close to the Cu-T3 as being pivotal in the in vivo CueO metalation. Moreover, we will discuss how far this activation process can be extended to other MCOs than CueOs. This electrochemically induced CueO metalation paves the way for the large-scale production of MCOs followed by in vitro maturation, as high copper concentrations are toxic in vivo.



References

[1] I. Mazurenko et al. Electrochemistry of copper efflux oxidase-like multicopper oxidases involved in copper homeostasis. Curr. Op. Electrochem. 2022.
[2] U. Contaldo et al. Methionine-rich domains emerge as facilitators of copper recruitment in detoxification systems. PNAS 2024.
[3] U. Contaldo et al. How the larger methionine-rich domain of CueO from Hafnia alvei enhances cuprous oxidation. JACS Au 2025.
[4] V. Saska et al. Tuning O2 enzymatic reduction: roles of methionine-rich domains and electrochemical metalation of active centers, Bioelectrochem. 2025

Fully Inkjet-Printed Electrochemical Sensors for the Detection of Living Bacteria

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Electroanalytical sensors – amperometric, voltammetric, and impedimetric – are promising diagnostic tools for the detection of bacterial cells and antimicrobial resistance (AMR). Rather than targeting DNA, RNA, or lysed-cell biomarkers, we follow the general approach of detecting living bacterial cells using metabolic redox markers. These markers, which act as alternative final electron acceptors in the bacterial respiratory chain, can be electrochemically monitored to provide rapid, quantitative readouts. Adding antibiotics to the test enables concurrent antimicrobial susceptibility testing (AST).

However, in diagnostically relevant fluids like blood, low bacterial counts typically require extended bacterial culture periods. To overcome this, we previously demonstrated that antibody-coated paramagnetic beads can locally enrich bacteria at the sensor surface, enhancing sensitivity and reducing detection time [1]. Still, for real-world point-of-care (POC) use, systems must be simplified to minimize manual handling while upgrading performance.

Herein, we shall present fully inkjet-printed, miniaturized electrochemical platforms integrating bacterial capture, detection, and culture on a single chip. We will present our portfolio of inkjet-printed working electrode materials, functionalized and non-functionalized. All sensor layers are fully fabricated using drop-on-demand inkjet printing enabling the production of miniaturized sensors with minimal material waste and often combined with irradiation sources for simultaneous photochemical syntheses, i.e., Print-Light-Synthesis. We shall show in more detail for instance the thermal modification of the surfaces of graphene electrodes to significantly increase the sensitivity to bacterial redox markers [2]. Furthermore, porous, photopolymerized 3D matrices with integrated bacterial capture receptors are printed near the working electrode surface. Finally, we demonstrate the electrochemical detection of *Escherichia coli* and the results are confronted with those obtained with conventional bacteria detection.

Acknowledgments

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References

[1] Y. Zhu, M. Jović, A. Lesch, L. T. Lovey, M. Prudent, H. Pick, H. H. Girault, *Angew. Chem. Int. Ed*. **2018**, *57*, 14942-14946.
[2] F. Weyand, S. Gianvittorio, F. Longo, J. Wang, A. Lesch, *Electrochim. Acta* **2025**, *526,* 146174.

Surface-modified carbon nanotubes electrocatalysts for enhanced Lithium-Sulfur Battery performance

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Lithium-sulfur (Li-S) batteries, with a high theoretical energy density of 2600 Wh kg^{-1}, are promising for future energy storage [1]. However, the multiphase sulfur redox reaction remains challenging [2]. Herein, an organic framework-based electrocatalytic polymer composite, incorporating zinc(II) 5,10,15,20-tetrakis-(2,2'-bithien-5-yl)porphyrin (Zn-Por) into polybisthiophene (PBTH) linkers on carbon nanotube (CNT) surfaces, enhances redox kinetics. ZnPor-PBTH/CNTs was characterized by SEM, EDAX, XPS, and FTIR. In Li-S coin cells, electrochemical studies (CV, EIS, GCPL) showed a discharge capacity of 1144.14 mAh g^{-1} at C/20, low resistance (20 Ω), and stable cycling up to 50 cycles at C/10 with reduced polarization and suppressed polysulfide shuttling.

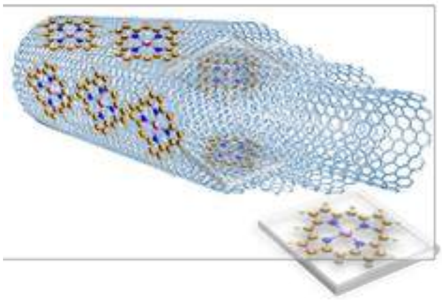

Figure 1. Carbon nanotubes functionalized with Zn-Por sites linked by PBTH.

Acknowledgement

The financial support from the National Science Centre, Poland in the form of grant OPUS 24 Project No. 202247BST503077 is acknowledged.

References

[1] B.Q. Li, H.J. Peng, X. Chen, S.Y. Zhang, J. Xie, C.X. Zhao, and Q. Zhang, *CCS Chem*istry **1**, 128 (2019).
[2] C.X. Zhao, X.Y. Li, M. Zhao, Z.X. Chen, Y.W. Song, W.J. Chen, J.N. Liu, B. Wang, X.Q. Zhang, C.M. Chen, B.Q. Li, *JACS* **143**, 865 (2021).

Oxygen reduction reaction on the “green” silver nanomaterial-coated electrodes

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In this contribution, we focused on application and understanding the activity of silver nanomaterials synthesized via a simple, one-pot eco-friendly process using brewery wastes, as catalysts of oxygen reduction reaction (ORR). The brewery wastes used in our work encompassed wort precipitate (BW5), brewer’s spent yeast (BW7), and waste left after filtration (BW9).

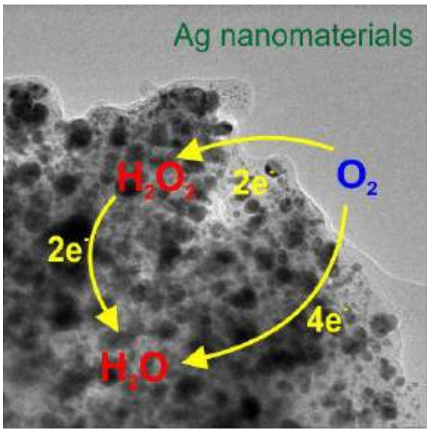

Figure 1: Oxygen reduction reaction on silver nanomaterials synthesized with use of brewer’s spent yeast.

Oxygen reduction reaction (ORR) is a significant reaction in biological processes, e.g., in respiration. It also gained importance in the field of energy conversion with development of fuel cells [1]. This reaction proceeds via two main routes in aqueous solutions (*i*) direct four-electron reduction of dioxygen to water or (*ii*) two-step process with two-electron reduction observed at each step. This leads to formation of hydrogen peroxide intermediate. The H_2O oxidation to O_2 and the O_2 reduction to H_2O require very high overpotentials [2]. The best known catalyst of the ORR is platinum. Unfortunately, this metal is rare and expensive. The search for alternative catalysts has led to the devising of several materials that successfully operate as commercial cathodes. However, designing alternative cathode materials is still challenging. To this end, silver nanomaterials gained attention as catalysts for ORR [3], as they are much cheaper than well-known catalytic metals, including platinum, palladium, and gold. Furthermore, the Ag nanomaterials were shown to be attractive alternatives for effective H_2O_2 production, which is important e.g. for wastewater treatment, decomposition of organic materials, textile and paper bleaching, and synthesis reactions.

Herein, we describe electrochemical studies of a range of silver nanomaterials as catalysts for ORR. The materials synthesized with help of the brewery wastes were composed of Ag, AgCl and Ag_3PO_4 in various proportions depending on synthesis parameters. They formed agglomerated nanocomposites containing nanoparticles (NPs) with sizes 2 - 50 nm.. Voltammetric and rotating ring-disk experiments have shown, that these nanocomposites predominantly facilitated the two-electron ORR, producing H_2O_2. The nanocomposites rich in Ag_3PO_4 having a thin organic coating promoted faster transfer of electrons and improved oxygen adsorption. Furthemore, irradiating the materials with γ-rays influenced importantly the catalytic effectiveness of nanomaterials prepared using BW7 and BW9.

Acknowledgments

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References

[1] C. Song, J. Zhang, Electrocatalytic oxygen reduction reaction, in: J. Zhang (Ed.) PEM fuel cell electrocatalysts and catalyst layers: Fundamentals and applications, Springer, London, **2008**, pp. 89-134.
[2] H. Ooka, J. Huang, K.S. Exner, *Front. Energy Res*., **9,** 654460 (2021).
[3] R. Guo, X. Lai, J. Huang, X. Du, Y. Yan, Y. Sun, G. Zou, J. Xiong*, ChemElectroChem*., **5,** 3822 (2018).

Day 4

17 November 2025

Profiling the pharmacology of GPCRs using time-resolved impedance monitoring of mammalian cells immobilized on thin-film electrodes

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G-protein coupled receptors (GPCRs) are among the most heavily addressed drug targets. About 40 % of all prescription pharmaceuticals target GPCRs. Screening for new agonists or antagonists has been largely based on optical endpoint assays that often require genetic engineering and do not reveal the time course of the cell response. Lately, non-invasive impedance analysis of cells directly grown on thin film electrodes has attracted considerable attention in the field as it allows monitoring the response of target cells with endogenous receptor expression in real time and label-free. The electrodes are integrated into regular cell culture dishes up to 96well multi-well plates. The talk will introduce the measurement principle and demonstrate impedance-based profiling of GPCR pharmacology.

Exploring the electroanalytical performance of tailored 3D-printable composites in (bio)sensing

Mateusz Cieślik[1], Gilvana P. Siqueira[1,2] Agata Rodak[1], Krzysztof Formela[1], Angelika Łepek[1], Robert Bogdanowicz[1], Mattia Pierpaoli[1], Rodrigo A. A. Muñoz[2], Jacek Ryl[1,†]

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3D printing thermoplastic composites and other rapid manufacturing technologies has gained significant attention for various electrochemical applications, particularly chemical analysis. This is primarily due to low material cost and high accessibility, printout customizability and capability to fabricate on demand, alongside sustainability originating from substrates biodegradability.

Different routes may boost the electrochemical performance of 3D-printed electrodes; the three most notable are 1) heteroatom dopants, 2) post-printing surface treatments referred to as activation and 3) surface engineering by catalytic nanoparticles and thin films. The talk will present our group's recent findings in both of these areas. Recently, new 3D-printable composites have been designed and studied, whose catalytic performance originates from the presence of diamondised nanocarbons as additives. As a result, the detection limits of selected anti-inflammatory drugs, antibiotics, neurotransmitters and many more may decrease significantly. The above study serves as one of many proof-of-concept devices for low-cost, on-demand, and fully customisable 3D-printed cells for rapid environmental screening with high sensitivity.

Moreover, such modified electrodes can accommodate various bioreceptors or respond to external stimuli, which is a relatively facile strategy for biosensor manufacturing. Combining additive-manufacturable microelectrode arrays with complex, machine-learning-aided impedimetric analyses paves the way for a new family of (bio)sensing systems with enhanced sensing capabilities.

Acknowledgments

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Edible and Flexible Biosensors: A Frontier in Personalized and Sustainable Health Monitoring

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Edible and flexible biosensors represent a transformative class of devices for real-time, non-invasive monitoring of biochemical markers, enabling personalized diagnostics, localized therapy, and sustainable healthcare solutions [1,2]. These systems integrate biocompatible, ingestible, and conformable materials with functional elements such as enzymes, nanoparticles, and hydrogels [3,4]. Key challenges include maintaining stability and performance under physiological stress while ensuring safety and regulatory compliance. Recent advances in soft bioelectronics and smart materials are driving the development of multifunctional platforms for integrated sensing, therapy, and data transmission [5].

Acknowledgment

We acknowledge financial support under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.1, Call for tender No. 1409 published on 14.9.2022 by the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU– Project "Title gReen analytical methods for PAHs detection in EVOO: from lABoratory to smart LabEl" (RELIABLE) – CUP H53D23007750001- Grant Assignment Decree No. 1386 adopted on 01/09/2023 by the Italian Ministry of Ministry of University and Research (MUR).

References

[1] Marchianò, V., Tricase, A., Cimino, A., Cassano, B., Catacchio, M., Macchia, E., ... & Bollella, P. (2025). Inside out: Exploring edible biocatalytic biosensors for health monitoring. Bioelectrochemistry, 161, 108830.
[2] Wu, Y., Ye, D., Shan, Y., He, S., Su, Z., Liang, J., ... & Jiang, H. (2020). Edible and nutritive electronics: Materials, fabrications, components, and applications. Advanced Materials Technologies, 5(10), 2000100.
[3] Xu, Y., Hu, J., Hu, J., Cheng, Y., Chen, X., Gu, Z., & Li, Y. (2023). Bioinspired polydopamine hydrogels: Strategies and applications. *Progress in Polymer Science*, *146*, 101740.
[4] Liu, L., Liu, Y., Tang, R., Ai, J., Ma, Y., Chen, Y., & Feng, X. (2022). Stable and low-resistance polydopamine methacrylamide-polyacrylamide hydrogel for brain-computer interface. *Science China Materials*, *65*(8), 2298-2308.
[5] Perkucin, I., Lau, K. S., Morshead, C. M., & Naguib, H. E. (2022). Bio-inspired conductive adhesive based on calcium-free alginate hydrogels for bioelectronic interfaces. *Biomedical Materials*, *18*(1), 015020.

Low-cost sensors for detecting GHB and its derivatives

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Date-rape drugs can make individuals vulnerable to theft and sexual assault, including rape. These substances are colourless, tasteless and odourless, and their short half-life in the victim's body makes it extremely challenging to provide evidence of their use. The most effective way to address these crimes is to empower potential victims with the means to detect the presence of such drugs using a specialised sensor. However, due to the variety of molecules involved, as well as the wide range of sample types in which these drugs can be administered, a comprehensive solution has not yet been developed.

This study presents low-cost electrochemical sensors based on copper, nickel and platinum for the detection of gamma-hydroxybutyrate (GHB) and its derivatives, such as butane-1,4-diol. Sample results are presented in Figure 1. The sensors were tested in model buffer samples and real samples of beer, vodka, Coke, energy drink and milk. We are also exploring the possibility of using several sensors coupled with multivariate data analysis to separate the signals of different compounds and account for background interference.

