Book of Abstracts

16th International Workshop on Engineering of Functional Interfaces (EnFI2025)

London, 7-8 July 2025

Queen Mary University of London

School of Engineering and Materials Science

Sponsored by

Welcome to EnFI 2025

Dear Colleagues,

On behalf of the organising committee and the scientific advisory board, it is my great pleasure to welcome you to the 16th International Workshop on Engineering of Functional Interfaces (EnFI2025) at Queen Mary University of London (QMUL). This is the first time for this workshop to be hosted in the UK, and I am immensely grateful that you have taken the time and effort to attend and contribute.

Queen Mary has a long, proud history built on four historic institutions stretching back to 1123 including St Bartholomew's Hospital Medical College, London Hospital Medical College, Westfield College and Queen Mary College.

Today, Queen Mary has six campuses across East and Central London as well as an international presence in China, France, Greece and Malta. The Mile End campus is the largest self-contained campus of any London-based university. Queen Mary is organised into three faculties – the Faculty of Humanities and Social Sciences, the Faculty of Science and Engineering, and Barts and The London School of Medicine and Dentistry. In 2023/24 the university had around 26,000 students. Queen Mary is a member of the Russell Group of British research universities.

This year, we will, once again, follow the tried and tested format of previous EnFIs. Four internationally renowned speakers will kick off our four sessions: A: Advanced Materials and Characterisation, B: Biological interfaces and Sensors, C: Molecularly imprinted polymer and sensors, D: Electrochemical Methods and Sensors. Poster presenters will advertise their work in short 3-min flash talks, which will be followed by 1-hour poster sessions giving all participants ample time for discussion and networking.

Talks will be presented in the Skeel Lecture Theatre; the poster sessions, which double as coffee breaks and lunch will take place in the Great Hall. The conference dinner will be held in the iconic Octagon. Built in 1887, the Octagon was originally the Queen Mary library, designed by Victorian architect ER Robson and inspired by the Reading Room at the British Museum. It is a beautiful room with a high domed ceiling and bookshelves with brightly coloured leather-bound books lining the walls creating an atmospheric setting.

At the end of the workshop on Tuesday, you will have the opportunity to visit some of our labs in the School of Engineering and Materials Science. As every year, you will have the option to publish your results in a topical section on "Engineering of Functional Interfaces" in the journal *Physica Status Solidi A.*

I wish you a very enjoyable and productive conference with many interesting discussions and lots of fun.

Steffi Krause

(Chair of EnFI 2025)

Organizing Committee

Steffi KRAUSE	Queen Mary University of London
Christopher CHAPMAN	Queen Mary University of London
Marloes PEETERS	University of Manchester
Ying TU	Imperial College London

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Practical Information

At registration, you will be given a name badge that should wear at all times as it will give you access to coffee breaks, lunch and dinner. A certificate of attendance will be sent to registered participants by email upon request after the conference.

The conference venue

The conference will be held in the People's Palace on the Mile End campus of QMUL, which is located on Mile End Road, a short walk from two tube stations, Mile End Station and Bethnal Green Station. Mile End Station is on the Central, District and Hammersmith and City lines; Bethnal Green is on the District and Hammersmith and City lines.

The entrance to the People's Palace is easy to spot as it is to the left of the clock tower of QMUL. The registration desk will be in the foyer of the people's palace, from where you can walk straight into the Great Hall to set up your posters. The Skeel lecture theatre where the oral presentation will be given is upstairs in the People's Palace.

Tutorial Lectures

Tutorial lectures are scheduled to last 40 minutes plus 10 minutes of discussion.

Flash talks

The short oral presentations have to be presented with PowerPoint and are strictly limited to 3 minutes.

Please double-check the schedule to find out what your presentation and poster numbers are. If you have not sent your presentation by email before the deadline announced by the conference organization, there are EnFI organizing team members present in the conference hall that will help you to load your presentation on the computer used for presenting. Please check beforehand in which section you will present and bring your presentation on a flash drive 1 hour before the start of the topical section, i.e. before the tutorial lecture. The PowerPoint file has to be named according to the assigned poster number and with the last name (e.g. A20_Krause).

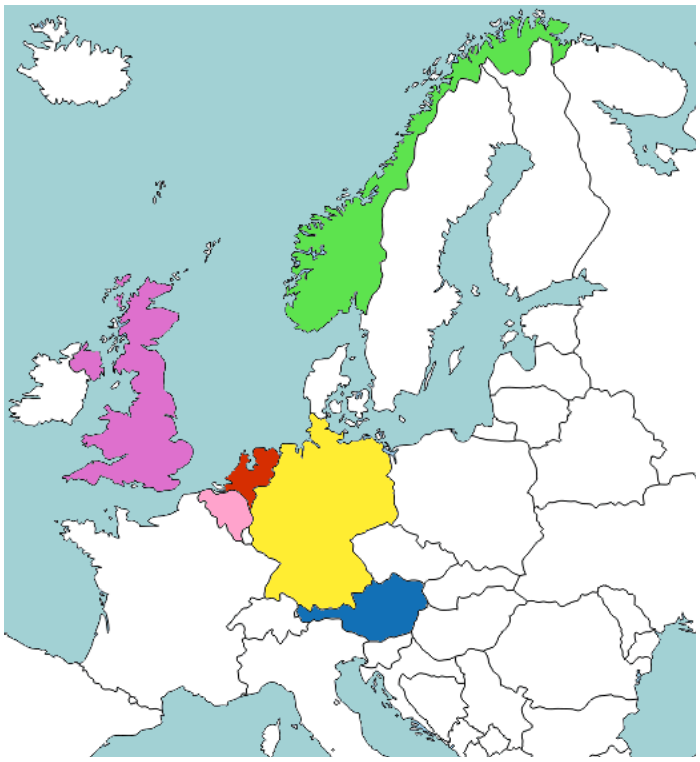
Poster presentation

The poster sessions will take place in the Great Hall. Poster boards will be labelled with the session codes and poster numbers, e.g. A10. The poster boards accommodate A0 posters presented in portrait format. Please arrive punctually at 8.30am on 7th July to put up your poster before the first session. Your poster will stay up for the entire duration of the workshop to allow for as much discussion and networking as possible. Please stay by your poster during the session you are presenting in so that other people can find you and chat with you about your work.

WIFI

Two free Wi-Fi networks are available on campus, Eduroam if you have an account through your institution and QMUL visitor.

EnFI 2025 participants by geographical spread



Austria: Johannes Kepler Universität Linz,

Belgium: Katholieke Universiteit Leuven

Germany: Hannover Medical School, Lower Saxony Centre for Biomedical Engineering, Rheinisch-Westfälische Technische Hochschule Aachen, University of Applied Science Aachen, Forschungszentrum Jülich, University of Hamburg

Japan: Kyoto Institute of Technology, Tohoku University

The Netherlands: Maastricht University

Norway: University of Oslo

United Kingdom: Queen Mary University of London, Imperial College London, University of Manchester, University of Bath, Alvatek Ltd, ATG Scientific Ltd, SciMed Ltd

Scientific Programme

Day 1 - Monday 7th July 2025

8:30 Registration (Tea, Coffee and Pastries)

9:00 Opening

Session A:

9:15 **Tutorial Lecture A:** Prof. Petra Agota Szilagyi (University of Oslo)
MOF-guest interfaces and their relevance in catalytic reactions

10:05 Poster Teaser A

11:00 Poster Market A (Tea and Coffee)

12:00 Lunch

Session B:

13:00 **Tutorial Lecture B:** Prof. Julien Gautrot (Queen Mary University of London)
Engineering Protein Assemblies and the Mechanics of Liquid-Liquid Interfaces for Stem Cell Technologies

13:50 Poster Teaser B

14:50 Poster Market: (Tea and Coffee)

Session C:

15:50 **Tutorial Lecture C:** Prof. Tom McDonald (University of Manchester)
Long-acting Therapeutics Enabled by Nanomedicines

16:40 Poster Teaser C

17:40 Poster Market: (Tea and Coffee)

18:40 Group Photo in front of the venue

19:00 Dinner in the Octagon

22:00 End of day 1

Day 2 - Tuesday 8th July 2025

Session D:

8.30 Tea, Coffee and Pastries

9:00 **Tutorial Lecture D:** Prof. Pedro Estrela (University of Bath)
Electrochemical Biosensors and Biodevices for Medical Diagnosis and Water Monitoring

9:50 Poster Teaser D

10:50 Poster Market D (Tea and Coffee)

12:00 Lunch

Closing Session

13:00 Poster Prices

Announcements EnFI2026,

Closing

13:30 Lab tours

16:00 End of EnFI

Topical Session A: Advanced Materials and Characterisation

Topical Session B: Biological interfaces and Sensors

Topical Session C: Molecularly imprinted polymer and sensors

Topical Session D: Electrochemical Methods and Sessions

Call for papers

physica status solidi a applications and materials science

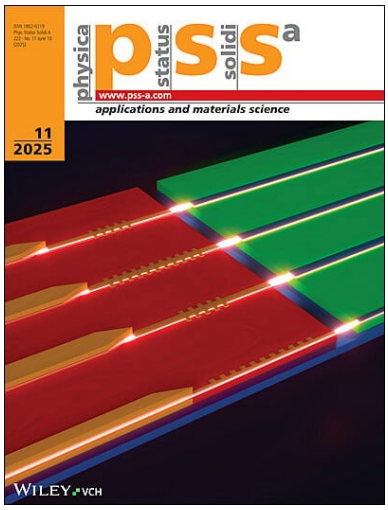
On behalf of our Guest Editors and organizing committee members of the EnFI series Steffi Krause, Patrick Wagner, Michael Josef Schöning and Theodor Doll, we sincerely invite you to contribute to this upcoming regular special issue (no conference proceedings)

Engineering of Functional Interfaces 2025

that will be published **in Physica Status Solidi A: Applications and Materials Science**. You are welcome to submit a Review or a Research Article manuscript (with new unpublished results) based on, or related to your conference presentation.

pss a is a peer-reviewed, well-known journal that is indexed in Web of Science (Impact Factor 2023 is 1.9). Articles related to EnFI fit perfectly to the scope of the journal and are regularly highlighted as cover articles already since 2009.

pss a is a hybrid Open Access (OA)/subscription journal. The OA option is compliant with national or funder mandates, supported by an ever-increasing number of countries and institutions around the world. Wiley has OA agreements with many European and other countries as well as academic and research institutions, for details see Wiley Author Services (https://bit.ly/3DZiqbd) and contact us with questions.



Deadline for papers to be included in the Topical section is **1st December 2025**.

MOF-guest interfaces and their relevance in catalytic reactions

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Abstract: Metal-organic frameworks (MOF) may effectively be described as a large extended inorganic-organic hybrid surface, organised in 3D through open micropores. As such they afford an unparalleled platform for generating and engineering functional interfaces between the MOF matrix and intrinsic or extrinsic guest molecules, ions, particles, etc. Through such intimate interface engineering on the atomistic scale gives rise to unprecedented properties, which may be exploited for sustainability applications.

Keywords: metal-organic frameworks, nanoclusters, ion conductivity, host-guest interactions

Introduction

MOFs are porous crystalline inorganic-organic hybrid materials with tuneable chemistry and textural properties. [1] We have previously demonstrated that the interaction of small molecules [2], metal atoms [3] and metal nanoclusters [4] may result in altering the properties of the guests. This change consequently can be exploited to tune the properties of the guest for particular functions, such as applications for sustainability, of which a few examples will be given.

Results and Discussion

MOFs with pore sizes near and below 1 nm (UiO-66, ZIF-8) have been synthesised and functionalised directly or post-synthetically by grafting various functional groups on the organic linker and/or embedding metal nanoclusters in their pores. The samples were screened for their interaction with reactants and electrolytes to uncover the relevant host-guest interactions and their impact on the materials' function.

I will be reviewing our latest results on MOFs' potential applications for sustainability as heterogenous catalysts for small-molecule conversion and solid-state ion conductors (*e.g.* Fig. 1).

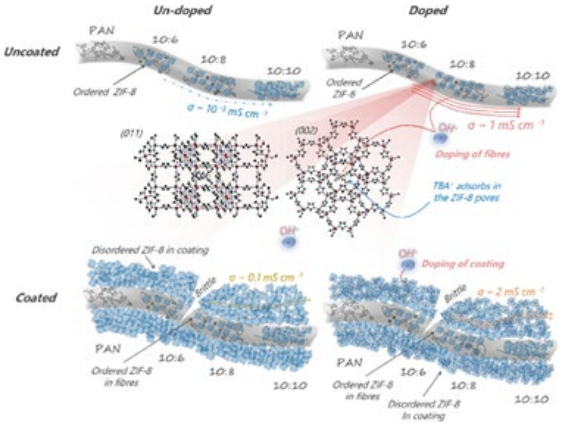

Figure 1: *Schematic representation of MOF-based self-supporting OH^--exchange fibre mats. [5]*

Conclusions

Through the precise engineering of the large interface between a MOF matrix and guests, particular and unique properties may be given rise to, including specific catalytic performances in the conversion of small molecules and the mobility of ionic species.

This flexible approach holds promise for the effective fine tuning of specific properties desirable in energy conversion and storage, as well as environmental processes.

References

[1] S. Kitagawa, *et al*., Angew. Chem. Int. Ed. 43, 2334 (2004)

[2] E. Callini, *et al*., Chem. Sci, 6, 666 (2016)

[3] D. E. Coupry, *et al.*, Chem. Commun. 52, 5175 (2016)

[4] P. Á. Szilágyi, *et al.*, J. Mater. Chem. A, 5, 15559 (2017)

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Acknowledgements

This work has been sponsored by NFR, JSPS, EU ERC Synergy, EPSRC, EU MSCA-DN.

Basic properties of tungsten oxide anodic memristors

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[2]Faculty of Medicine and Dentistry, Danube Private University, Steiner Landstraße 124, Krems an der Donau, Austria

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Abstract: The current work describes the fabrication and subsequent characterization of anodic tungsten memristors in a metal-insulator-metal configuration. The resulting devices exhibit pronounced self-rectification, with conduction following Poole-Frenkel emission in the high-resistive state, and Schottky emission in the low-resistive state. The memristors are of a forming free interfacial switching type, which enhances the device stability. Endurance and retention measurements demonstrate stable switching up to 10^6 cycles and high–low resistive state ratios of nearly three orders of magnitude. Moreover, the devices show volatile behavior, making them promising candidates for short-term synaptic plasticity in neuromorphic computing applications.

Keywords: anodic memristors; valve metals; self-rectifying; resistive switching

Introduction

Memristors are two-terminal metal–insulator–metal devices capable of retaining and recalling previous resistance states, making them highly relevant in non-volatile memory and neuromorphic computing. They display a resistive switching behaviour between a high-resistance state (HRS) and a low-resistance state (LRS), similar to binary "0" and "1," allowing efficient data storage and synaptic emulation. While various valve metals have been explored for memristive applications, anodically grown WO_3 remains largely underinvestigated. Due to its wide bandgap, WO_3 is able to support multiple conduction mechanisms, including Poole–Frenkel emission in the HRS and Schottky emission at the metal–oxide interface in the LRS [1].