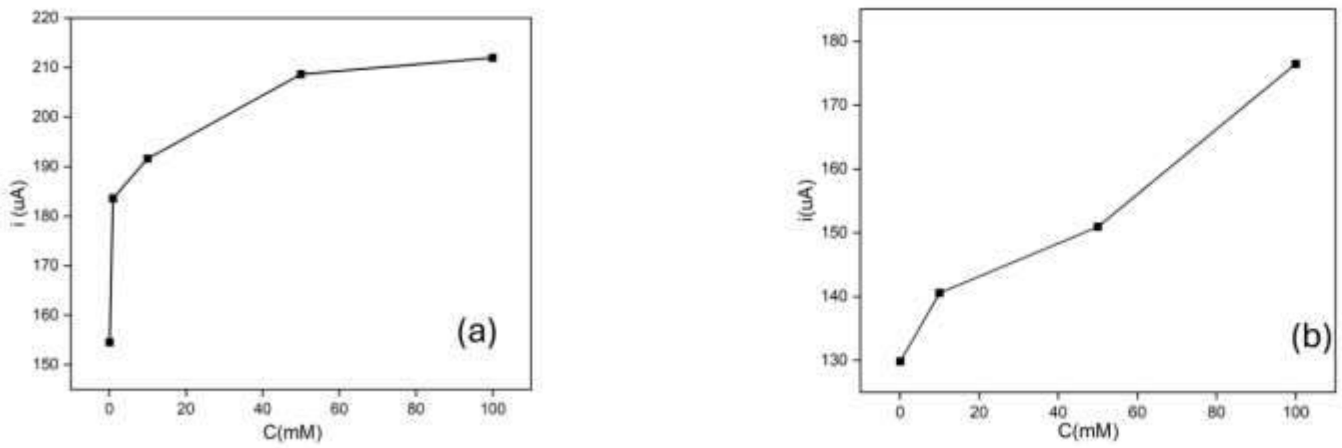

Figure 1: Current variation with increased amount of butane-1,4-diol (0.1, 1, 10, 50,100)mM in beer at a fixed potential of 0,7 V on (a) copper electrode and (b) nickel electrodes

Acknowledgments

The authors would like to thank the National Science Centre for funding the project under the NCN SONATA BIS 2023/50/E/ST4/00639 grant.

Mechanistic Insights into the Piezoelectric effect in Ionic Liquids. Implications for Sensing Applications

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The piezoelectric effect is well established in solid state materials that possess a center of inversion, and in a variety of composite materials. The piezoelectric effect has found extremely broad utility in sensing, with the ubiquitous deployment of accelerometers and as actuators in STM and AFM instruments, for example. Until our recent report,[1] the piezoelectric effect was not known to exist in liquids. Our work with ionic liquids has demonstrated both the direct and converse piezoelectric effects. The existing theory for the piezoelectric effect in solids couples Hooke's law and the displacement of charge in a dielectric, both of which are not easily reconciled with the physical properties of ionic liquids. Through an examination of several ionic liquid, we have determined that the application of compressive force to the ionic liquid causes a liquid-to-solid phase transition, and it is the solid form of the ionic liquid that is responsible for the piezoelectric response.

We have developed a means to quantitatively evaluate the piezoelectric coefficient, d33, of room temperature ionic liquids (RTILs) and use this methodology to understand how d33 varies with RTIL cation structure. The d33 quantitation method we developed also enables evaluation of the average size of pressure-induced, piezoelectrically active RTIL crystals. We evaluated d33 for RTILs composed of seven different cations and the common anion bis(trifluoromethylsulfonyl)-imide (TFSI–) and find that its magnitude varies predictably with the extent of conjugation and the length of the cation's aliphatic chain. These findings offer insight into how the constituent ion structures of RTILs can be rationally optimized to enhance piezoelectric activity. With this information in hand, we consider some of the most promising areas for the application of the piezoelectric response of RTILs.

Adding Colour to Ion-Selective Sensing

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Ion-selective sensors typically rely on a receptor composition comprising an ionophore and an ion-exchanger embedded within a plasticized polymeric matrix. These components are generally not optically active, resulting in conventional electrochemical, potentiometric ion-selective sensors that are colorless.

Incorporating dyes into ion-selective membranes presents an attractive challenge, potentially enabling the extension of highly selective sensors to other detection modes, such as absorption (colorimetry) or emission (fluorimetry). Even more challenging is achieving this enhancement without disrupting sensing performance or inducing undesired pH sensitivity. This can be accomplished using Nile Blue and/or Nile Red dyes [1].

The inclusion of these dyes in ion-selective membranes offers several advantages, including the ability to record ratiometric signals. Furthermore, it enables tracing of sensor pretreatment [2] and utilizing this process as an analytical signal itself [3].

Acknowledgments

The authors gratefully acknowledge financial support from the National Science Centre, Poland, through project OPUS 21: "Optical emission insight into processes occurring in the ion-selective sensors operating under electrochemical trigger – towards ion-selective spectrofluoroelectrochemistry", grant no. UMO-2021/41/B/ST4/03401

References

[1] A. Konefał, P. Piątek, K. Maksymiuk, A. Michalska, *Sens. Actuators B: Chemical*, **391** 134022 (2023).
[2] E. Stelmach, K. Węgrzyn, P. Piątek, K. Maksymiuk, A. Michalska, *Sens. Actuators B: Chemical*, **422,** 136653 (2025).
[3] D. Buczyńska, E. Stelmach, M. Jankowska, A. Ruszczyńska, P. Piątek, K. Maksymiuk, A. Michalska, *Talanta*, **286**, 127497 (2025).

Modification of inkjet printed graphene electrode surface by intense pulsed light for improved voltammetric sensing and biosensing

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Inkjet printing offers a green and cost-effective route for fabricating miniaturized, disposable electrochemical sensors. It uses less conducting material, yet it remains underdeveloped compared to screen printing. Inkjet-printed ion-selective electrodes are easily realized [1], since the bulk of the electrode resistance comes from the polymeric ion-selective membrane. However, due to the reduced amount of the printed conducting material, voltammetric sensing with inkjet printed electrodes is more challenging.

In this talk, flexible low-cost inkjet printed graphene electrodes on polyimide sheets will be presented (Figure 1). After printing, the electrodes are processed by intense pulsed light (IPL) – a photonic processing technology that delivers high intensity white light in short time intervals or bursts. The IPL treatment lasts only 3 ms, yet these electrodes outperform thermally treated inkjet printed electrodes and commercial screen-printed carbon electrodes in terms of electrochemical and electroanalytical performance. IPL processing causes the formation of craters on the electrode surface, thus increasing the electroactive surface area and facilitating electron transfer (demonstrated with a hexacyanoferrate (II/III) redox probe). Consequently, voltammetric determination of the antibiotic azithromycin showed improved sensitivity in both batch and flow analysis [2].

The versatility of IPL-processed electrodes was further demonstrated for biosensing: the electrodes were modified by inkjet printing of a Prussian Blue nanoparticle suspension. This enabled sensitive amperometric determination of hydrogen peroxide at low potentials. In the last step, lactate oxidase was immobilized, and lactate determined (via determination of the enzymatically produced hydrogen peroxide) in a broad linear range covering sweat lactate concentrations [3]. Systems like this should enable the development of a variety of low-cost flexible miniature sensors and biosensors, particularly attractive for distributed and wearable sensing.

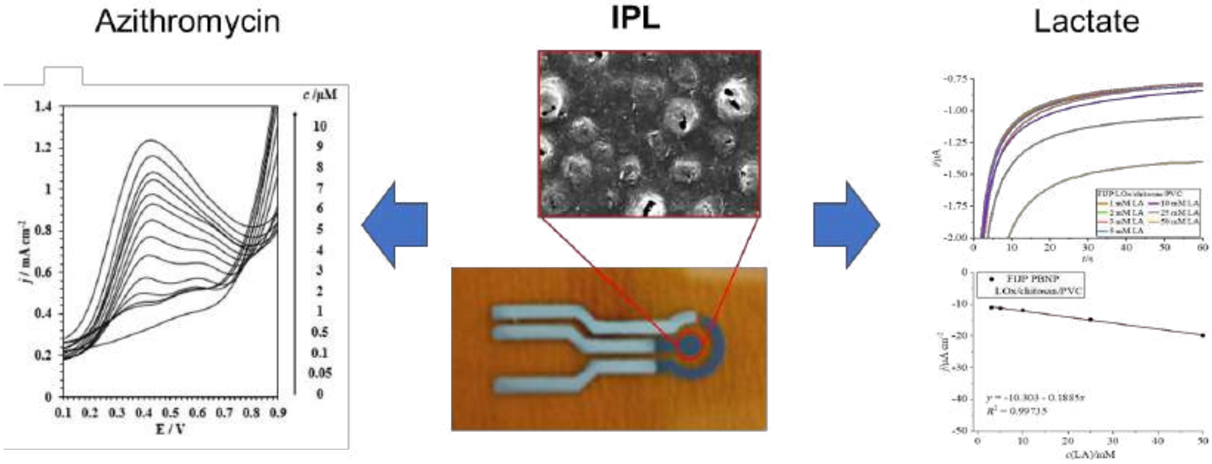

Figure 1: IPL processing improves determination of azithromycin and lactate.

Acknowledgments

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References

[1] 1. S. Krivačić, Ž. Boček, M. Zubak, V. Kojić, P. Kassal, *Talanta* **279** (2024) 126614.
[2] 2. M. Zubak, P. Kassal, *Electrochim. Acta* **513** (2025) 145561.
[3] 3. Ž. Boček, M. Zubak, P. Kassal, *Biosensors* **15** (2025) 28.

Nanofiber-Based Analytical Device (nFAD) as a Novel Alternative to Paper-Based Sensors for Fluoride Detection

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An innovative alternative to traditional paper-based analytical devices is presented. This nanofiber-based analytical device (nFAD) features a porous structure and is fabricated from a plasticized, lipophilic polymer incorporating a fluoride-selective corrole ionophore and an ion-exchanger. This material functions as a sensing layer enabling camera-assisted optical detection of fluoride ion concentration changes in a sample, mediated by the Si-corrole ionophore. The device exhibits a linear correlation between the color intensity (in the red or green channel) and the logarithm of the analyte concentration over the range from 10^{-6} to 10^{-1} M. Notably, the analytical response is obtained rapidly and no pH buffer is required in the sample.

The device offers rapid response, operating without pH adjustment due to its optimized hydrophobic environment. The nanofiber structure ensures mechanical flexibility, durability, and chemical resistance. This study demonstrates the feasibility of nFAD as a robust, optically readable sensor for environmental, healthcare, and food safety applications, combining the structural advantages of nanomaterials with the specificity of synthetic ionophores

Acknowledgments

The authors gratefully acknowledge financial support from the National Science Centre, Poland, through project OPUS 21: "Optical emission insight into processes occurring in the ion-selective sensors operating under electrochemical trigger – towards ion-selective spectrofluoroelectrochemistry", grant no. UMO-2021/41/B/ST4/03401. Your acknowledgment text goes here.

References

[1] J. Kalisz, A. Jelińska, F. Caroleo, E. Jaworska, E. Stelmach, C. Di Natale, K. Maksymiuk, R. Paolesse, A. Michalska, *Sensors and Actuators B: Chemical*, **441**, 137945 (2025).
[2] A. Jelińska, J. Kalisz, D. Pociecha, K. Maksymiuk, A. Michalska, *Electroanalysis*, **36**, e202300287 (2023).

Polydopamine-Tailored Molecular Imprinted Polymer for Ultra-Sensitive PAH Detection

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Molecularly imprinted polymers (MIPs), introduced by Prof. Günther Wulff, are synthetic polymers with selective binding sites formed by polymerizing a monomer-template complex. After template removal, these sites enable specific molecular recognition. MIPs can be made via bulk polymerization, surface grafting, or electropolymerization and target a wide range of analytes.

This study presents a self-signaling biosensor using polydopamine-based MIP enhanced with Prussian Blue nanoparticles for detecting polycyclic aromatic hydrocarbons (PAHs), achieving an LoD of 2.1 ± 0.7 pM, which is significantly lower than current PAHs regulatory thresholds for PAHs [4]. The sensor showed strong selectivity, an imprinting factor of 11 ± 3, and 93.4% recovery in olive oil.

Acknowledgments

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References

[1] G. Wulff, «Molecular Imprinting in Cross-Linked Materials with the Aid of Molecular Templates— A Way towards Artificial Antibodies», Angew. Chem. Int. Ed. Engl., vol. 34, fasc. 17, pp. 1812–1832, set. 1995, doi: 10.1002/anie.199518121.

[2] A. Tricase, V. Marchianò, E. Macchia, N. Ditaranto, L. Torsi, e P. Bollella, «Ultrasensitive and Highly Selective o-Phenylenediamine Molecularly Imprinted Polymer for the Detection of 2,4-Dichlorophenoxyacetic Acid», Electrochimica Acta, vol. 494, p. 144430, ago. 2024, doi: 10.1016/j.electacta.2024.144430.

[3] M. Valentino et al., «Electropolymerized molecularly imprinted polypyrrole film for dimethoate sensing: investigation on template removal after the imprinting process», Anal. Methods, vol. 15, fasc. 10, pp. 1250–1253, 2023, doi: 10.1039/D2AY02024F.

[4] Commission Regulation (EU) 2015/1933 amending Regulation (EC) No 1881/2006

Synthetic Lipid Bilayers as Versatile Platforms for Investigating Ion Channels and Membranolytic Antimicrobial Agents

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Synthetic lipid bilayers mark a substantial advancement in membrane architecture research, serving as vital platforms for elucidating the complex interactions between membranes and biologically active molecules, including antimicrobial agents and ion channel-forming peptides. Biomimetic membranes enable the investigation of structural and functional properties of lipid bilayers such as permeability, stability, and hydration using advanced surface-sensitive techniques including electrochemical impedance spectroscopy (EIS), surface-enhanced infrared absorption spectroscopy (SEIRAS), quartz crystal microbalance (QCM-D), and atomic force microscopy. [1]

Our recent studies demonstrate that supported bilayers prepared via liposome spreading or bicelle self-assembly can accommodate membrane-active compounds while preserving functionality, especially when polymer cushions such as PEG, PLA or chitosan derivatives are used.[2,3] These architectures ensure sufficient submembrane hydration and spatial separation from the solid support, which are essential for reconstitution of ion channels like antimicrobial peptide gramicidin A. In particular, we show that gramicidin A channel activity can be modulated not only via steric blockage at the pore entrance, but also through alterations of the lipid matrix that shift peptide conformation toward inactive states. Such multifactorial modulation highlights the importance of the lipid environment in ion channel regulation. Additionally, artificial lipid membranes were used as platforms for studying the activity of membranolytic compounds such as antibiotic peptides or peptidomimetics. In particular, lipooligourea foldamers, which are synthetic mimics of antimicrobial peptides, demonstrate concentration-dependent membranolytic effects on model bacterial membranes composed of DPPG/POPG/cardiolipin.[4] At low concentrations, these compounds interact superficially, while at higher levels, they disrupt acyl chain packing, induce solubilization, and ultimately disintegrate the bilayer.

Together, these findings underscore the utility of synthetic lipid bilayer models in understanding membrane dynamics and in supporting the development of novel antimicrobial agents. Integrating such systems with sensitive analytical techniques offers a robust framework for elucidating molecular mechanisms of membrane-targeting therapeutics, particularly in the context of combating antibiotic resistance.

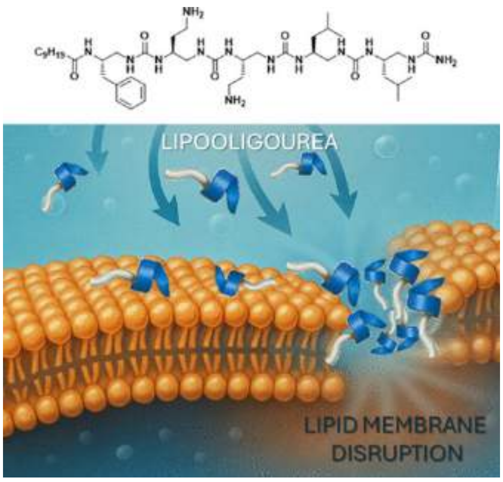

Figure 1: Structure of lipooligourea foldamer and illustration of its disruptive action on artificial lipid membrane. Adapted from reference [4] under CC-BY 4.0 license.