Results and Discussion

The memristive behavior of anodically fabricated W/WO_3/Pt devices was investigated, showing multilevel switching capabilities visible through the *I–U* sweeps performed at various current compliances. Furthermore, the devices exhibited both Poole–Frenkel conduction in the HRS and Schottky emission in the LRS, supported by a high degree of correlation (R^2 = 0.99). Notably, self-rectifying properties were reported, resulting from the asymmetry at the metal–oxide interface, eliminating the need for separate selector elements. The devices were also forming-free, therefore avoiding high-voltage electroforming steps and improving overall energy efficiency. Endurance and retention tests confirmed stable operation for up to 10^6 cycles, with reliable HRS/LRS ratios of 10^3 with no significant material degradation. Further, endurance testing revealed volatility, which makes the device suitable for neuromorphic tasks, where short-term memory and low-power operation are crucial. Although the anodization of W may lead to partial oxide dissolution, electrochemical analysis indicated mainly diffusion-controlled behavior, suggesting that further fabrication optimization could result in thicker, more uniform oxide layers.[1]

Conclusions

Anodic WO_3 memristive devices were successfully fabricated, showing promise for scalable, energy-efficient memory and neuromorphic computing. Ongoing research will focus on further optimization of device performance, including exploring W alloying with other valve metals to enhance material properties and functionality for memristive applications.

References

[1] E.Atanasova, A. Greul, A.Udovicic, A.W.Hassel, A.I. Mardare, *Phys. Status Solidi A*, 2025, accepted for publication.

Acknowledgements

This research was funded in whole or in part by the State of Upper Austria through the Linz Institute of Technology [project COMSENS, LIT-2023-12-SEE-111]. The authors also gratefully acknowledge the experimental support from the Center for Surface and Nanoanalytics at Johannes Kepler University Linz for XPS analysis.

Bioinspired copper active sites in UiO-67 for selective C-H activation in methane

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[3]HUN-REN Wigner Research Centre for Physics, Budapest, Hungary

Abstract: This study focuses on the development of a catalyst to directly convert methane into methanol, addressing global warming concerns. Using a metal-organic framework (MOF) as catalyst support material, a bioinspired copper(I) complex has been designed to mimic a proposed active site in a *particulate methane monooxygenase* (pMMO). Characterization confirmed the successful integration of the bioinspired moiety, while studies on porosity, thermal stability, and hydrophobicity highlighted the MOF's potential for efficient methane conversion.

Keywords: Heterogenous catalysis; bioinspired catalyst; metal-organic framework; C-H activation; hydrophobic.

Introduction

Atmospheric methane is a major driver of global warming. Transforming methane to methanol is a desirable strategy for utilising and thus abating anthropogenically released methane, since methanol is more easily handled as a fuel and versatile as chemical feedstock.[1] Thus, a catalyst that can directly and selectively convert methane to methanol remains sought-after. *Particulate methane mono-oxygenases* (pMMOs) and *lytic polysaccharide monooxygenases* (LPMOs) are two groups of enzymes that can selectively activate C-H bonds to form alcohols; both utilise N-ligated copper as cofactor,[2,3] and can be used as blueprints for designing novel catalysts for partial methane oxidation. pMMO contains a hydrophobic cavity of particular interest to emulate, as it is suspected of being a binding site for methane.[3] Due to its renowned stability and high specific surface area, the UiO-67 metal-organic framework (MOF) has proven to be promising as a support material for heterogeneous biomimetic catalysts.[4]

Results and Discussion

In this work, the UiO-67 MOF has been embellished with a bioinspired copper active site, as shown in Figure 1; the ligand has been fitted with a hydrophobic moiety mimicking the hydrophobic cavity in pMMO, in order to increase the interaction between methane and the MOF surface. The materials were synthesised by first introducing the N-ligand into the UiO-67 topology via solvent-assisted linker exchange (SALE), followed by grafting of copper(I).

Post-digestion ^{1}H-NMR and TGA were used to confirm and quantify the integration of the bioinspired ligand. N_2 adsorption and TGA showed that the porosity and thermal stability of the parent UiO-67 were largely retained following SALE. Volumetric and gravimetric adsorption measurements have been conducted to assess the effect of the hydrophobic group on the overall hydrophobicity of the MOF surface.

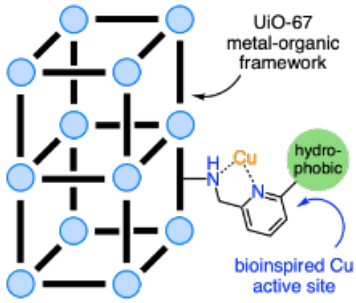

Figure 1: *Schematic of the synthesised material; a UiO-67 functionalised with a copper(I) active site inspired by LPMO and pMMO enzymes.*

Successful copper incorporation was verified by MP-AES, with UV-Vis indicating the presence of copper(I), however XAS indicates the presence of two anchoring sites for copper; likely, the copper can coordinate to the inorganic zirconium node of the UiO-67 framework, as well as to the bioinspired N-ligand.

References

[1] Olah, G. A. *Angew. Chem. Int. Ed.* **44** (2005) 2636-2639.

[2] Quinlan, R. J. *et al. Proc. Natl. Acad. Sci.* **108** (2011) 15079-15084.

[3] Koo, C. W. *et al. Science* **375** (2022) 177-182.

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Acknowledgements

This project has received funding from the European Research Council (ERC) through the Horizon 2020 research and innovation program (grant agreement No 856446 (CUBE)). The Swiss-Norwegian beamlines (SNBL at ESRF) are acknowledged for the provision of beamtime at BM31.

Ferroelectric – photocatalyst nanocomposites for enhanced solar fuel generation

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[1] School of Engineering and Materials Science, Queen Mary University of London, London, UK

Abstract: Hydrogen production via water splitting is currently inefficient due to high levels of charge recombination. In this research photocatalysts are coupled to the ferroelectric BTO to utilise its intrinsic field to improve charge lifetimes. Different synthesis methods are studied, ultimately deciding on electrodeposition of hematite which allows for the best pore penetration. Polarising the intrinsic field in the correct direction results in a 76% increase in photocurrent.

Keywords: water splitting, renewable hydrogen, photocatalysts, BaTiO3, ferroelectrics

Introduction

Metal oxide semiconductors can be utilised in photoelectrochemical (PEC) water splitting to produce green hydrogen. The key redox reaction to make hydrogen is bottle-necked by the sluggish kinetics of oxidation at the photo-anode, and large rates of charge recombination can reduce solar to hydrogen efficiencies. A potential avenue to raising efficiencies is to integrate ferroelectrics into the photo-anode[1,2] . Ferroelectrics possess internal fields which can be used to improve charge separation. This poster presents a proof of concept where a ferroelectric material Barium Titanate (BTO) is combined with a metal oxide photo-catalysts suffering from large recombination rates (Bismuth Vanadate and hematite), to create a nanocomposite ferroelectrically coupled system.

Results and Discussion

The research discussed centres on determining the best method to produce the nanocomposite film. Two different deposition methods are compared: spin-coating, and electrodeposition. The BTO layer is porous possessing a high resistance, so the deposited catalyst layer needs to completely penetrate through the BTO to reach the electrical contact. Additionally, the photocatalyst should strongly couple to the ferroelectric, such that the material maintains high photocurrent. In depth studies are also presented on the difference due to electrochemically poling, the technique used to favourably align dipoles and the intrinsic field. Electrodeposited hematite is found to be the best across all quantifiers, with poling resulting in a current density percentage increase at 1.23 VRHE of 76%. Photoanodes consisting of just BTO see an increase of 33% after poling, indicating that there is strong coupling between the BTO and the hematite.

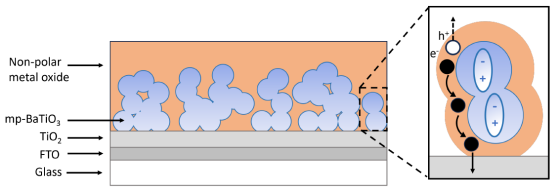

Figure 1: *The structure of the ferroelectric coupled electrodes. Consists of the hole blocking TiO2, the porous ferroelectric BTO, and the metal oxide photocatalyst (BVO) which penetrates through the pores.*

Conclusions

The feasibility of using ferroelectrics to reduce recombination in water splitting systems is demonstrated by an increase on photocurrent. Additionally, electrodeposition is found to be the most effective synthesis method as the BTO's porous structure is fully penetrated. Now that a functioning system has been made the next step is to study the behaviour of excited charges more closely.

References

[1] M.R. Morris, et al., 2016, Effect of Internal Electric Fields on Charge Carrier Dynamics in a Ferroelectric Material for Solar Energy Conversion, Advanced Materials, 28(33), pg. 7123-7128

[2] A. Augurio, et al., 2022, Controlled Porosity in ferroelectric BaTiO3 Photoanodes, Applied Material & Interfaces, 14, pg. 13147–13157

Molecular rotors: a real-time approach to assess polymerization process

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Abstract: The study uses molecular rotors (MRs) to monitor polymerization of polydimethylsiloxane (PDMS) in real-time, enabling optimization of properties and minimizing waste. The increased fluorescent emission intensity during polymerization responds to polymer cross-linking state changes, facilitating continuous, in situ measurement of polymer properties and minimizing mechanical perturbation.

Keywords: molecular rotors; PDMS; Polymerization monitoring; real-time

Introduction

This study investigates the real-time monitoring of PDMS polymerization using the molecular rotor (MR) farnesyl-(2-carboxy-2-cyanovinyl)-julolidine (FCVJ) [1]. MRs offer a cost-effective, non-invasive method for tracking polymerization dynamics by correlating fluorescence emission with viscosity changes [2]. Unlike conventional methods, MRs provide real-time data without the need for bulky instrumentation, offering significant advantages for process optimization [3]. This research aims to extend MR-based monitoring to a broader range of polymers, enabling precise control over material properties in industrial and biomedical applications.

Results and Discussion

We conducted a comparative analysis of the rheometer measurements against the fluorescent emission of FCVJ at temperatures of 100°C and 60°C, as illustrated in Figure 1. At 100°C, the emission curve demonstrates a remarkable 70% increase within the initial 20 minutes of the reaction. Significantly, approximately 10 minutes post-initiation, the polymer exhibits a transition from elastic to viscoelastic behavior, suggesting the attainment of the gel point. In contrast, the polymerization process at 60°C proceeds at a markedly slower rate, extending up to five times longer to achieve completion compared to the reaction at 100°C. The findings indicate that the gel point is reached around 25 minutes after the reaction commences, during which a fluorescence increase of 40% is already evident. The initial phase of the reaction can be effectively modeled using the Förster-Hoffman equation (1), applicable during the stage when the material demonstrates fully viscous behavior.

$$\log(I_f) \propto x\log(\eta) + C \qquad (1)$$

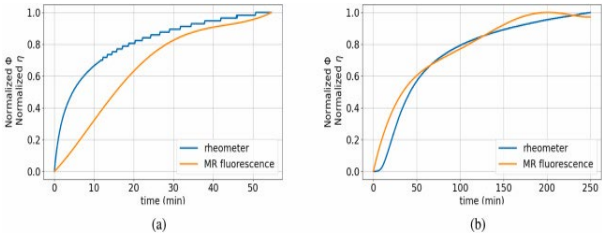

Figure 1: *Comparison of normalized values of rheometric measurements and MRs fluorescent emission at 100°C (a) and 60°C (b).*

Conclusions

The paper presents a new technique for monitoring the polymerization behavior of PDMS using fluorescent quantum yield analysis at different temperatures. It reveals a strong dependence on curing temperature and the importance of environmental temperature conditions in interpreting viscosity assessments.

References

[1] Haidekker, M.A., Ling, T., Anglo, M., Stevens, H.Y., Frangos, J.A., Theodorakis, E.A., 2001. New fluorescent probes for the measurement of cell membrane viscosity. Chemistry & biology 8, 123–131.

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[3] Dubé, M.A., Salehpour, S., 2014. Applying the principles of green chemistry to polymer production technology. Macromolecular Reaction Engineering 8, 7–28.

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Improving stability of PEDOT nanowire composites through elastomer matrix immobilised dopants

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Abstract: This work addresses the challenge of improving the long-term stability of bioelectronic sensors. We present a composite material composed of high-conductivity poly(3,4)-ethylenedioxythiophene (PEDOT) nanowires embedded in an elastomer matrix with immobilized sulfonate groups (TESET). This composite aims to enhance both the electrical and mechanical properties of bioelectronic devices for implantable applications. We demonstrate that TESET with dialysed PEDOT exhibits superior bulk conductivity compared to polyurethane (PU) with dialysed PEDOT, making it a promising material for implantable electrical devices.

Keywords: Bioelectronic sensors; conductive elastomers; PEDOT; implantable devices

Introduction

Bioelectronic sensors play a key role in bioelectronic medicine, where electrical devices treat and monitor diseases such as cancer, relying on ng-term performance. Current implantable materials used for implantable devices face issues with degradation of material properties and electrical performance over their lifespan. Conducting polymers (CP), also known as conjugated polymers, have shown unique promise for their ability to improve the long-term electrical properties of bioelectronic sensors. However, their use in clinical settings has been limited by chronic instability due to dopant mobility and a lack of mechanical durability. Conductive elastomers (CE) have attempted to improve the mechanical stability of CPs to improve long-term stability at a cost to overall electrical performance.

In this work, we present a composite material comprised of chemically synthesised high conductivity CP poly(3,4)-ethylenedioxythiophene (PEDOT) nanowires [1] embedded in an elastomeric matrix with immobilised sulphonate groups (TESET) to achieve chronic stability of both electrical and mechanical properties of the composite material.

Results and Discussion

Electrical properties of the newly synthesised CE with immobilised sulphonate dopant (TESET) were measured using electrical impedance spectroscopy (EIS) in dry and wet conditions to evaluate bulk conductivity and behaviour in a saline environment. Cyclic voltammetry was also performed for more insight into electrochemical properties of the CEs. These measurements were compared to those obtained with a CE made with a pure polyurethane (PU) matrix and the same PEDOT nanowires as filler material. Repeated measurements after chronic exposure to physiological saline were conducted to assess differences in the stability of the CEs.

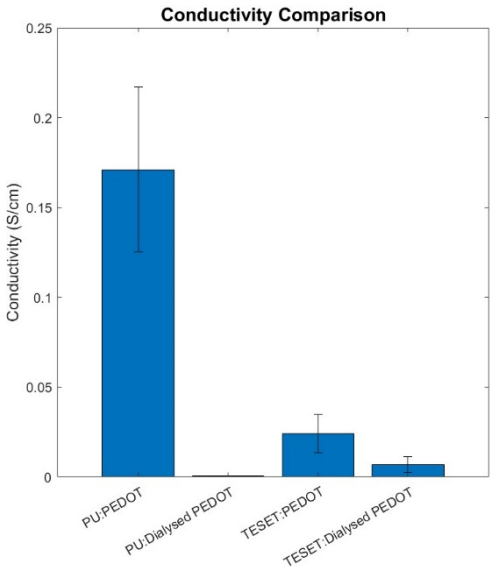

Figure 1: *Bulk conductivity of TESET and PU CEs with non-dialysed and dialysed PEDOT nanowires calculated from EIS measurements under dry conditions.*

Conclusions

TESET CEs with dialysed PEDOT show higher bulk conductivity than PU CEs with dialysed PEDOT. This improvement is likely due to the immobilized sulfonated groups in TESET, making it a promising material for implantable electrical devices

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Acknowledgements

This work was supported by generous funding from The Royal Society [RGS\R2\242541] and Queen Mary University of London. We sincerely thank Dr. Richard Spontak and Kacie Wells for providing the TESET polymer used throughout this project.