Acknowledgments

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References

[1] Lipkowski, J. *Phys. Chem. Chem. Phys*., **2010**,*12*, 13874-13887.
[2] Dziubak, D.; Sek, S. *Bioelectrochemistry* **2023**, *153*, 108482.
[3] Paria Pashazadeh Panahi et al. *Electrochim. Acta* **2025**, 528, 146292
[4] Kinga Burdach *et al. J. Phys. Chem. B* **2025**, 129, 26, 6517-6527

Cocaine and other drugs – rediscovering a Scott test

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The Scott test is a widely used qualitative analytical method for the detection of cocaine in forensic samples. This colorimetric assay involves a series of chemical reactions that produce a characteristic color change, typically from colorless to blue, in the presence of cocaine hydrochloride, cobalt thiocyanide, and chlorinated solvent. The test is usually used on the spot or during preliminary screening. Its simplicity, rapid results, and minimal equipment requirements are compromised by the false positive/negative readings.

In this story, I plan to tell how the biphasic Scott test was an inspiration to make a dual sensor response combining the electrified liquid-liquid interface and a simple color change readout. This project will also be a good example of how the control experiments can add a lot of drama to the scientific work. Finally, a brief overview of the electroanalytical progress related to different illicit molecules detection will be presented.

Acknowledgments

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Reactions in Droplets on Electrode Surfaces

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Compartmentalised chemistry takes place in a plethora of natural and artificial environments [1]. Examples of the former range from biology to geology and include gametes, synaptic vesicles, nucleoli, fluid inclusions, Pele's tears, *etc.* Artificial environments likewise have broad industrial applications, such as micelles in chemical emulsions, coacervates, in molten metal manufacturing, *etc.* This is a diverse utility of fluid droplets, and a key question revolves around how the chemical environment of the droplet impacts on its functional application.

For electrochemical systems, sessile droplets bathed by a fluid environment give rise to the opportunity for reactions at the three-phase boundary – the locus of the droplet edge in contact with both the electrode and the surrounding fluid, since this is where the current density is the greatest [2]. However, transport both inside and outside the droplet, effects due to reaction partitioning, surface tension gradients and interfacial kinetics can change the dynamics of droplet operations.

This presentation will first illustrate the interplay of factors affecting the dynamics of the electrochemical response of droplet-modified electrodes, highlighting the roles played by particular droplet chemistry, as well as the droplet volume, contact angle and distribution. These issues enable a critical assessment of claims of reaction rate acceleration of redox catalytic reactions within supported single droplets on electrode, as well as "thermodynamic dispersion" in protein-film voltammetry [3].

Acknowledgments

This work was funded by EPSRC (GR/N EP/G020833/1) and The University of Hull.

References

[1] See, for example, G. Lloyd, R. S. Forgan (eds.), *Reactivity in Confined Spaces*, Royal Society of Chemistry, London, 2021.
[2] See, for example, F. Scholz, U. Schröder, R. Gulaboski, A. Doménech-Carbó, *Electrochemistry of Immobilised Particles and Droplets: Experiments with Three-Phase Electrodes*, 2nd edn., Springer, Heidelberg, 2015.
[3] See, for example, H. O. Lloyd-Laney, M. J. Robinson, A. M. Bond, A. Parkin, D. J. Gavaghan, A spotter's guide to dispersion in non-catalytic surface-confined voltammetry experiments, *J. Electroanal. Chem.*, 2021, **894**, 115204.

Molecular Sensing with Graphene Foam Electrodes

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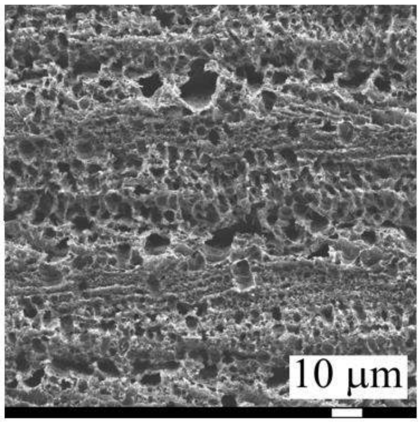
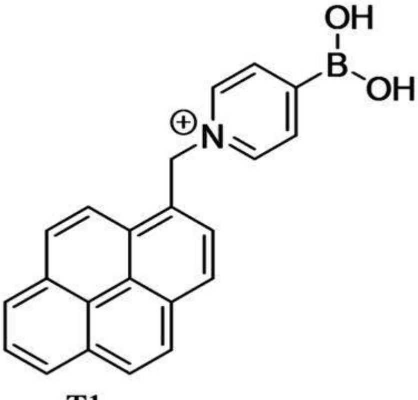
Graphene foam electrodes provide high surface area and low-cost film electrodes for sensing. Recently, new approaches based on boronic acids adsorbed to the graphene foam surface (see Figure [1,2]) have been reported. The sensing mechanism can be either based on current or based on capacitance. Binding the boronic acid "T1" onto graphene foam produces an order of magnitude change in capacitance (linked to quantum capacitance [3]). Interaction of the boronic acid in T1 can produce further capacitance signals. Therefore, sensing using capacitance (without the need for power) is feasible.




T1

In this study, graphene foam electrodes are investigated by voltammetry, impedance spectroscopy, microscopy, and molecular effects are modelled at molecular/electronic level with molecular dynamics and density functional theory. Examples of sensing applied to glucose are discussed.

Acknowledgments

O.M. thanks the University of Bath and Integrated Graphene Ltd. for a PhD scholarship and University of Bath's Research Computing Group (doi.org/10.15125/b6cd-s854) for their support in this work. [4]

References

[1] S. Steeds, L. Parker, S.M. Wikeley, B. Kersch-Hunt, M. Caffio, P. Lozano-Sanchez, P.J. Fletcher, S.E.C. Dale, T.D. James and F. Marken, *Talanta* **292**, 127938 (2025).
[2] S.M. Wikeley, P. Lozano-Sanchez, M. Caffio, T.D. James and F. Marken, *Sens. Actuators B-Chem*. **377**, 133089 (2023).
[3] S.M. Wikeley, J. Przybylowski, J.E. Gardiner, T.D. James, P.J. Fletcher, M.A. Isaacs, P. Lozano-Sanchez, M. Caffio and F. Marken, *ACS Sensors* 9, 1565-1574 (2024).
[4] University of Bath, Research Computing Group, DOI: 10.15125/b6cd-s854

Development of conductive hydrogels for flexible bioelectronics

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Hydrogel bioelectronics is a rapidly developing field that bridges the gap between hard electronic devices, which rely on electronic charge carriers, and soft biological tissues, which primarily conduct ionic signals. In this work, we explored various hydrogels to engineer conductive hydrogel materials suitable for applications in biosensing and bioelectronics. Our main focus was on developing photocurable conductive hydrogels that can be seamlessly adapted to additive manufacturing technologies. Notably, we observed that conductive hydrogel membranes coating laser-induced graphene (LIG) electrodes significantly enhanced electrochemical signals in the presence of redox probes, as illustrated in Fig. 1a. Moreover, electrical measurements confirmed high electrical conductivity with minimal variation across a broad frequency range, as depicted in Fig. 1b. Importantly, 3D printing of the developed conductive hydrogel into microneedle structures demonstrated excellent printability and high resolution using a DLP printer. The obtained results demonstrated that these conductive hydrogels hold great promise as sensing platforms.

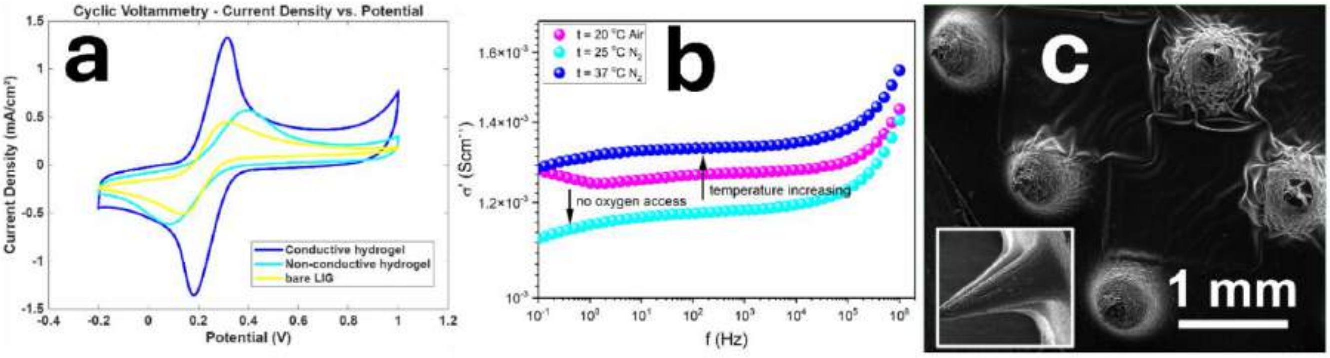

Figure 1. (a) Cyclic voltammograms (CVs) recorded for bare LIG and hydrogel-coated LIG samples in 5 mM $[Fe(CN)_6]^{3-/4-}$ solution at a scan rate of 50 mV/s. (b)) electrical conductivity of the hydrogel vs. frequency at three different temperature; (c) SEM images of the 3D printed conductive hydrogel microneedles captured from the top view and side view. Keywords: Conductive hydrogels, 3D printing, hydrogel bioelectronics, laser-induce graphene, biosensor.

Intrinsically Microporous Polymers in Electrochemical Processes

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Polymers of intrinsic microporosity (or PIMs) have been developed over the past decade as molecularly rigid and highly processable materials that are readily applied to electrode surfaces or employed as free-standing membranes. Two prototypical PIMs are PIM-1 [1] and PIM-EA-TB [2] (see Figure below). Both possess rigid molecular backbones and pack into porous solid/glassy films with high surface area and with typically 1 nm pore size [3].

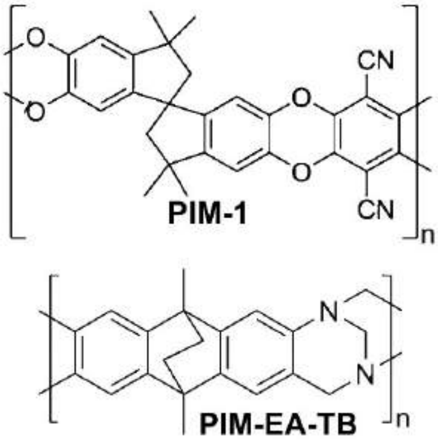

Figure 1: Molecular structure for PIM-1 and for PIM-EA-TB.

PIMs have been introduced into electrochemical applications in energy storage devices [3] and in sensors [4]. They provide fertile ground for fundamental studies on ion transport and electroosmotic water transport [5]. Intrinsic microporosity leads to binding and transport with size selectivity and chemical selectivity. Binding of gases into nanoparticulate PIM materials is responsible for localised gas activity increases under triphasic conditions (solid|liquid|gas for oxygen [6] or for nitrogen [7]). Localised storage of gases has been reported for example for hydrogen [8].

References

[1] F. Marken, E. Madrid, Y. Zhao, M. Carta, and N.B. McKeown, *ChemElectroChem* **6**, 4332 (2019).
[2] E. Madrid, Y.Y. Rong, M. Carta, N.B. McKeown, R. Malpass-Evans, G.A. Attard, T.J. Clarke, S.H. Taylor, Y.T. Long, and F. Marken, *Angew. Chem. Inter. Ed*. **53**, 10751 (2014).
[3] L. Wang, Y. Zhao, B.B. Fan, M. Carta, R. Malpass-Evans, N.B. McKeown, and F. Marken, *Electrochem. Commun*. **118**, 106798 (2020).
[4] F. Marken, L. Wang, Y. Zhao, Z.K. Li, M. Amiri, and H. Imanzadeh, *Curr. Opinion Chem. Engineer*. **35**, 100765 (2022).
[5] Z.K. Li, R. Malpass-Evans, N.B. McKeown, M. Carta, K. Mathwig, J.P. Lowe, and F. Marken, *Electrochem. Commun*. **130**, 107110 (2021).
[6] M.A. Beluomini, Y. Wang, L. Wang, M. Carta, N.B. McKeown, S. Wikeley, T.D. James, P. Lozano-Sanchez, M. Caffio, N.R. Stradiotto, M.V.B. Zanoni, and F. Marken, *Electrochem. Commun*. **143**, 107394 (2022).
[7] C.V.S. Almeida, L.K. Ribeiro, L.H. Mascaro, M. Carta, N.B. McKeown, and F. Marken, *Green Chem.* (2025) https://doi.org/10.1039/D5GC00612K.
[8] A. Morris, M. Carta, N.B. McKeown, P.J. Fletcher, and F. Marken, *Electrocatalysis* **16**, 162 (2025).

Electrochemically reshaped MXenes - as versatile platforms for sensing and catalysis

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The increasing demand for highly sensitive, selective, and robust electrochemical sensors has positioned MXenes, two-dimensional transition metal carbides and nitrides, at the forefront of surface modification research for chemical and biochemical sensing. While these materials were traditionally synthesized via hazardous hydrofluoric acid etching, there is a growing shift towards electrochemical methods that employ milder, safer conditions. Electrochemical synthesis not only offers improved environmental sustainability and user safety but also provides precise control over parameters such as applied voltage, current density, electrolyte composition, and etching duration. This level of control facilitates the tailoring of MXene flake size, surface chemistry, and defect density, which are key attributes for optimizing sensor performance.

Recent studies have demonstrated that a top-down electrochemical approach, particularly via cyclic voltammetry, enables the direct transformation of the two-dimensional Ti_3AlC_2 MAX phase into unique microspherical MXene structures. In this template-free method, MAX phase powder is suspended in electrolyte containing tetramethylammonium tetrafluoroborate and tetrafluoroboric acid, with glassy carbon serving as both the working and counter electrodes. Proposed configuration eliminates the need for binders or pre-fabricated solid electrodes, simplifying the fabrication process, enhancing reproducibility, and facilitating scalable production comparing to the other electrochemical approaches, where precursor MAX phase is in the form of tablet or layer deposited onto the conducting substrate.

Although the primary focus of this research is the controlled synthesis and morphological modulation of MXenes using sustainable electrochemical routes, it is also important to highlight the broad versatility these materials offer for surface modification. Electrochemically synthesized MXenes exhibit robust electrical conductivity, high hydrophilicity, and notable biocompatibility, while their surfaces can be readily functionalized with bioelements. These characteristics make them promising candidates for integration into chemical and biochemical sensors capable of detecting biomarkers, pharmaceutical compounds, and environmental pollutants. Notably, recent advances have leveraged MXene-based platforms for hormone sensing, where surface biofunctionalization with aptamers or antibodies enables highly selective and sensitive detection at trace levels.