Impact of illumination on characteristics of Al_2O_3- and Ta_2O_5- type extended-gate ion-sensitive field-effect transistors

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Abstract: This work investigates the influence of illumination on the pH-sensing properties of Al_2O_3- and Ta_2O_5-type extended-gate ion-sensitive field-effect transistors (EG-ISFETs). Packages tested in this work contain three EG-ISFETs, each with an adjustable floating-node charge, enabling individual calibration. Light-induced signal response of these devices was evaluated under constant pH conditions.

Keywords: extended-gate ISFET, floating-node, ALD, Al_2O_3, Ta_2O_5, light sensitivity

Introduction

Ion-sensitive field-effect transistors (ISFETs) are, besides many benefits, known for their light sensitivity [1]. Incoming light has been demonstrated to cause disturbances in their long-term stability behavior [1]. The present work investigates the stability of floating-node ISFETs under repeated light change.

Results and Discussion

Two types of sensors, Al_2O_3- and Ta_2O_5 EG (extended gate)-ISFETs were compared according to their light-induced signal response. By using a modular measurement platform, four packages with a total of 12 EG-ISFETs, including six Ta_2O_5- and six Al_2O_3 EG-ISFETs were studied in parallel. For sensor characterization, the packages were mounted in one well module, sharing the same analyte. After overnight conditioning at Titrisol buffer, pH 7, in darkness, the sensors were measured repeatedly for 30 minutes each in darkness and under illumination for a period of 24 hours, at constant pH 7 conditions. The chips were illuminated by white LEDs at 6,100 lx (measured by Gossen Mavolux Luxmeter). All tested sensors showed a slow increase in output voltage under illumination, as well as a slow signal reduction in darkness, as depicted as cyclic behavior in Figure 1. It was observed that the light-induced signal change starting from 22 mV/h and 26 mV/h for Ta_2O_5 and A_2O_3 sensors, respectively, decreased over illumination cycles until it saturated at 8 mV/h for both Ta_2O_5 and A_2O_3 sensors. This light sensitivity is well known and is attributed to polarization effects in the insulator layer (here Ta_2O_5 or Al_2O_3) [1]. No post-deposition treatment, like thermal annihilation was applied, thus the studied pH-sensitive layers are amorphous. In literature, light-induced drift rates of amorphous Ta_2O_5 ISFETs are reported to vary between 20 and 56 mV/h [1,2].

Conclusions

The present work examined the light-induced reaction of Ta_2O_5- and Al_2O_3-type ISFETs, providing important information for later practical application of those sensors.

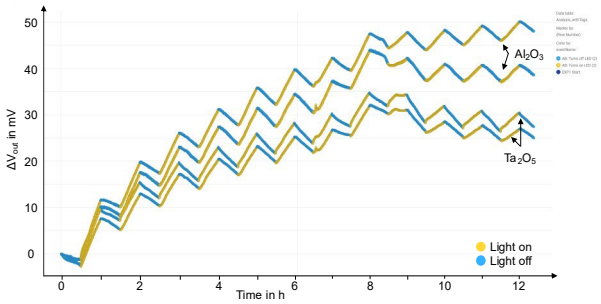

Figure 1: *Signal response of two Ta_2O_5 - and two Al_2O_3 -EG-ISFETs to LED illumination, measured in pH 7 buffer.*

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Optimized High Performance α-Fe_2O_3 Semiconductor towards Ultra-Fast Photoelectrochemical Imaging

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Abstract: An optimized hematite semiconductor substrate for photoelectrochemical imaging (PEI) is introduced for high resolution cell imaging and biosensing applications. A photoresist pattern on a hematite substrate was imaged in both direct (DC) and alternating current (AC) modes, showing ultra-fast imaging response and great signal stability. The setup will be used for dynamic imaging of cell signalling processes.

Keywords: photoelectrochemical imaging; hematite semiconductor; fast imaging

Introduction

Photoelectrochemical imaging (PEI) is one of the most recently developed electrochemical characterization methods applied in biosensing and cell imaging.[1] PEI is based on the excitation of local photocurrents in a semiconductor substrate. Its excellent spatial and temporal resolution makes is suitable for the mapping of dynamic electrochemical processes with micron resolution. Unfortunately, fast imaging was previously limited to semiconductor materials such as silicon, which has poor stability in electrolyte solutions. Hematite (α-Fe_2O_3) has garnered attention due to its favorable band gap, natural abundance, and stability under operational conditions.[2] In this work, the hematite semiconductor was optimized to improve the temporal resolution in bioimaging applications.

Hematite precursor was electrodeposited onto fluorine doped tin oxide (FTO) coated glass and then annealed optimizing a previously described method.[1] The hematite film was used as the working electrode (WE) for PEI to generate local photocurrents. Direct current (DC) was measured by applying constant laser excitation; AC current was measured modulating the laser intensity at 1 kHz. SU-8 photoresist was patterned on the substrate by photolithography. Fast imaging was carried out with a previously described mirror scan PEI setup.[1]

Results and Discussion

The resolution of ultra-fast PEI was determined to be 1.6 µm by scanning the laser across the edge of a photoresist pattern with AC mode. DC and AC fast scans are presented in figure 1a and b, respectively. The DC scan was completed in 3.6 s with 10,000 pixels acquired in the image, proving the potential of high temporal resolution applications. The corresponding AC scan was completed in 14.4 s under white light illumination. The image shows a good stability in simultaneous photocurrent image and optical image acquisition. Figure 1c shows a smaller grain size and higher surface area compared to previously reported hematite.[1] Figure 1d shows an XPS survey scan. It is assumed that an increased tin concentration and an improved morphology increased the charge carrier mobility leading to a higher imaging speed.

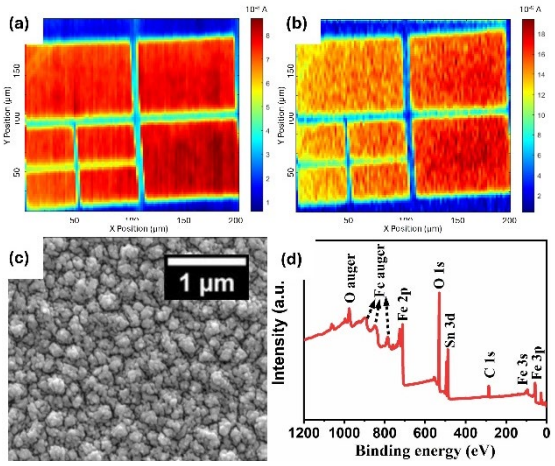

*Figure 1. (a) Fast DC photocurrent scan and (b) AC scan of a 200 * 200 µm SU-8 pattern, (c) SEM image of the optimized hematite surface and (d) XPS survey scan of the surface.*

Conclusions

A new optimized hematite semiconductor for bioimaging was presented. The new substrate is acquiring high imaging speed and high stability at the same time. The new hematite films will be used for high resolution cell imaging and electrochemical signal measurements.

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Acknowledgement

The authors are grateful to the China Scholarship Council for PhD studentships for RL, JZ and YF and to EPSRC (EP/R035571/1) for funding.

Intrinsic defect engineering in anodic memristors

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Abstract: Electrical and memory properties of Hf- and Ta-based memristors are further tuned by carefully selecting the anodization electrolyte or other electrochemical parameters, which plays a crucial role in positioning and sizing of conductive filaments within the memristive oxide. Spatial pinning of conductive filaments relies on a controlled nanostructuring of the memristive film at the nm scale. The Rayleigh-Taylor effect is exploited in this work for electrochemical nanostructure control in composite anodic oxides. The concept of defect engineering is introduced from the electrochemical side as an intrinsic, efficient and low-cost approach for device fabrication.