Acknowledgments

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Advances in Protein Recognition Using Bio-Inspired Polynorepinephrine and Novel Imprinting Strategies

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The search for ethical and sustainable alternatives to antibodies has led to bio-inspired polymers mimicking molecular recognition. Despite progress in antibody engineering, conventional immunoassays remain costly, unstable, and animal-dependent. In contrast, neurotransmitter-based receptors—like dopamine, norepinephrine, and serotonin—allow eco-friendly, one-step synthesis of Molecularly Imprinted Bio-Polymers (MIBPs). We present advances in polynorepinephrine-based MIPs (MIPNEs), including a novel “finger-imprinting” strategy using biological extracts and an automated method for epitope selection. These innovations offer robust, selective, and affordable tools for protein detection in diagnostics and personalized medicine

Acknowledgments

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Electrified Liquid-Liquid Interfaces for Direct Electroanalysis of Nitrate in Cyanobacterial growth

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Nitrate (NO_3^-) is an essential nutrient of biosphere, pivotal in agricultural productivity and healthy vegetation of aquatic ecosystem. However, excessive nitrate accumulation in water bodies due to agricultural runoff, industrial discharge, and wastewater contamination leads to severe environmental consequences, including eutrophication, harmful algal blooms, and hypoxic zones [1]. These disruptions threaten aquatic biodiversity, compromise water quality, and pose risks to human health, such as methemoglobinemia (blue baby syndrome) [2]. Therefore, accurate and efficient nitrate monitoring is critical for environmental protection and sustainable water management. In this study, we developed an electrochemical sensing strategy based on the electrified liquid-liquid interface (eLLI) coupled with voltammetry to enable onsite and periodic nitrate monitoring in cyanobacteria growth medium. At eLLI the nitrate detection is governed by its interfacial ion transfer behaviour rather than its redox activity. Unlike conventional spectroscopic or chromatographic methods that require sophisticated instrumentation, the eLLI-based approach offers a simpler, portable, and real-time detection technique [3]. The sensor demonstrated a linear detection range from 20 to 500 µM with detection and quantification limits of 1.5 and 14.6 µM, respectively, ensuring high sensitivity and reliability. Given the complexity of natural aquatic environments, we systematically investigated the influence of chloride ions and other competing anions present in the algae growth medium. In particular, the simple in-situ chemical precipitation strategy was found to be powerful to eliminate chloride interference and improving sensor accuracy. The validated eLLI-based sensor was successfully applied to Z8 medium, a standard nutrient solution for *Microcystis aeruginosa* cyanobacteria cultures. The results demonstrated the sensor's robustness for periodic nitrate monitoring, making it a promising tool for environmental water analysis and algal research [4]. A schematic illustration of nitrate sensing is given in Fig. 1.

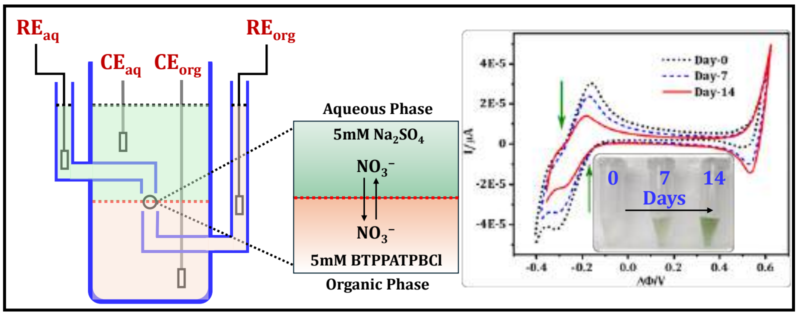

Figure 1: Schematic representation of the electrochemical cell (left) along with cycling voltammograms recorded in the algae growing medium.

Acknowledgments

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References

[1] D. Rosales, A. Ellett, J. Jacobs, G. Ozbay, S. Parveen, and J. Pitula, *Applied and environmental microbiology*, **88**, e00356-22 (2022).
[2] B. Patella, R. R. Russo, A. O'Riordan, G. Aiello, C. Sunseri, and R. Inguanta, *Talanta,* **221**, 121643 (2021).
[3] S. Sudalaimani, K. S. Kumar, A. Esokkiya, C. Suresh, and K. Giribabu, *Analyst*, **146**, 3208-3215 (2021).
[4] M. Annalakshmi, T. S. Balamurugan, K. Czarny-Krzymińska, K. Marciniak, and L. Poltorak,. *Sensors and Actuators B: Chemical*, **423,** 136863 (2025).

Day 5

18 November 2025

Bacterial electrochemistry

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Bacterial electrochemistry has become one of the hottest topics in bioelectrochemistry ever since it was shown that Geobacter sulfurreducens and Shewanella putrefaciens could electrochemically communicate directly with electrodes without the need to any redox mediator [1,2].

We have since 2004 pioneered "wiring" both Gram-positive and Gram-negative bacteria [3-6] (and thylakoid membranes [7-9]) to electrodes using osmium redox polymers (Os RPs) that strongly facilitate extracellular electron transfer (EET) reactions. Because of the cationic nature of the Os RPs they will electrostatically interact very strongly with bacterial cells and biological membranes to form hydrogels that will strongly attach onto electrode surfaces and will allow substrates and products to freely diffuse in and out of the hydrogel. We have investigated the influence of EÅã'-value and structure of the Os-complexes of the Os RPs on the rate of electron transfer. However, only recently we have obtained a much clearer picture on how the RPs and the cells interact and how the interaction changes with time. In these recent investigations we have "wired" wild type and some mutants of Enterococcus faecalis with both 4 different Os RPs as well as with a quinone RP [10-14]. Comparing the efficiency for EET for wild type and some E. faecalis mutants using an Os RP or ferricyanide we could prove that there are different ET pathways in this organism [14]. These recent results will be shown and discussed.

References

[1] D. R. Bond and D. R. Lovley, Appl. Environ. Microbiol., 2003,69, 1548–1555.
[2] B. H. Kim, H. J. Kim, M. S. Hyun, D. H. Park, J. Microbiol. Biotechnol., 1999, 9, 127-131.
[3] K. Hasan, S. A. Patil, D. Leech, and L. Gorton, Biochem. Soc. Trans., 2012, 40, 1330-1335.
[4] S. A. Patil, C. H.gerh.ll, and L. Gorton, Bioanal. Rev., 2012, 4, 159-192.
[5] G. Pankratova and L. Gorton, Curr. Opin. Electrochem., 2017, 5, 193-202.
[6] G. Pankratova, L. Hederstedt, and L. Gorton, Anal. Chim. Acta, 2019, 1076, 32-47.
[7] G. Pankratova, D. Pankratov, K Hasan, H.-E. .kerlund, P.-.. Albertsson, D. Leech, S. Shleev, and L. Gorton, Adv. Energy Mater., 2017, 1602285.
[8] G. Pankratova, D. Pankratov, and L. Gorton, Curr. Opin. Electrochem., 2020, 19, 49-54.
[9] D. Pankratov, G. Pankratova, and L. Gorton, "Current Trends in Development of Photosynthetic Bioelectrochemical Systems for Light Energy Conversion", in "Novel Catalyst Materials for Bioelectrochemical Systems: Fundamentals and Applications", Eds. L. Singh, D. M. Mahapatra, H. Liu, ACS Book Ser. 2020, 1342, 123-146.
[10] G. Pankratova, K. Hasan, D. Leech. L. Hederstedt, and L. Gorton, Electrochem. Commun., 2017, 75, 56–59.
[11] G. Pankratova, D. Leech, L. Gorton, and L. Hederstedt, Biochemistry, 2018, 57,4597−4603.
[12] G. Pankratova, E. Szypulska, D. Pankratov, D. Leech, and L. Gorton, ChemElectroChem, 2019, 6, 110-113.
[13] G. Pankratova, D. Pankratov, R.D. Milton, S. D. Minteer, and L. Gorton, Adv. Energy Mater, 2019, 1900215.
[14] L. Hederstedt, L. Gorton, and G. Pankratova, J. Bacteriol., 2020, 202, e00725-19.

H_2 photogeneration at droplet placed on recessed electrode

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Light-driven HER at liquid|liquid (LL) interface with metallocene as electron donor is a strategy to reduce protons without additional photosensitizer [1,2]. Here, we will demonstrate a system allowing the decrease of the volume of the organic phase and continuous electrochemical recycling of the electron donor. For this purpose, a droplet of decamethylruthenocene (DMRc) solution in trifluorotoluene (TFT) was placed on a recessed Pt microelectrode in contact with aqueous acid. LL interface was chemically polarized by dissolving different salt of highly hydrophobic tetrakis(pentafluorophenyl) borate anion (TB^-) in both phases to ensure proton transfer from aqueous to organic phase [3]. This system differs from that earlier proposed, because it does not require precise positioning of the microelectrode below LL interface [4] and cancerogenic 1,2-dichloroethane was replaced by TFT [5].

SECM was employed for the detection of generated hydrogen. Substrate generation/tip collection mode was applied in an Ar saturated acidic solution, whereas feedback mode was used in H_2 saturated neutral electrolyte. In both conditions, hydrogen was detected above an organic droplet in the presence of light.

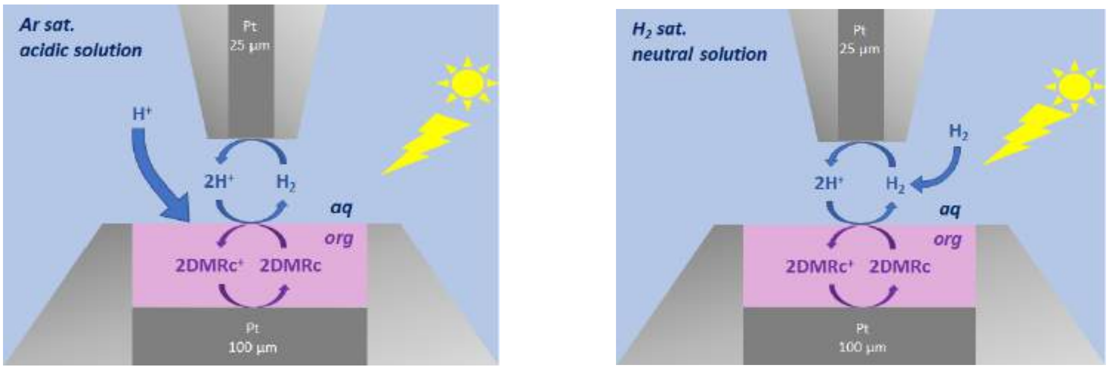

Figure 1: Schemes of detection of H_2 photogenerated at liquid|liquid interface with electrochemical recycling of electron donor.

Acknowledgments

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References

[1] L. Rivier, T.J Stockmann, M.A Méndez, M.D Scanlon, P. Peljo, M. Opallo and H.H Girault, *J. Phys. Chem C* **119** 25761 (2015).
[2] L. Rivier, P. Peljo, L.A.C. Vannay, G.C. Gschwend, M.A. Mendez, C. Corminboeuf, M.D. Scanlon and H.H. Girault, *Angew. Chem. Int. Ed.* **56** 2324 (2017).
[3] I. Hatay, B. Su, F. Li, R. Partovi-Nia, H. Vrubel, X. Hu, M. Ersoz and H. H.Girault, *Angew. Chem. Int. Ed.* **48** 5139 *(*2009).
[4] J. Jedraszko, W. Adamiak, W. Nogala, H. H. Girault and M. Opallo, *J.Electroanal. Chem.* **819** 101 (2018).
[5] W. Adamiak,, J. Jedraszko, O. Krysiak, W. Nogala, J.C. Hidalgo-Acosta, H.H. Girault, and M. Opallo, J Phys Chem C **118** 23154 (2014)**.**

Sensitive electrochemical detection of small structural changes of proteins.

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Proteins, as essential components of life, are the focus of a wide array of research fields. Understanding their behavior is crucial, for instance for advancing diagnostic methodologies and medical treatments. Given that numerous biochemical processes occur at membrane-liquid interfaces, electrochemical analysis emerges as a powerful approach for studying biomolecules at charged liquid|electrode interfaces.

Electrochemical methods offer a powerful and rapid approach for probing protein structural dynamics and interactions with biomolecular partners such as DNA, other proteins, and peptides [1, 2]. These techniques are highly sensitive to subtle conformational changes, particularly under conditions of surface polarization to highly negative or positive potentials, where partial unfolding or denaturation may occur. The charged surface plays a crucial role in this type of analysis since the proteins are accumulated at the uncharged surface, where they retain their folded structures. Subsequently, electrode polarization to negative/positive potentials can lead to structural change in an extreme case to denaturation/unfolding [3]. Even minor conformational protein changes can influence protein stability at charged interfaces, altering the accessibility of electroactive groups and thereby modulating the electrochemical signal [2]. This approach enables differentiation between monomeric and dimeric protein forms as well as the analysis of weak biomolecular interactions, such as those between lectins and carbohydrates [4, 5].

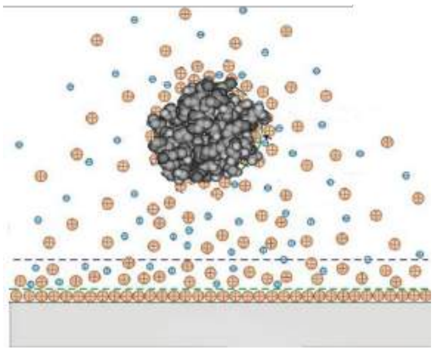

Figure 1: Protein at liquid|electrode interfaces

References

[1] V. Ostatná, H. Cernocká, T. Galicová, S. Hason, Electrochemical analysis of proteins important in cancer: Behavior of anterior gradient receptors, p53 protein and their complexes at charged surfaces, Current Opinion in Electrochemistry, 39 (2023) 101269.

[2] E. Palecek, J. Tkac, M. Bartosik, T. Bertok, V. Ostatna, J. Palecek, Electrochemistry of nonconjugated proteins and glycoproteins. Toward sensors for biomedicine and glycomics, Chemical Reviews, 115 (2015) 2045-2108.

[3] V. Ostatna, R.M. West, Effects of ex situ chronopotentiometric analysis on stability of bovine serum albumin on mercury electrodes, J. Electroanal. Chem., 860 (2020) 113884.

[4] T. Galicová, S. Hasoň, V. Ostatná, Interaction of lectin *Sambucus nigra* with sialylated trisaccharides in the presence of osmolytes. Chronopotentiometric sensing, Bioelectrochemistry, 152 (2023).

[5] T. Staronová, J. Holcáková, P. Vonka, R. Hrstka, V. Ostatná, Impact of galectin-1's redox state on its lectin activity and monomer-dimer equilibrium. Focusing on oxidized Gal-1, Int. J. Biol. Macromol., 295 (2025).

Ferrocene Films on Platinum Electrode Working in Aqueous Media

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Ferrocene (Fc) is an established redox standard for the measurement of potentials in non-aqueous media. Nevertheless, measurements with free Fc in solution are complicated by adsorption and mass transport phenomena and solvation effects. The water insolubility of Fc renders any analysis of it in aqueous media impossible. To overcome these difficulties, we anchored ferrocene (*via* vinyl moiety) onto a platinum disk electrode surface from its non-aqueous solution. The performance of the resulting Fc-platinum electrode (Fc/Fc^+ redox transformation) was then explored by cyclic voltammetry in not only non-aqueous but, for the first time, in aqueous media as well.

References

[1] *J. Phys. Chem. Lett.* 2025, 16, 2487–2491;
[2] *Chem. Listy* 2024, 118, 602–607

Time-resolved Electromechanical and Conductive Behavior of Nanostructured Bilayers Tethered to the Electrode with Incorporated Channel Proteins and Peptides for Sensor Development

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The preparation of well-defined, biomimetic layers on solid electrodes remains crucial, due to their essential role in investigating and controlling the ion-conducting behavior of membrane integral proteins and channel peptides. Furthermore, the information gained in such studies can be utilized in the field of electrophysiology, e.g., in describing nerve conduction, the functioning of the membrane respiratory chain, enabling the selectivity of ion flux and its modulation by the transmembrane potential and other external factors such as channel inhibitors or activators that affect their behaviour [1-3]. This, in turn, underpins not only the development of derived sensors and electronic junctions but also of the screening platforms for the development of new drugs.