Keywords: anodic memristors; valve metals; ultra-thin films; anodization

Introduction

Valve metals will always be in the focus of electrochemical community due their anodization particularities at the nm scale. Their anodic oxides have shown promising qualities as memristive elements, in which the resistance state of a device can be switched between two or more levels by externally applied electrical fields. This impacts the conductive pathways (filaments) formation, which is mediated by oxygen vacancies and/or cations, and their field-activated movement inside the oxide [1].

Results and Discussion

Concomitant anodization of two superimposed metallic films (e.g. Hf/Ta) intrinsically leads to a columnar growth of one oxide within the other, if the metal in direct contact with the electrolyte produces an oxide more insulating as compared to the oxide produced by the underlaying metal [2]. This results from the ionic current preferring the less resistive paths, enhancing the growth of the correspondent oxide. The obtained oxide fingers (e.g. Ta_2O_5 within HfO_2) and especially their interfaces are responsible for conductive filament easier formation and spatial pinning. Oxide resistivities and structures, transport numbers, Pilling-Bedworth ratios are all considered as determining factors for the anodization process of such superimposed systems. Predicting the position and shape/thickness of a conducting filament may eventually lead to enhanced device stability and resistive states control. The boundary between Hf and Ta oxides may influence the conductive pathways required for the memristive effect, thus being most relevant for fabrication of highly stable and forming-free memristors. Additionally, the use of superimposed films with gradient but complementary thicknesses allows investigating the ideal Hf/Ta ratios for which the best memristive behaviour is obtained. One pronounced zone relevant for memristive applications is found for Hf/Ta thickness ratios between 4 and 5. Here, unipolar and bipolar memristors are identified, with remarkable endurance and retention capabilities.

Conclusions

Controlled O vacancies generation is a critical factor in switching uniformity and reproducibility. Therefore, oxide “fingers” formation is a promising electrochemical approach towards defect-engineered memristors. Further investigation of the composite oxide formation, particularly in Hf/Ta superimposed system, is topical. Until now, such systems were not recognized in the literature for the ReRAM applications. This is highly promising since both memory and electrical characteristics are improved by the forming-free nature of the memristors with filaments mediated by oxide nanostructuring. Advanced characterization of these functionalized anodic oxides helps further understanding and developing of the proposed concepts.

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Scanning Photoelectron Yield Spectroscopy for Visualization of Hydrogen in Steel Specimen

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Abstract: Photoelectron yield spectroscopy (PYS) is an analytical method that can detect the change of the work function due to hydrogen invasion into steel. In this study, the scanning PYS was developed. The obtained profile of the work function reflected the position where hydrogen entered into steel.

Keywords: work function, photoelectron yield spectroscopy, atmospheric conditions

Introduction

The use of high tensile strength steel has been increasing in the industry. However, this type of steel is known to be sensitive to hydrogen embrittlement. Therefore, analysing the hydrogen that enters into the steel, diffuses, and is accumulated is important to use the steel safely.

However, label-free detection of hydrogen permeation in steel remains challenging. Recently, we proposed an application of photoelectron yield spectroscopy (PYS) to detect hydrogen [1]. PYS is able to measure the work function of steel by measuring the photoelectrons emitted by a light illumination, and we found that the work function of the steel decreased by introducing hydrogen [2].

In this study, we focused on the light-addressability of the PYS measurement. Based on this advantage, the novel "scanning" setup of PYS was developed to achieve a spatially-resolved hydrogen detection.

Results and Discussion

Figure 1 shows the experimental setup of the scanning PYS. A light beam from a monochromator illuminates the specimen surface. A bias voltage was applied between a counter electrode and the specimen, and the emitted photoelectron was recorded as a function of wavelength (i.e. emission yield spectrum). An objective lens and a mechanical stage were implemented to scan the specimen surface, and a series of spectra can be obtained in a spatially-resolved manner.

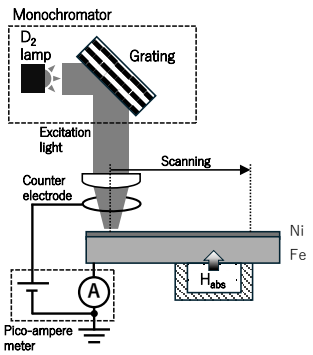

Figure 1: *Experimental setup of the scanning photoelectron yield spectroscopy (PYS) for detection of hydrogen permeation.*

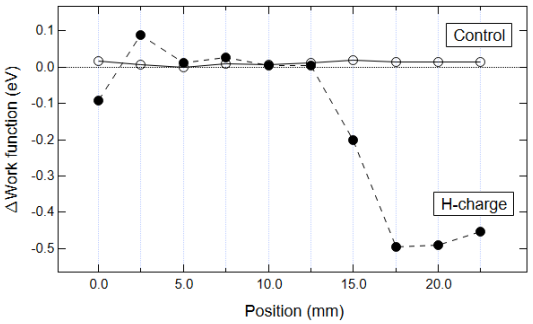

Figure 2: *The changes of the work function profile before and after the introduction of hydrogen.*

Hydrogen was locally introduced into the specimen from a solution cell mounted on the backside of that. The one-dimensional profile of the work function is obtained as shown in Figure 2. At one end of the scanning area where the hydrogen was introduced, the lowering of the work function was successfully observed.

Conclusions

The profile of the work function reflected the position where hydrogen was introduced. The scanning PYS can be a novel approach to visualize hydrogen in steel.

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Acknowledgements

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Biofilm Formation of *Porphyromonas gingivalis* on Titanium Surfaces in Response to 1,4-Dihydroxy-2-Naphthoic Acid: An Integrative *In Vitro-In Silico* Approach

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Abstract: *Porphyromonas gingivalis* colonization of dental implants contributes to peri-implant disease. This study assessed the effect of 1,4-dihydroxy-2-naphthoic acid (DHNA) on biofilm development over six days on grade IV titanium surfaces with distinct roughness. DHNA modestly enhanced growth, accelerated the shift to ammonia-independent metabolism, and promoted surface-dependent biofilm expansion. Surface roughness significantly affected biofilm volume and aggregate structure. Experimental data were used to calibrate a finite element model simulating biofilm dynamics. This *in vitro-in silico* approach highlights how DHNA modulates *P. gingivalis* colonization and supports the development of biofilm-resistant implants and personalized therapies.

Keywords: *P. gingivalis* biofilms; dental implants; peri-implant disease; titanium surface roughness; DHNA

Introduction

Colonization of the key oral pathogen *P. gingivalis* on dental implant materials contributes to long-term severe peri-implant diseases[1]. This study investigated the impact of 1,4-dihydroxy-2-naphthoic acid (DHNA) on *P. gingivalis* biofilm development over six days on two grade IV titanium surfaces with distinct roughness. Considering the influence of surface characteristics on biofilm formation, a more rigorous assessment of titanium surfaces, particularly through detailed analysis of 3D surface texture parameters, could improve the consistency and reproducibility of biofilm-related studies in dental research.

Results and Discussion

DHNA modestly stimulated bacterial growth, accelerated transition to ammonia-independent metabolism, and promoted biofilm expansion in a surface-dependent manner. Surface roughness significantly influenced both the overall biofilm volume and the size of bacterial aggregates. Experimental findings were integrated into a finite element model simulating biofilm development dynamics over time. This modelling confirmed the crucial role of nutrient utilization in shaping *P. gingivalis* colonization patterns on titanium implants with different surface roughness.