By employing chronoamperometry and electrochemical impedance spectroscopy (EIS), we investigated the electromechanical properties of tethered biomimetic membranes (tBLMs) on gold electrodes, as well as the conductivity behavior of the mitochondrial inner membrane potassium channel - ROMK2 and channel-forming peptides – Gramicidin A and Amphotericin B incorporated into these membranes. EIS allowed us to follow the membrane dielectric and conducting parameters related to the incorporation of ROMK2 and channel peptides. In the chronoamperometric experiments, the two time constants were resolved by applying a potential step across the membranes. We interpreted this behavior in terms of a fingerprint of electromechanical response of the membrane dielectrics – the electrostriction of tBLM under the influence of an external electric field, and the second time constant was[i] due to the passage of potassium through the channels. These conclusions were verified when potassium was replaced by sodium during the electrochemical measurements, allowing also the assessment of the number of conducting channels incorporated into the tBLMs. The effect of membrane structure on electromechanical behavior was investigated in hybrid bilayers with varying lengths of alkanethiols, revealing the impact of hydrocarbon length [4].

Although the obtained results provide only a rough estimate of the number of ROMK2-ND or Gramicidin channels, they also demonstrate the potential of utilizing tBLMs as biocompatible platforms for membrane protein biophysical studies, as well as bio-components in sensor device development. Due to their robustness and stability, these membranes exhibit substantial capabilities that can be utilized in research and screening platforms for potential pharmaceuticals and innovative drugs, as well as bio-based nanoelectronic devices. The obtained results also highlighted the crucial role of the interaction between the substrate and the membrane in the mechanical properties of the tBLM. Therefore, the potential-induced changes in the tBLMs should be considered in further studies on the structural, mechanical, and electrical properties of biomimetic films deposited on the electrodes.

Acknowledgments

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References

[1] R. Guidelli, L. Becucci, Electrochemical Science Advances (2021) 1-57.
[2] J. Lipkowski, Advances in Planar Bilayers and Liposomes (2014) 20 1-49.
[3] A. Stefanowska, et al., Bioelectrochemistry (2025) 162 108848.

Investigation of biomolecular recognition of C-reactive protein by phage display-derived biosensing elements

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The phage display technique from molecular biology was used to isolate new binding molecules/receptors (bacteriophages, peptides and nanobodies) that specifically recognise CRP, a marker of inflammatory processes in the human body. The interactions between CRP and the new receptors were evaluated using experimental (biological and physicochemical) methods, with the support of theoretical simulations (computational modelling analysis), in the case of peptide receptors (designated as P2, P3, and P9). The new CRP binding molecules were successfully applied a sensing elements for the development of CRP-sensing platforms [1-5].

Firstly, CRP-binding bacteriophages (phages, viruses of bacteria) were identified. The performed studies showed that phage P2 exhibits the highest affinity to CRP. Therefore, this phage was used to modify the electrode as a new CRP receptor. It was deposited together with CNFs using a layer-by-layer approach on a glassy carbon electrode. This was possible due to the electrostatic interactions that occur between the P2 phage (negatively charged) and the CNFs (positively charged). The obtained phage-based electrode was applied for CRP detection [1].

In the case of peptides derived from phages, numerical and experimental studies have consistently shown that the P3 peptide is the most effective CRP binder. Therefore, this peptide was used as a recognition element. Firstly, P3 was used for CRP recognition on silicate-modified indium tin oxide-coated glass electrodes [2]. Then, the P3 peptide was successfully incorporated into a point-of-care testing sequential microfluidic device and used for CRP detection. The device was tested with serum, plasma, and whole blood samples to validate its applicability, yielding satisfactory results and a very low limit of detection compared to an antibody-based device on the same platform [3].

Nanobodies are small protein fragments of approximately 15 kDa, derived from the VHH domain of camelid antibodies, and are capable of binding specific antigens. In our studies, we utilised the E12 anti-CRP nanobody, which exhibited the highest affinity for CRP among those selected via phage display [4]. The selected nanobodies were successfully applied in an NFC smartphone-based electrochemical microfluidic device for the detection of CRP [5].

The presented new receptors are more resistant towards external factors. They recognise CRP in a concentration range similar to monoclonal antibodies. Therefore, new CRP binding receptors could become the sought-after solution as an alternative to antibodies and can be used for differentiating between viral and bacterial infections

References

[1] K. Szot-Karpińska, P. Kudła, A. Szarota, M. Narajczyk, F. Marken, J. Niedziółka-Jonsson. *Bioelectrochemistry* 136 (2020) 107629.
[2] K. Szot-Karpińska, P. Kudła, U. Orzeł, M. Narajczyk, M. Jönsson-Niedziółka, B. Pałys, S. Filipek, A. Ebner, J. Niedziółka-Jönsson, *Analytical Chemistry*, 95 (2023) 14475.
[3] S. Boonkaew, K. Szot-Karpińska, J. Niedziółka-Jönsson, B. Pałys, M. Jönsson-Niedziółka, *Sensors and Actuators B: Chemical* 397 (2023) 134659.
[4] S. Oloketuyi, R. Bernedo, A. Christmann, J. Borkowska, G. Cazzaniga, H. W. Schuchmann, J. Niedziółka-Jönsson, K. Szot-Karpińska, H. Kolmar, A. de Marco, *Biosensors* 11 (2021) 496.
[5] S. Boonkaew, K. Szot-Karpińska, J. Niedziółka-Jönsson, A. de Marco, M. Jönsson-Niedziółka, *ACS Sensors* 9 (2024) 3066.

Posters

Detection of 4-methyl-*N*-nitrosopiperazine in antitubercular drugs using MIP based sensor

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N-nitrosoamines are broad class of compounds, mostly classified as carcinogens, that have been identified as impurities of food, medicines and water. Contamination of numerous drugs with nitrosamines results from manufacturing processes or long-term storage of finished drug products [1]. This poses a serious threat to the population. Nitrosamine impurities in drugs are strictly controlled and their level should not exceed the acceptable intake limit (AI) set by the relevant authorities. For the routine determination of nitrosamines, separation techniques with mass spectrometry detection: GC-MS and LC-MS are used, ensuring low detection limits (LOD). Nitrosamines are volatile, polar and highly water-soluble compounds, and their isolation and determination is a challenge.To determine the level of 4-methyl-N-nitrosopiperazine (MNP) in antitubercular drug rifampicin, we have developed an MIP based sensor film which allows us to detect MNP in rifampicin at sub ppt concentration, even with the presence of other active pharmaceutical ingredients. This is crucial, since rifampicine in drug products is often used in combination with isoniazide, pyrazinamide and ethambutol for complex therapy. Polytiophene-based MIP films were deposited on Pt and Au electrodes by potentiodynamic electropolymerisation. MIP contained monomers modified with thymine moiety for selective binding of target molecules. In our analytical assay we have used differential pulse voltammetry to determine NMP in presence of redox probe.

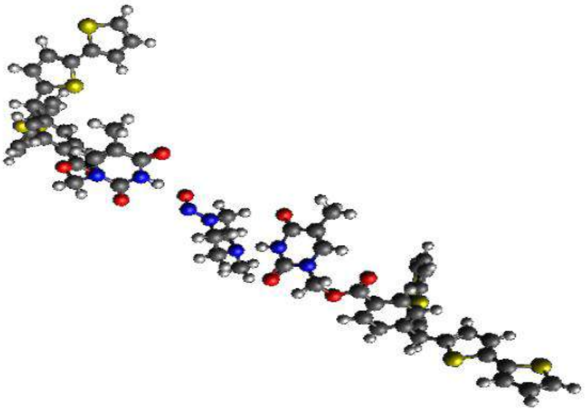

Figure 1. A complex between 4-methyl-N-nitrosopiperazine and two functional monomeres.

Acknowledgments

The financial support from the National Science Centre, Poland Project No. 2022/47/B/ST5/02337 (to M.C.) is acknowledged.

References

[1] Witkowska, A. B.; Zezula, M.; Glice, M.; Stolarczyk, E. U. New Aspects of the Methodology of *N*-Nitrosamines Determination. Przemysl Chemiczny 2021, 100 (3), 230–239. https://doi.org/10.15199/62.2021.3.3.

Optimization of pH sensitive polymeric coatings on flexible printed electrodes for biomedical sensing purposes

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Flexible electrochemical pH sensors can play a significant role in healthcare since the pH level affects most biochemical reactions in the human body. Polyaniline (PANI) is one of the most widely used pH–sensitive materials, owing to its strong pH sensitivity, conductivity, chemical stability and low cost. PANI has been widely used in wearable devices due to its easy deposition and high flexibility [1]. Therefore, pairing PANI with additive manufacturing methods, such as printing technologies for electrode fabrication, would facilitate integration of flexible and low-cost electrochemical sensing platforms.

Multiple deposition methods for modifying the electrode surface with polyaniline were tested, including electropolymerization from an aniline monomer solution and drop casting of PANI emeraldine base or PANI/carbon black (CB) composite dispersion directly onto the electrode. Deposition methods were tested on different electrode substrates, including glassy carbon, screen printed carbon and inkjet printed graphene. Electrochemical characterization was conducted through cyclic voltammetry, chronopotentiometry and electrochemical impedance spectroscopy measurements in 0.1 M KCl to determine capacitance of the PANI coatings. Analytical properties were evaluated through potentiometric measurements in phosphate buffers with pH values adjusted to the physiological range (pH 5-8). Hydrogen selective electrodes (H-ISE) were also prepared and characterized for comparison by modifying the electrodes with a plasticized PVC-based membrane containing Hydrogen ionophore I. Aside from optimizing the working electrode, an optimization of reference electrode modification procedure was conducted to ensure a stable reference point in a flexible format. AgCl deposition on printed Ag substrate was conducted chemically (with $FeCl_3$ solution) or electrochemically (applying constant current of 2.5 mA in 3 M KCl) by varying the duration of the experiment. A stable reference potential was provided by ensuring a constant chloride background in measuring solutions.

With optimal deposition, H-ISE performance showed a reliable Nernstian sensitivity of about 60 mV/pH regardless of substrate, while sensitivity of PANI-modified pH sensors ranges from subnernstian (~40 mV/pH) values for PANI-CB composite to supernernstian values (~70-75 mV/pH) for electropolymerized PANI films. All electrodes exhibited an excellent linearity ($R^2 > 0.99$) in a wide physiologically relevant pH range. Further work includes optimizing the flexible sensor configuration for biomedical sensing purposes, such as testing the permeability of an artificial lung membrane.

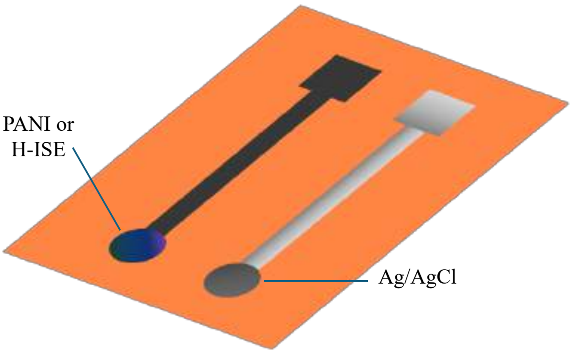

Figure 1: Flexible inkjet printed potentiometric pH sensor.

Acknowledgments

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References

[1] Y. Tang, L. Zhong, W. Wang, Y. He, T. Han, L. Xu, X. Mo, Z. Liu, Y. Ma, Y. Bao et. al., *Membranes* **12**, 504 (2022).

Molecularly imprinted polymer-based electrochemical sensor for detecting low molecular weight compounds

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Molecularly imprinted polymers (MIPs) are synthetic materials formed through polymerisation in the presence of a template molecule. They are designed to contain specific binding sites that match the shape, size, and functional groups of that molecule. Often described as 'plastic antibodies', MIPs can replicate the molecular recognition abilities of natural antibodies, offering both high selectivity and affinity [1]. Unlike biological receptors, MIPs are more stable, resistant to harsh environmental conditions, and less expensive to produce. Given these advantages, these polymers can be utilised for detecting low-molecular-weight compounds, such as food contaminants, drugs, and environmental pollutants [2, 3]. MIP preparation typically involves (i) self-assembly of functional monomers with the template molecule in solution, (ii) chemical or electrochemical polymerisation forming a rigid polymer network, and (iii) template removal to create selective binding cavities [3].

In this study, electrochemical sensors based on polypyrrole-based molecularly imprinted polymers (MIPs) were developed for the selective detection of low-molecular-weight compounds, including L-tryptophan [2], melamine [3], and salicylic acid. The MIPs were prepared by electropolymerizing a pre-polymeric solution containing pyrrole as the functional monomer and the target template molecules. The polymer layers were deposited directly onto the surfaces of graphite electrodes and screen-printed carbon electrodes using an amperometric method. Following polymerisation, the template molecules were removed through an extraction procedure, leaving behind specific binding sites within the polymer matrix. As a control, non-imprinted polymer (NIP) electrodes were prepared under the same conditions, but without the addition of the template.

The properties of all polypyrrole films were evaluated using cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS). The interactions between the template molecules and the polymer layers were assessed by comparing the oxidation peak currents obtained through differential pulse voltammetry (DPV). The results, along with the calculated apparent imprinting factors, demonstrate that the designed MIPs are suitable for developing electrochemical sensors for the detection of low-molecular-weight molecules.

Acknowledgments

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References

[1] J. Joseph BelBruno. Molecularly Imprinted Polymers. *Chemical Reviews*, **119**(1), 94–119 (2019). https://doi.org/10.1021/acs.chemrev.8b00171

[2] V. Ratautaite, E. Brazys, A. Ramanaviciene, A. Ramanavicius. Electrochemical sensors based on L-tryptophan molecularly imprinted polypyrrole and polyaniline. *Journal of Electroanalytical Chemistry*, **917**, 116389 (2022). https://doi.org/10.1016/j.jelechem.2022.116389

[3] E. Brazys, V. Ratautaite, B. Brasiunas, A. Ramanaviciene, L. Rodríguez, A. Pinto, D. Milea, U. Prentice, A. Ramanavicius. Molecularly imprinted polypyrrole-based electrochemical melamine sensors. *Microchemical Journal*, **199**, 109890 (2024). https://doi.org/10.1016/j.microc.2024.109890

ATRP as a powerfull tool for polymer design with many purposes

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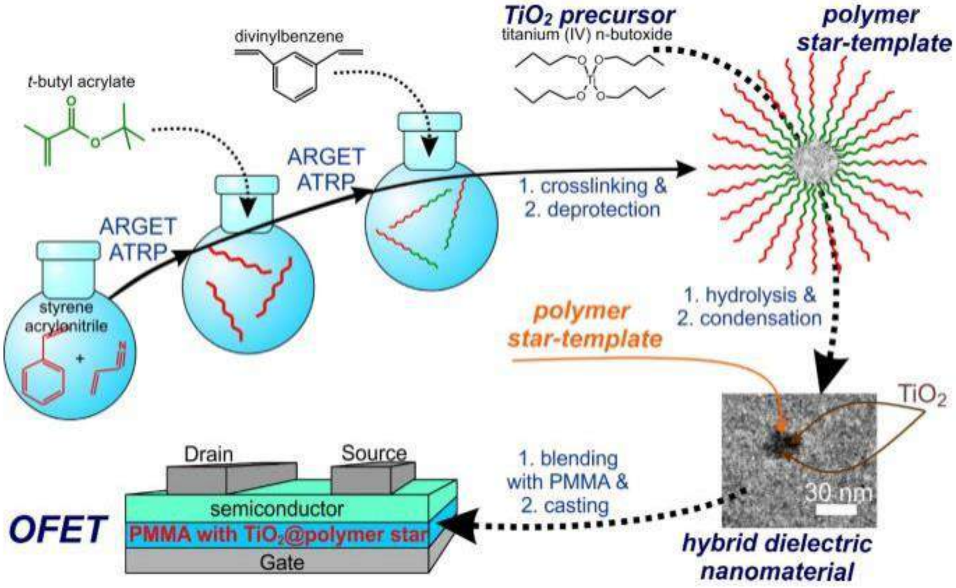
ATRP(Atom Transfer Radical Polymerisation) is a type of polymerisation, which can be perfectly controlled [1]. Using this mechanism, varied polymer topologies can be achieved [2], moreover the control over polymer composition, its molecular weight and functionality allows obtaining the materials with very unique properties [3].

Herein, we present the properties of star-shaped polymers, used as universal nanoreactors for the synthesis of titanium (IV) oxide nanoparticles. Obtained nanocomposites acted as components of dielectric layer in OFETs (Organic Field Electric Transistors) [4].



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References

[1] Siegwart, D.J., Oh J.K., Matyjaszewski K., *Progress in Polymer Science*, 2012, 37(1): p. 18-37.
[2] Pietrasik, J., et al., Macromolecular Templates for Synthesis of Inorganic Nanoparticles, 2018, p. 169-200.
[3] Rahimi M, Galeziewska M, Jerczynski K, Wrobel S, Pietrasik J., *Polymers for Advanced Technologies*, 2024, 35(4): e6387
[4] Budzalek K, Ding H, Janasz L., Wypych-Puszkarz A, Cetinkaya O., Pietrasik J., Kozanecki M., Ulanski J., Matyjaszewski K., *Journal of Materials Chemistry C*, 2021, 9(4): 1269-1278.

Ferrocene modification of protein imprinted MIP films

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Molecularly imprinted polymers (MIPs) are bio-mimicking recognizing materials used for sensors fabrication [1, 2]. Analytical parameters of these chemosensors, such as sensitivity, selectivity, and detectability, are almost as high as those of biosensors. MIP-based chemosensors are superior concerning their ease of fabrication, durability, and tolerance to harsh experimental conditions, including elevated or decreased temperature, high ionic strength, extreme pH values, the presence of heavy metal ions and organic solvents. Therefore, MIP-based chemosensors found numerous applications in environmental analysis [3], food quality control [4] and clinical analysis [5].

For the electrochemical determination of non-electroactive analytes, some external redox probe is usually added to the test solution [6, 7]. In our previous works we have proven that it is possible to immobilize redox probe inside of the MIPs' polymer matrix by co-polymerization of monomers containing ferrocene groups [8, 9]. These sensors enabled label-free sensitive determination of target analytes. Herein, ferrocene moieties were introduced to MIP molecular cavities via post-imprinting modification [10]. Obtained redox active MIPs' were characterized with scanning electrochemical microscopy and capacitive impedimetry.

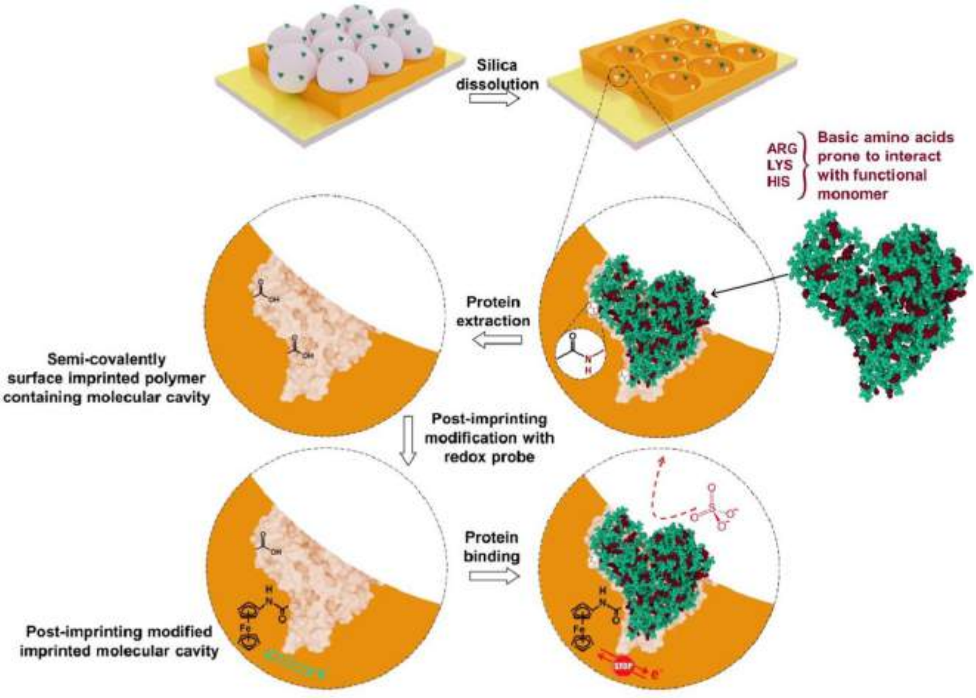

Figure 1: Fabrication of ferrocene modified MIP.

Acknowledgments

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References

[1] P.S. Sharma, Z. Iskierko, A. et al., Electrochem. Commun. 50 (2015) 81.
[2] L. Chen, X. Wang, et al., Chem. Soc. Rev. 45 (2016) 2137.
[3] P. Rebelo, E. Costa-Rama, et al., Biosens. Bioelectron. 172 (2021) 112719.
[4] J. Ashley, M.-A. Shahbazi, et al., Biosens. Bioelectron. 91 (2017) 606.
[5] M. Feroz, P. Vadgama, Electroanalysis 32 (2020) 2361.
[6] Y. Yoshimi, A. Narimatsu, et al., J. Artif. Organs 12 (2009) 264.
[7] P.S. Sharma, A. Garcia-Cruz, et al., Curr. Opin. Electroche. 16 (2019) 50.
[8] P. Lach, M. Cieplak, et al., Sens. Actuators B Chem. 344 (2021) 130276.
[9] P. Lach, A. Garcia-Cruz, et al., Biosensors and Bioelectronics 236 (2023) 115381.
[10] J. Kalecki, M. Cieplak, et al., Journal of Materials Chemistry B 11 (2023) 1659.

Development of MIP-Modified Gold Chips for Electrochemically Assisted Surface Plasmon Resonance Sensing

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Electrochemically assisted surface plasmon resonance (E-SPR) combines the optical sensitivity of traditional SPR with electrochemical control, enabling the development of advanced hybrid sensing platforms. This involves the use of Molecularly Imprinted Polymers (MIPs), structured as thin films or nanoparticles, deposited on gold SPR chips. These MIPs act as synthetic recognition elements with high selectivity for target analytes. Upon analyte binding, the MIP layer induces changes not only in the refractive index—detected via SPR—but also in the electrochemical behaviour of redox-active species [1]. This dual modulation leads to a new form of transduction, where both optical and electrochemical signals respond synergistically to molecular recognition events [2]. E-SPR platforms incorporating MIP layers hold significant promise for highly selective and sensitive chemosensing and biosensing applications, including clinical diagnostics, environmental monitoring, and food safety.

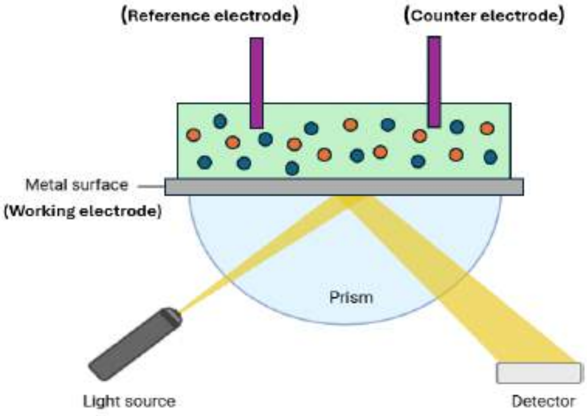

Figure 1: Electrochemically assisted SPR for sensing

Acknowledgments

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References

[1] Lach, P., et al., *Self-reporting molecularly imprinted polymer with the covalently immobilized ferrocene redox probe for selective electrochemical sensing of p-synephrine.* Sensors and Actuators B: Chemical, 2021. **344**: p. 130276.
[2] Wang, S., et al., *Electrochemical surface plasmon resonance: basic formalism and experimental validation.* Analytical chemistry, 2010. **82**(3): p. 935-941.

Catalytic Degradation of Pharmaceuticals by Ferrocene-Modified Polypyrrole Nanoparticles

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The rapid development of medicine and pharmacy observed in recent decades has significantly improved people's quality of life and average lifespan, largely due to patients taking appropriately selected effective pharmaceuticals. However, the prevalence of drugs reaches an alarming level, as evidenced by statistics conducted in the United States in 2021, which show that more than half of Americans take medications prescribed by doctors every day [1]. Such high demand generates the increase in the content of drugs and their metabolites in the environment yearly, exposing flora, fauna, and people themselves [2].

More than ever, it is therefore necessary to focus on materials that effectively break down pharmaceuticals and explore ways to use these materials in the large-scale purification of environmental samples from undesirable chemicals. The polypyrrole nanoparticles we synthesized and then chemically modified with a ferrocene derivative proved an excellent matrix for the photochemical degradation of duloxetine – one of the most popular drugs against depression. Their small size of around 50 nm implies a high surface-to-volume ratio, making them an excellent material for heterogeneous catalysis (Figure 1a). Our study demonstrated the photochemical activity of ferrocene-modified polypyrrole nanoparticles (NP2F) after irradiation of aqueous solutions of duloxetine with an ultraviolet lamp. The changes in drug concentration over time during photochemical degradation activity were controlled using UV-Vis spectrophotometry. Our preliminary results showed that only two hours of UV irradiation in the presence of a 1% suspension of nanoparticles was enough to degrade approx. 50% of the drug (Figure 1b), which sheds light on the potential use of our material for large-scale applications.

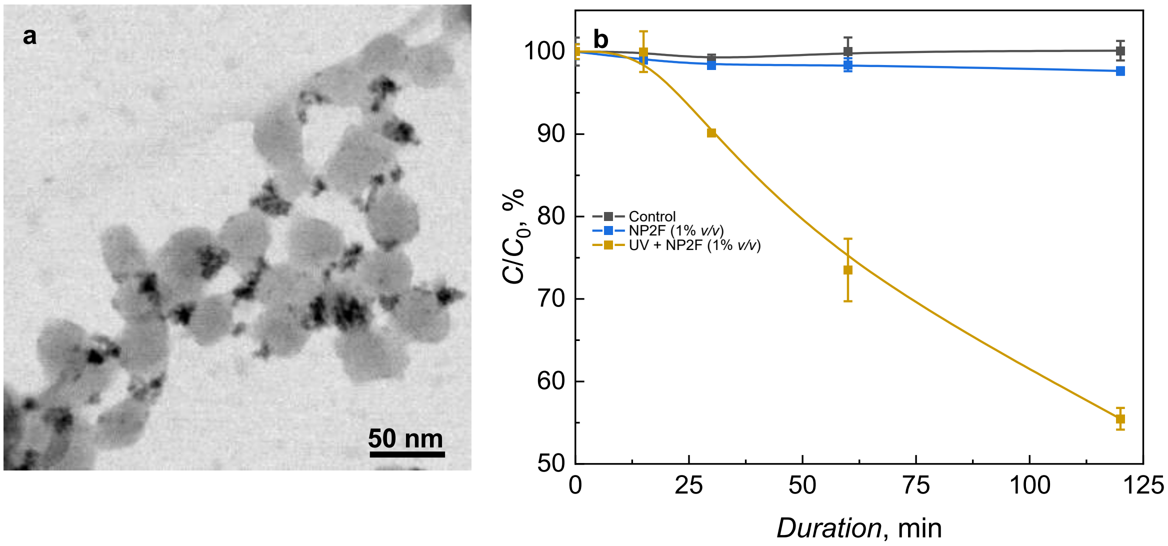

Figure 1: (a) TEM image of ferrocene-modified polypyrrole nanoparticles. (b) Concentration profiles of duloxetine degradation observed in the presence of ferrocene-modified polypyrrole nanoparticles alone and under UV irradiation. Control measurement was performed in the absence of NPs and UV.

Acknowledgments

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References

[1] A. Fleck, "More Than Half of Americans Take Prescribed Meds Daily", *Statista*, (2023).
[2] S.L. Gould, M.J. Winter, W.H.J. Norton, and C.R. Tyler, *Environ. Sci. Technol.* **55**, 16299−16312 (2021).

Pyrolyzed MOF-based Solid Contacts for Stable and Reproducible Potentiometric Sensors

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Potentiometric sensors are widely used for ion activity monitoring due to their simple design and high selectivity. Their performance critically depends on the solid-state transducer layer, which governs potential stability and reproducibility.

Metal–organic frameworks (MOFs) are promising candidates for solid-contact layers because of their tunable porosity, high surface area, and adjustable chemistry. Here, we report the mechanochemical synthesis of cobalt imidazolate frameworks (ZIF-67) and ZIF-67 with encapsulated fullerene C_{60} as an efficient, green alternative for preparing MOF-based solid contacts.

We systematically investigated how in-pore fullerene encapsulation and subsequent pyrolysis affect ZIF-67's structure (PXRD, FTIR), capacitance (electrochemical impedance spectroscopy), and hydrophobicity (water contact angle). Pyrolysis of the fullerene encapsulated ZIF-67 at 750 °C, in nitrogen atmosphere resulted in a superhydrophobic material, with a water contact angle higher than 160°. Our results show that optimized MOF-based solid contacts significantly enhance electrode response reproducibility and long-term stability by minimizing potential drift compared to bare commercial screen-printed electrodes.

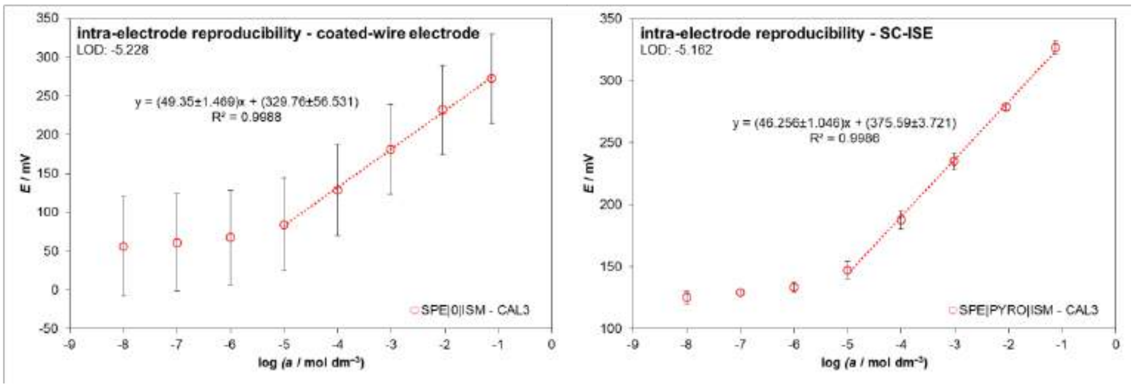

Figure 1: Potentiometric response reproducibility of screen-printed electrodes before and after including the pyrolised solid-state transducer layer.