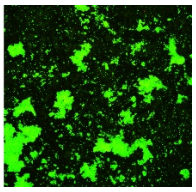

Figure 1: *Aggregates of DHNA-stimulated P. gingivalis biofilms on rough surface, as visualized by Confocal Laser Scanning Microscopy.*

Conclusions

This integrative approach demonstrates that DHNA-dependent *P. gingivalis* biofilm development is significantly influenced by titanium surface properties. The findings support future design of biofilm-resistant implant surfaces and the development of personalized therapies targeting peri-implant diseases.

(This manuscript is currently under revision in Microbiology Spectrum).

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Triazine-functionalized Graphene Oxide for realization of wafer-scale two-dimensional nanoelectronic interfaces with high reproducibility

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Abstract: Graphene oxide (GO) interfaces are promising for electronic and bio-related applications but are often limited by structural defects and poor electrical performance. In this work, GO was covalently functionalized with triazine via a nitrene-based [2+1] cycloaddition to produce thin films with improved consistency and conductivity. The fabrication process yielded reproducible GO-Trz films on silanized Si/SiO_2 substrates, confirmed by structural and electrical characterizations. Electrical measurements demonstrated stable and enhanced conductive properties, supporting the material's suitability for integration into functional device platforms.

Keywords: graphene oxide (GO), thin film, self-assembly formation, covalent functionalization, [2+1] cycloaddition reaction, electrical properties.

Introduction

Graphene oxide (GO) offers significant potential for electronic and biosensing interfaces due to its chemical versatility and ease of processing [1]. Chemical modifications of GO often introduce structural defects that hinder its electrical performance. Among various functionalization strategies, nitrene [2+1] cycloaddition has shown promise for grafting functional groups while preserving π-conjugation [2]. Although this chemistry has been widely applied to bulk carbon materials, its use in thin-film systems for device integration remains relatively unexplored. In this study, we present a reproducible surface modification approach for fabricating uniform triazine-functionalized GO films with consistent electrical behavior and structural integrity. These features make the material highly suitable for future applications in nanoelectronic and sensing platforms.

Results and Discussion

GO-Trz thin films were prepared using a nitrene-based [2+1] cycloaddition approach, followed by self-assembly on silanized Si/SiO_2 substrates. The process was repeated across multiple fabrication cycles to evaluate reproducibility, resulting in consistent film morphology and surface coverage. Characterization by SEM, AFM, Raman spectroscopy, and XPS confirmed the structural integrity and homogeneity of the deposited layers.

Furthermore, the films were subjected to electrical testing. I–V characteristics displayed stable and repeatable conductive behavior across devices. Impedance spectroscopy revealed reduced interfacial resistance compared to unmodified GO films, indicating successful interface engineering. These results highlight the potential of GO-Trz for applications requiring stable and tunable 2D materials.

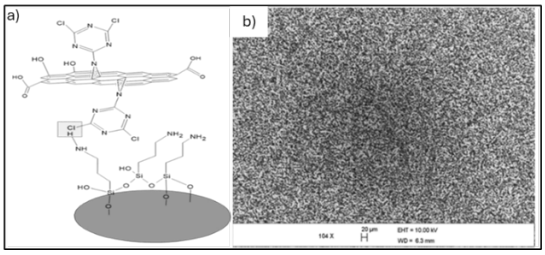

***Figure 1**. a) Schematic representations of realization of GO-Trz thin films on a 4-Inch wafer b) SEM image shows the homogeneity and size distribution of GO-Trz; 104x magnification for an overall view of the deposit and its homogeneity*

Conclusions

We demonstrate a reproducible and chemically controlled method to covalently functionalize GO with triazine via nitrene [2+1] cycloaddition, yielding uniform and conductive thin films. The addition of electrical characterization confirms their suitability as functional components in future bioelectronic and sensor devices. This approach paves the way for scalable engineering of 2D materials with application-tuned electronic properties.

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Acknowledgements

We acknowledge Central Laboratory for Micro- and Nanotechnology (ZMNT) from RWTH and BioeconomieREVIER project no. *031B1134C* (ProtLab2) funded by BMBF for their generous support.

Immobilizing aptamers on sputtered gold nanostructures

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Abstract: Gold was sputtered on Si-substrate chips with a Ta_2O_5 surface. Gold layer thickness was adjusted by sputtering time. SEM (scanning electron microscopy) investigation revealed incomplete (3 nm gold) or gapless (10 nm gold) surface coverage with gold. Thiol-modified aptamers with fluorescein label were immobilized on the Si-SiO_2-Ta_2O_5-Au chips via drop-casting. Successful binding was confirmed by fluorescence microscopy.

Keywords: Ta_2O_5 surface; sputtered gold; aptamers; thiol binding; fluorescein

Introduction

We studied a protocol for a prospective functionalization of ion-selective field-effect transistors (ISFETs) in order to use them as biosensors. Aptamers were chosen as bioreceptors due to their adaptability against almost any desired analyte [1]. As a model, we applied an aptamer with affinity to C-reactive protein (CRP), described by Wu *et al*. [2]. It was modified with a thiol group at the 3' end and fluorescein isothiocyanate (FITC) label at the 5' end. The thiol group can form a stable binding to gold without additional reagents required [3]. To form a compatible gold surface, sputtering was used as straightforward method to produce thin-film layers. Adjusting the appropriate sputtering parameters, substrate, and coating material can lead to the formation of discontinuous nanostructures, as demonstrated for gold on SiO_2, for example [4]. A discontinuous layer is important for our purpose, as a tight array of independent, micrometer-scale ISFETs should be functionalized, which may not be short-circuited to each other by a fully electrically conducting gold layer. However, since the presented study was a pilot test, we did not functionalize ISFETs, but 10 mm × 10 mm silicon chips with the same Ta_2O_5 surface chemistry.

Results and Discussion

The process steps of chip treatment are overviewed in Figure 1 (bottom). After sputtering with gold, chips were investigated by SEM (Figure 1, top left). For depositing a 10 nm layer, the surface coverage with gold appeared gapless in 500.000× magnification, while discontinuous nanostructures were found for 3 nm layers. CRP aptamer solutions were drop-casted on the gold layer. The solutions contained salts (NaCl or $MgCl_2$) in different concentrations.

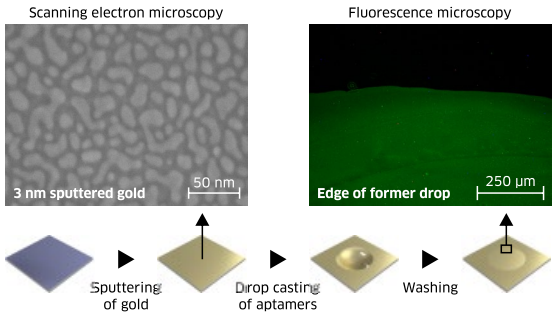

Figure 1: *Modification of a Si-SiO_2-Ta_2O_5 chip by gold sputtering and aptamer immobilization.*

Chips were washed to remove unbound aptamers after 0.5 h to 20 h. The aptamer coverage was analyzed by fluorescence imaging (Figure 1, top right). There was no evident difference between the tested immobilization times. In contrast, salts had a distinct impact on coverage with aptamers. $MgCl_2$ additions in the solutions improved the aptamer density more than NaCl, evident by brighter fluorescence. The underlying gold layer had an influence as well. Obviously, a fragmented 3 nm gold layer offers fewer binding sites for thiolated aptamers, which reduced the fluorescence intensity on respective samples.

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Interface induced shear viscosity control for 3d printing of medical grade silicone

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Abstract: Extrusion-based additive manufacturing (AM) of medical-grade silicones is constrained by their high viscosity, limiting resolution and microstructural fidelity. To address this, we present a novel printhead concept featuring a rotating element that induces localized shear within the nozzle, reducing viscosity in situ. This method leverages the shear-thinning and thixotropic behavior of selected silicones to allow narrower nozzles and improved mixing. Validation with shear-thinning analogues shows enhanced flow and mixing, supporting this approach for patient-specific silicone printing in biomedical use.