Acknowledgments

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Fe_3O_4@Pt@Polylevodopa nanozymes and their application for sensitive detection of SARS-CoV-2 antigen

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Nanozymes mimic enzymatic activity, offering promising potential for developing robust bioassays and biosensors [1]. Herein, we report (Fe_3O_4@Pt@Polylevodopa) nanozymes. Platinum nanoislands were deposited on magnetite nanoparticles, followed by polymerisation of levodopa to introduce functional groups and impart the desired properties. The nanoparticles were thoroughly examined at each stage of synthesis. The immobilisation of a SARS-CoV-2 antibody (Ab1) was applied to obtain functional bioconjugates, which were employed in a colorimetric immunoassay targeting the SARS-CoV-2 nucleoprotein. Antigen binding formed a sandwich complex with a secondary antibody (Ab2) on a microplate. The important observations of the proposed system will be discussed within the framework of this presentation.

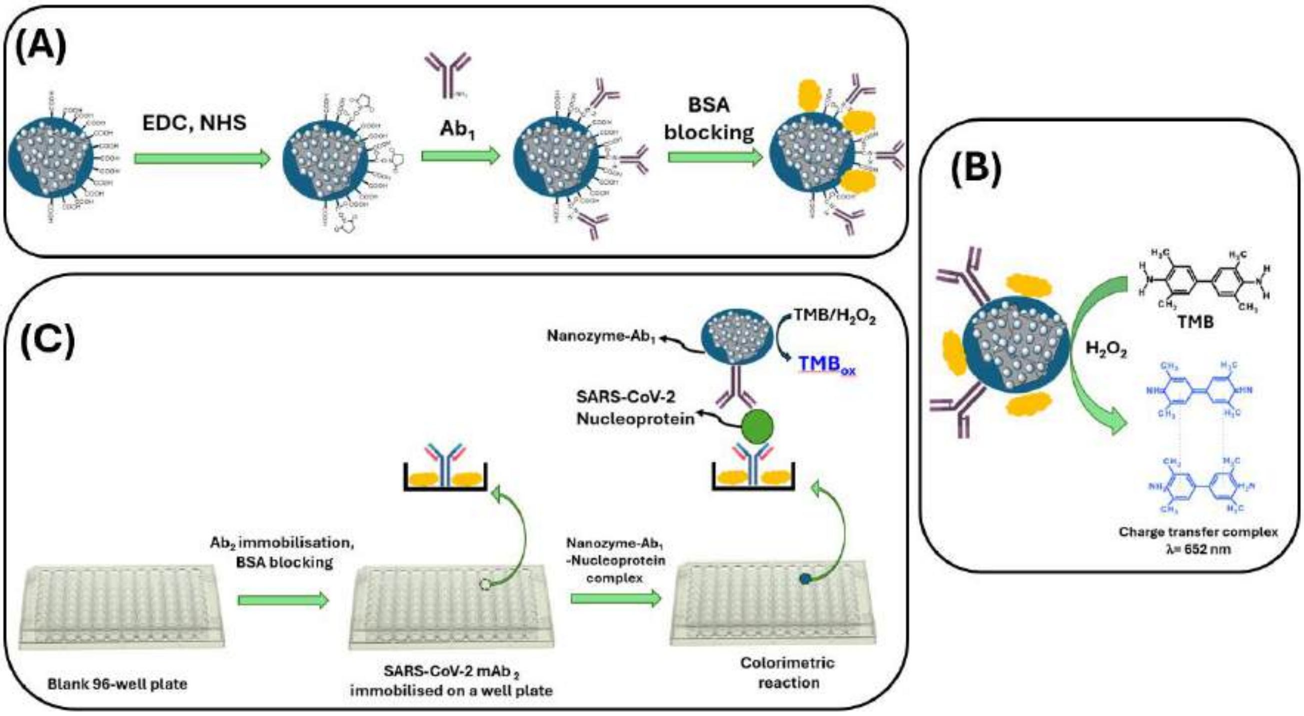

Figure 1: Schematic illustration of (A) the preparation Fe_3O_4@Pt@Polylevodopa -Ab_1 bioconjugates, (B) peroxidase-like activity of the nanocomposite, and (C) process involved in Fe_3O_4@Pt@Polylevodopa nanozyme-based immunosensing of SARS-CoV-2 nucleoprotein detection.

Acknowledgements

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References

[1] M. Wang, H. Liu, and K. Fan, *Small Methods*, **7** (2023).

One-pot functionalization of liposomes with gold nanoparticles: combining electrostatic and covalent strategies for tailored biological interactions

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Surface modification is a key strategy for tailoring the physicochemical and biological performance of nanocarriers in biomedical applications. Gold-modified liposomes (LipoAuNPs) represent a versatile class of hybrid nanostructures with promising potential not only as drug delivery systems but also as functional platforms for biochemical sensing, thermal imaging, and combined anticancer therapy. In addition to providing a functionalizable surface that enables signal amplification, supports electrochemical signal generation, and can be readily integrated with sensing platforms, the liposomal matrix can reduce the tendency of gold nanoparticles to aggregate, thereby improving their colloidal stability. Moreover, anchoring AuNPs on the liposomal surface alters their optical properties, including the maximum absorption wavelength, enabling fine-tuning of plasmonic characteristics to match specific diagnostic or therapeutic needs.

In this work, we present a facile, one-step approach to engineer liposomal surfaces with gold nanoparticles (AuNPs), yielding LipoAuNPs that combine the high drug encapsulation capacity of liposomes with the unique optical and electronic properties of AuNPs. The attachment of AuNPs is achieved through a synergistic mechanism involving electrostatic attraction between permanently cationic liposomes and negatively charged AuNPs, as well as covalent anchoring via thiol-containing lipids. Formation of LipoAuNPs was confirmed using ζ-potential analysis, dynamic light scattering (DLS), transmission electron microscopy (TEM), and voltammetric measurements at the electrified liquid–liquid interface. Surface modification significantly altered the biological interactions of the liposomes: flow cytometry revealed enhanced cellular uptake by cancer cells, while confocal microscopy demonstrated reduced colocalization with acidic compartments, suggesting improved endosomal escape. These findings highlight how nanoscale surface engineering can profoundly influence nanocarrier behavior, offering a versatile platform for designing next-generation drug delivery systems, multifunctional biosensing interfaces, and theranostic nanomaterials.

Acknowledgments

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Electrochemical Studies of Branched Carbazole Monomers and their Polymer Films – towards application for the Molecularly Imprinted Polymers

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Electrochemical studies on three selected branched carbazole monomers with cross-linking properties, as well as their polymer films, were conducted in order to assess their potential application in the synthesis of molecularly imprinted polymers (MIPs) [1]. The studied structures differ in the number of phenyl rings and the presence or absence of thiophene substituents, which are expected to influence the polymerization process, as well as properties of the resulting polymer films. The primary objective was to evaluate the electroactivity of both the monomers and the polymer layers electrochemically deposited on electrode surfaces and to investigate how structural variations between the monomers affect the electrochemical behaviour and morphology of their corresponding polymers.

The polymer films were electrodeposited under potentiodynamic conditions and their electrochemical behavior of the monomers was analysed. Subsequently, the fabricated polymer films were subjected to detailed electrochemical characterization. Special attention was given to the reversibility and character of redox processes occurring within the polymer layers.

The morphology of the deposited films was investigated using scanning electron microscopy (SEM), which enabled the assessment of layer uniformity and the identification of structural differences between the polymers prepared from various monomers. Furthermore, spectral characterization of the polymer films was performed in order to gain insight in the film composition and electronic properties. To gain deeper insight into the polymerization mechanism, density functional theory (DFT) calculations of the monomers and their cation radicals were performed. These computational studies provided information on the geometric and electronic structures of the monomers and their influence on the resulting polymer properties.

The results lay the groundwork for further studies on employing these monomers in the synthesis of MIPs selective toward antiviral drugs intended for use as recognition layers in chemosensors for the detection of pharmaceuticals in human body fluid samples.

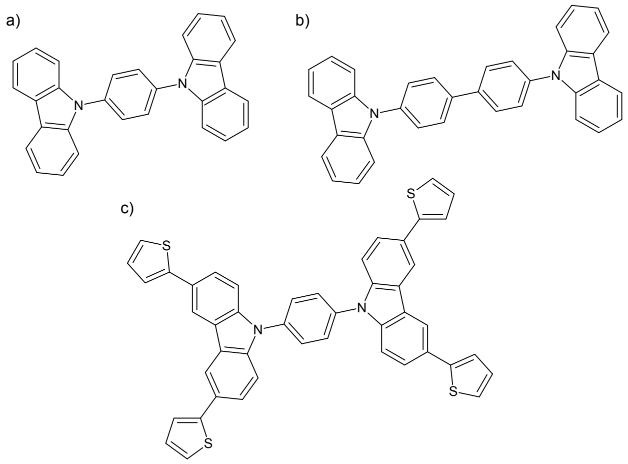

Figure 1: Investigated cross-linking structures:
a) Carb-Phe-Carb, b) Carb-Phe-Phe-Carb, c) Th-Carb-Phe-Carb-Th.

Acknowledgments

This work was supported by the National Science Centre (NCN) under grant OPUS25 2023/49/B/NZ7/02718.

References

[1] Gajda M. et al., *Biosens Bioelectron*, **169**, 112589 (2020)

Electrocatalysis via Freely Dispersed Au Nanoparticles at Ultramicroelectrode in Alkaline Media

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Gold nanoparticles (Au NPs) are widely known for their high surface reactivity and electrocatalytic potential, making them useful in various applications such as sensing, energy storage, and catalysis. This study investigates the electrocatalytic behavior of freely dispersed Au NPs in alkaline media using chronoamperometry and cyclic voltammetry at a carbon fiber microelectrode.

Unlike traditional systems where nanoparticles are immobilised on electrodes, this work demonstrates that non-immobilised Au NPs can also significantly enhance catalytic processes and currents, particularly above 0.7 V vs Ag/AgCl (Figure 1). We observe that the catalytic enhancement is strongly dependent on the electrolyte composition and scan rate.

This work introduces a non-conventional catalytic mode where transient interactions such as brief adsorption, collisions, or near-surface electron transfer might be facilitating charge transfer. This behaviour resembles concepts from impact electrochemistry, where individual nanoparticles catalyse reactions during stochastic collisions with an electrode. The findings offer a perspective on nanoparticle-mediated catalysis and suggest promising routes for developing dynamic, solution-based electrochemical systems.

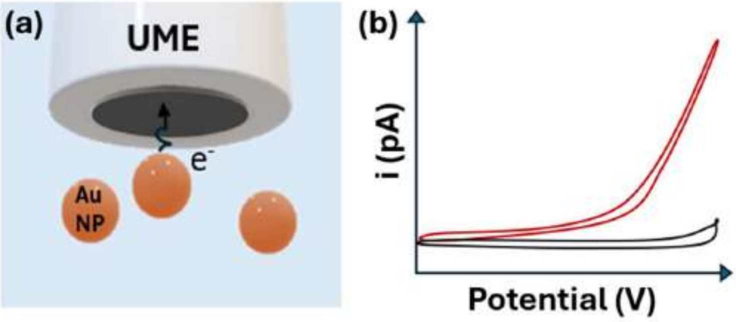

Figure 1. (a) Interaction and assembling of nanoparticle with microelectrode surface, (b) corresponding cyclic voltammogram showing catalytic activity in the presence of solution-dispersed Au nanoparticles.

Acknowledgments

The financial support from National Science Centre, Poland (OPUS nr. 2023/49/B/ST11/01771) is greatly acknowledged.

References

[1] Sani, Mahnaz Azimzadeh, and Kristina Tschulik. *Current Opinion in Electrochemistry* 37 (2023): 101195.
[2] Peng, Yue-Yi, et al. *ChemElectroChem* 5.20 (2018): 2982-2985.
[3] Patrice, Fato Tano, et al. *Annual Review of Analytical Chemistry* 12.1 (2019): 347-370.

Functional Conducting Polymer: Synthesis and Its Application in Chemosensing

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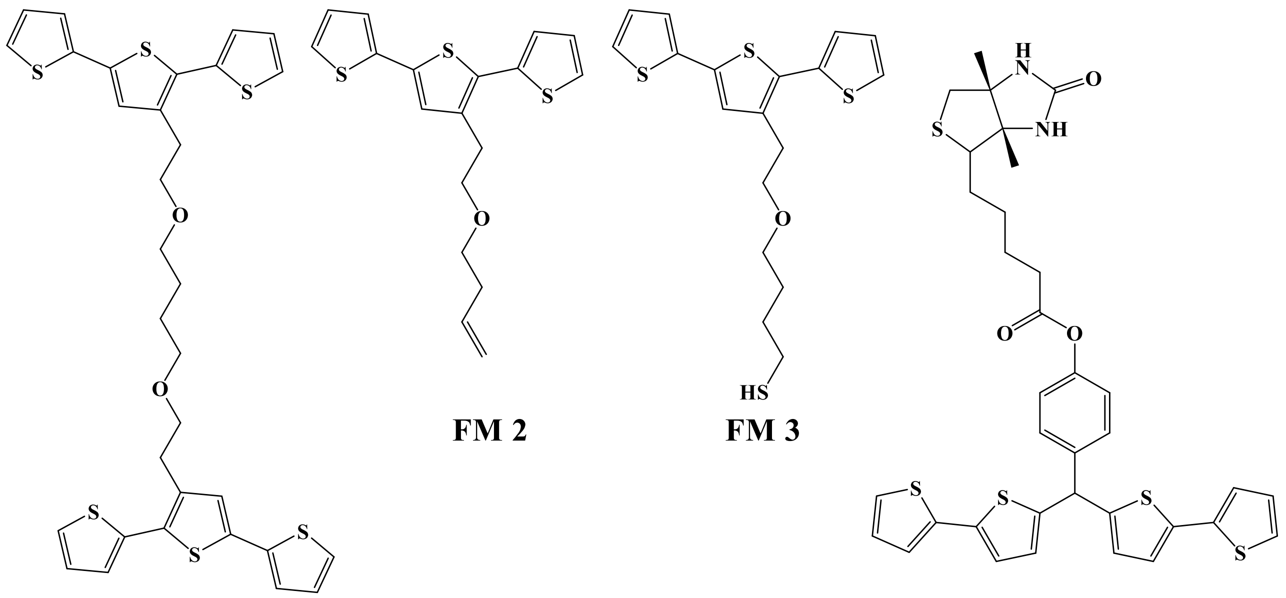
Current work describes the synthesis and electrochemical studies of derivatives of bis-bithiophene and terthiophene (Scheme 1). We studied the influence of solvents and the supporting electrolytes on the resulting polymer morphology and electrochemical stability after electropolymerization. The structural formulas of the studied monomers are provided in Scheme 1. Among all studied monomers, the lowest oxidation potential was observed for **FM** 1, and the highest oxidation potential was observed for **FM 4**. Additionally, we investigated the morphology of the functionalized conducting polymer by SEM. Later, we correlate the morphology of the polymer with electrochemical stability. In the final step, we foresee the application of these functional monomers in chemosensing of antibiotics, which is in progress.



FM 1 **FM 2** **FM 3** **FM 4**

Scheme 1. Structural formulas of different derivatives of terthiophene and bisbithiophene.

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Electroactive Polypyrrole Nanoparticles for Different Functions

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Here, we report synthesis of poly(vinyl alcohol) (PVA)-based polypyrrole (PPy) nanoparticles (NPs) with high electroactivity. The polymerization process, initiated by $FeCl_3$, is known for obtaining the PPy with appreciable conductivity [1]. Polymer growth was terminated with an excess of PVA chains, surrounding the forming polymer structures with PVA chains by limiting the interactions between pyrrole cation radicals. Hence, the polymer formation was terminated on the stage of NPs, not on a bulk polymer (Figure 1a).

Additionally, we synthesized PVA-stabilized PPy NPs enriched with a mer derivatized with carboxyl groups. Copolymerization with a carboxyl derivative was confirmed by XPS. DLS measurement confirmed that copolymerization with a carboxyl derivative of pyrrole introduced charge and electrostatic properties on the NPs, which resulted in the increase of zeta potential. SEM imaging confirmed the synthesis of spherical (Fig. 1a), uniformly small and well-dispersed NPs of the size below 50 nm (Figure 1b).

These PPy and PPy-PyCOOH NPs were extensively characterized by CV. PPy NPs showed high electroactivity in comparison to PPy-PyCOOH NPs. The redox activity of $K_4Fe(CN)_6/K_3Fe(CN)_6$ measured over PPyNP modified shows current enhancement (Figure 1c). However, such enhancement was only visible when potential was scanned in the potential window where PPy electroactivity was observed.

Electroactivity of PPy-PyCOOH NPs was slightly lower than PPy NPs. Presence of COOH group on NPs allowed further modification of the NPs with ferrocene moiety. NPs with functionally tuned shell surfaces can be applied in applications, such as electrocatalysis, and sensing.

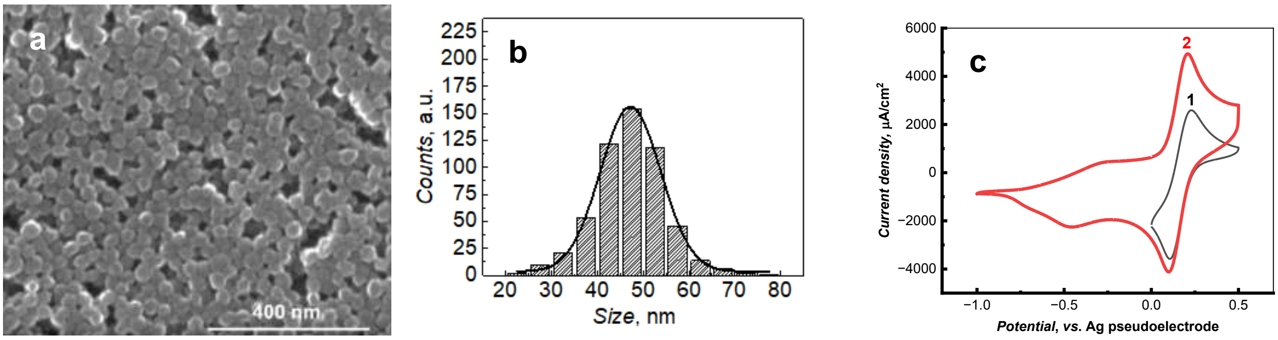

Figure 1. (a) SEM image of PPy NPs and (b) statistical size distribution. (c) CV measured on PPy NP modified GC in the presence of 10 mM $K_4Fe(CN)_6/K_3Fe(CN)_6$ in 100 mM phosphate buffer containing NaCl and KCl.

Acknowledgment

The present research was financed by the National Science Centre, Poland, within the OPUS grant UMO-2023/49/B/ST11/01771.

Reference

[1] X. Zhang, J. Zhang, W. Song, Z. Lu, Controllable synthesis of conducting polypyrrole nanostructures, J. Phys. Chem. B. 110 (2006) 1158–1165.

[2] A. Kisiel, D. Korol, A. Michalska, Krzysztof Maksymiuk, Polypyrrole nanoparticles of high electroactivity. Simple synthesis methods and studies on electrochemical properties, Electrochim. Acta 390 (2021) 138787.

Refinement of fast-scan cyclic voltammetry for improved dopamine detection in physiological environments

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Dopamine, as one of the principal monoaminergic neurotransmitters, plays a pivotal role in regulating both neurological and physiological processes in the human body [1]. It modulates a wide range of functions, including mood, motivation, reward, learning, memory consolidation, and motor control [2]. Beyond the central nervous system, dopamine is also involved in the regulation of cardiovascular function, endocrine signaling, and renal activity. Its role in the extrapyramidal motor system is particularly crucial, where it contributes to the coordination and regulation of skeletal muscle tone and voluntary movements [3].

Dysregulation of dopamine transmission—whether through excessive degradation, receptor malfunction, or impaired synthesis—is strongly implicated in a spectrum of neurodegenerative and psychiatric conditions, such as Parkinson's disease, schizophrenia, depression, and attention-deficit disorders [4]. As such, dopamine serves not only as a target of therapeutic intervention but also as a highly informative biomarker in both clinical diagnostics and research.

Given its central biological role, there is a growing demand for analytical methods capable of monitoring dopamine concentrations with high temporal and spatial resolution, especially under physiologically relevant conditions, both in vitro and in vivo. Among the available techniques, electrochemical sensing has emerged as a promising approach due to its affordability, simplicity, and compatibility with miniaturized platforms. In particular, fast-scan cyclic voltammetry (FSCV) offers real-time monitoring of sub-second fluctuations in neurotransmitter levels, making it especially suited for dynamic neurochemical investigations [5].

This study aimed to develop a refined FSCV protocol that enhances the sensitivity and selectivity of dopamine detection while addressing the challenges posed by complex biological matrices. Furthermore, we designed and fabricated custom carbon-based microelectrodes, modified with nanostructured materials, to further improve detection accuracy and reproducibility. The integration of these approaches contributes to the advancement of robust electrochemical tools for neurochemical sensing in both fundamental research and potential clinical applications.

Acknowledgments

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References

[1] A.G. Salinas, J.O. Lee, S.M. Augustin, S. Zhang, T. Patriarchi, L. Tian, M. Morales, Y. Mateo, D.M. Lovinger, Nat. Commun. 14, 5915 (2023).

[2] L. Liv, *Synth. Met.* **309**, 117765 (2024).

[3] Kong, Z. Zhang, L. Zhang, Z. Huang, X. Liu, H. Deng, Z. Liu, J. Cui, X. Li, Z. Xu, W. Zheng, Diamond Relat. Mater. 149, 111540 (2024).

[4] B.P. Guiard, G. Gotti, *Molecules* **29**(2), 496 (2024).

[5] B.J. Venton, Q. Cao, *Analyst* **145**, 1158–1168 (2020).

E-SPR analysis for MIP sensors

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Electrochemical Surface Plasmon Resonance spectrometry (E-SPR) [1-3] is an advanced technique that combines electrochemical techniques with readout of plasmonic effects to study interfacial interactions at the electrode surface. It allows to gather both electrochemical and optical information simultaneously, by using gold substrate as working electrode and as reflecting object [1]. Optimization of E-SPR involves selecting appropriate electrochemical conditions and observing plasmonic effects using proper wavelength and angle of incident light. This way, sensor's selectivity, detection limits and sensitivity may be improved. The principle of E-SPR method has been illustrated on Figure 1.

The aim of this project is to examine the potential of E-SPR application for sensors based on molecularly imprinted polymers (MIP) devising. To this end, SPR and cyclic voltammetry (CV) operating parameters were optimized, providing reproducible conditions and synchronized results.

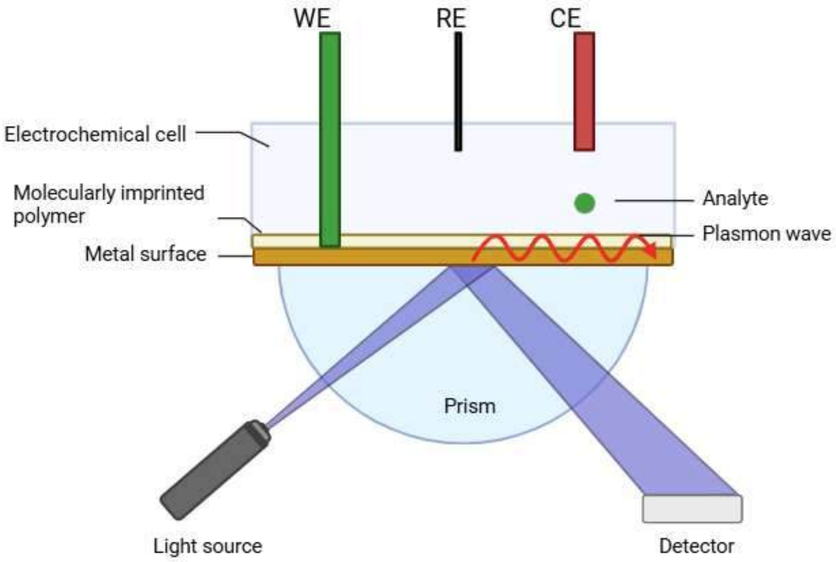

Figure 1. Ilustrative scheme of E-SPR system. Created in https://BioRender.com

Acknowledgments

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References

[1] A. Baba, P. Taranekar, R. R. Ponnapati, W. Knoll, and R. C. Advincula, *ACS Appl. Mater. Interfaces* **2**, 2347 (2010).
[2] A. Blidar, B. Feier, M. Tertis, *et al.*, *Anal. Bioanal. Chem.* **411**, 1053 (2019).
[3] H. Yang, X. Xu, and B. Shu, *Int. J. Electrochem. Sci.* **19**(9), 100739 (2024).

Interactions of Organometallic Galectin Ligands with Serum Albumin Using Electrochemical Approaches

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Galectin protein interactions play a crucial role in numerous biological processes, such as cell adhesion, immunosuppression, cell signaling, and, notably, tumor metastasis. Studying these interactions with natural or synthetic ligands is essential for understanding their nature and for the development of potential therapeutics [1].

Electrochemical properties of ferrocene ligands containing one or two ferrocene moieties attached to mono- or disaccharide scaffolds were studied using cyclic voltammetry (CV), AC voltammetry (ACV), and chronopotentiometric stripping analysis (CPS) at hanging mercury drop electrode (HMDE), as well as fluorescence spectroscopy. Their interactions with the electrode surface and bovine serum albumin (BSA) were also investigated. Due to the hydrophobic nature of the ligands, an organic cosolvent was required for effective dissolution. Dimethyl sulfoxide (DMSO) was chosen for this purpose. DMSO can also influence ligand affinity to surfaces and proteins, and this effect was examined in the study.

Monoferrocene ligands, being more hydrophilic, exhibited diffusion-controlled electrode processes, while bisferrocene analogs showed better adsorption onto the surface due to their more hydrophobic character. Dissociation constants for interactions with BSA were determined using fluorescence of tryptophan and tyrosine residues, with the highest affinity observed for the bisferrocene disaccharide (thiodigalactoside). These interactions were also studied using CPS. The influence of DMSO on ligand interactions with the surface and BSA was analyzed using ACV and CPS. Around a potential of –0.5 V, strong adsorption onto the mercury drop was observed, which was more pronounced for biferrocene ligands and inhibited by increasing concentrations of DMSO. Low DMSO concentrations (up to 1 %) enhanced ligand binding to BSA, while higher concentrations (up to 5 %) significantly reduced this binding.

This work provides insight into the interactions of ferrocene ligands with the mercury drop surface and serum albumin, and demonstrates the influence of an organic cosolvent on interaction affinity. The presented electrochemical methods can serve as simple, fast, and cost-effective techniques for studying these interactions.

Acknowledgments

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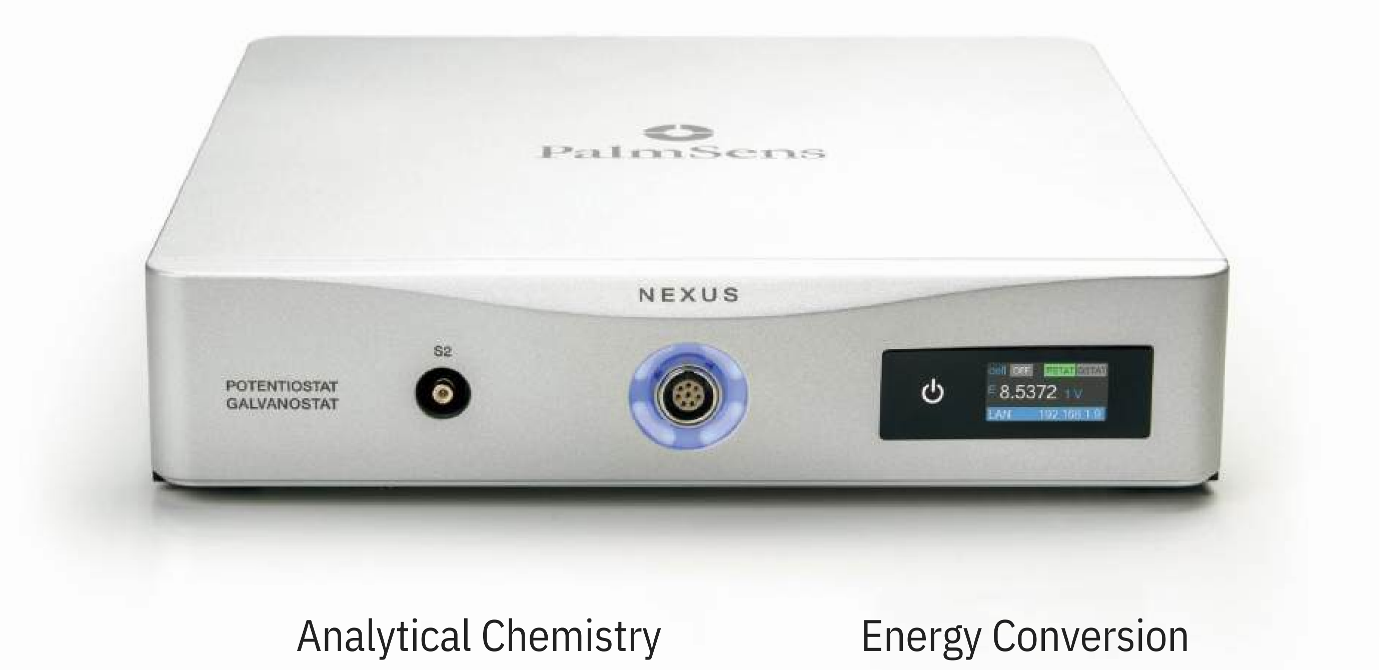
References

[1] V. Hamala, M. Kurfiřt, L. Červenková Šťastná, H. Hujerová, J. Bernášková, K. Parkan, J. Kaminský, N. Habanová, J. Kozák, A. Magdolenová, M. Zavřel, T. Staroňová, V. Ostatná, L. Žaloudková, A. Daňhel, J. Holčáková, P. Voňka, R. Hrstka, J. Karban, Ferrocene- and ruthenium arene-containing glycomimetics as selective inhibitors of human galectin-1 and -3, Inorg. Chem. Front. 11 (2024) 7588–7609. https://doi.org/10.1039/D4QI01555J.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