Keywords: medical silicone; 3D printing; shear-thinning; implantable devices

Introduction

Additive manufacturing (AM), particularly extrusion-based 3D printing, has gained traction in the biomedical field due to its potential for patient-specific device fabrication, design flexibility, and rapid prototyping. In personalized medicine, AM enables the production of anatomically tailored implants, prosthetics, and scaffolds with complex internal geometries often unachievable using conventional methods.

Medical-grade silicones are especially attractive for implantable applications due to their biocompatibility, chemical stability, and long-term in vivo performance. However, their high viscosity poses a major challenge, particularly when printing through the small orifices required for high-resolution features or minimally invasive use.

Certain RTV-2 (room-temperature vulcanizing) silicone formulations, such as Sylgard 186, have been reported to exhibit shear-thinning and/or thixotropic behavior [1], suggesting that in-process rheological control may help overcome these limitations. We are therefore investigating an extrusion-based printing concept that introduces localized shear within the printhead to dynamically reduce viscosity during deposition. A custom printhead with an integrated rotating element is being developed to generate in situ shear, aiming to enable finer nozzles, enhance resolution, and expand the design space for silicone-based medical structures without compromising material integrity or biocompatibility.

Methods

To explore the hypothesis that localized shear induced by a rotating element can facilitate the extrusion of high-viscosity materials through narrow channels, a custom test setup is currently being developed. The concept involves glass capillaries with an inner diameter of around 100 µm, arranged in a Y-shaped junction with an inlet angle of approximately 60°, aiming to minimize dead volume and support flow efficiency.

A rotating element with a diameter of roughly 85 µm is intended to be positioned within the main channel, reaching close to the outlet. This element is to be driven by a motor and sealed with a dynamic PTFE seal. The goal is to generate shear forces that lower the material's viscosity and enable in situ mixing of the two silicone components.

For initial proof-of-concept experiments, sodium laureth sulfate is being considered as a surrogate material due to its similar high viscosity and shearthinning behavior.

Two approaches are being considered to evaluate the concept:

1. **Gravimetric Flow Analysis** - Comparing flow rates with and without shear force to observe potential improments in throughput
2. **Mixing Homogeneity Assessment** - Investigating the quality of mixing.

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Acknowledgements

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Device Design for Green Kerosene Synthesis via Electroadsorptive Effect

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Abstract: We design electronic devices for gas adsorption and manipulation. They comprise an open semiconductor surface which allows using the electroadsorptive effect (EAE). This contributes to a broad goal of developing novel chemistry methods, moving beyond Fermi-level based classical catalysis. The immediate aim is to demonstrate the application of the device for CO_2 + H_2 reaction for potential green kerosene synthesis.

Keywords: electroadsorptive effect, green kerosene, solid-state dielectric, fuel synthesis.

Introduction

The electroadsorptive effect (EAE) provides means to manipulate the conformation of adsorbed molecules using an electric field (**E**). These changes are directly observable via spectroscopic property alterations, governed by the Franck-Condon conformational shift.

The realization of the EAE requires electric fields in the range of 30–100 kV/cm, which exceeds the dielectric strength of air (≈30 kV/cm). As a result, conventional air-gap parallel-plate capacitors are not suitable. Instead, we employ a semiconductor structure with a SiO_2 layer, which offers dielectric strength values of 4700–6700 kV/cm, allowing us to safely apply the required field intensities. Moreover, we plan to incorporate incident free electrons into our experimental approach.

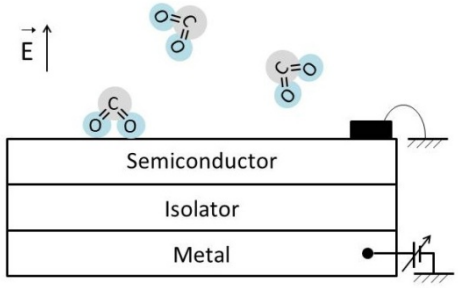

Figure 1: *MIS device structure for the use of the electroadsorptive effect.*

Results and Discussion

A primary challenge is grounding the adsorption surface for X-ray photoelectron spectroscopy (XPS). This is essential to prevent surface charging during photoelectron emission and ensure accurate measurements – ideally necessitating near flat-band conditions (minimal band bending). On the other hand, generating electrical fields (**E**) as required for EAE relies on inducing band bending at the same interface. Satisfying these fundamentally contradictory requirements simultaneously requires a complex 3D device architecture.

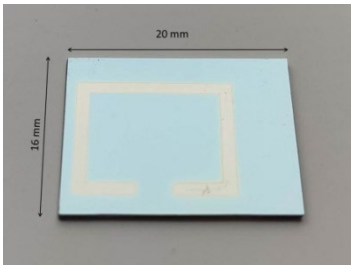

Figure 2: *MIS device with CeO_2 metal oxide thin film semiconductor layer for CO_2 adsorption experiments with surface grounding contact.*

Conclusions

We will explore both the EAE and energetic perturbation by free electrons as complementary tools for chemistry beyond the Fermi level.

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Acknowledgements

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Development of Novel Photovoltaic Devices Combining Ferroelectric Nanostructures with Perovskite Solar Cells

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Abstract: Lead halide perovskite solar cells already deliver impressive photocurrents, but their built-in electric field (BEF) is intrinsically weak. Here we integrate a ferroelectric, 33 %-porosity mesoporous $BaTiO_3$ scaffold—prepared by sol-gel spin-coating with P123-templating—into an N-I-P perovskite device. Electrochemical poling raises Voc from 0.31 V to 0.92 V and the power-conversion efficiency (PCE) from 0.23 % to 6.05 %. Control devices using a non-ferroelectric $SrTiO_3$ analogue show no comparable gain, confirming a ferroelectric origin. Additive-assisted infiltration with 5-AVAI boosts Jsc to 23.5 mA cm^{-2} and PCE to 9.1 %, while Triton X-100 increases Voc to 0.98 V. Combining both additives is now underway.

Keywords: ferroelectric; perovskite photovoltaics; $BaTiO_3$; bulk photovoltaic effect;

Introduction

Perovskite solar cells (PSCs) have progressed rapidly in the past fifteen years, yet their efficiency is ultimately limited by non-radiative recombination fostered by a weak BEF arising from near-isoelectronic transport layers and mobile ions [1,2]. Ferroelectric oxides such as $BaTiO_3$ (BTO) can, when poled, supply an internal field and exploit the bulk photovoltaic effect (BPVE) to generate anomalously high photovoltages [3]. Coupling these attributes with the high absorption coefficient of methylammonium lead iodide (MAPI) offers a promising route to higher PCEs.

Results and Discussion

Mp-BTO layers were fabricated by a sol-gel spin-coating route using Pluronic P123 as sacrificial polymer, yielding a surface porosity of 33 %. A $SrTiO_3$ (STO) analogue was prepared to separate ferroelectric effects from morphological ones. Poling was performed (i) electrochemically in 0.1 M $LiClO_4$ proppylene carbonate prior to perovskite deposition and (ii) by contact poling on the finished devices. Average efficiency increase with poled BTO was 13.7% to 6.05%. The large Voc gain in BTO confirms the contribution of the ferroelectric polarisation to the device BEF, whereas the STO control shows a slight decline after poling. Low Jsc values suggest incomplete infiltration of the thick scaffold. Infiltration additives were therefore screened. 5-ammonium valeric acid iodide (5-AVAI) promoted rapid perovskite nucleation, raising Jsc to 23.47 mA cm^{-2} and PCE to 9.12 % [4]. Addition of Triton X-100 improved wetting and increased Voc to 0.98 V [5]. Trials combining both additives are in progress and Kelvin probe force microscopy is being used to map the local BEF.

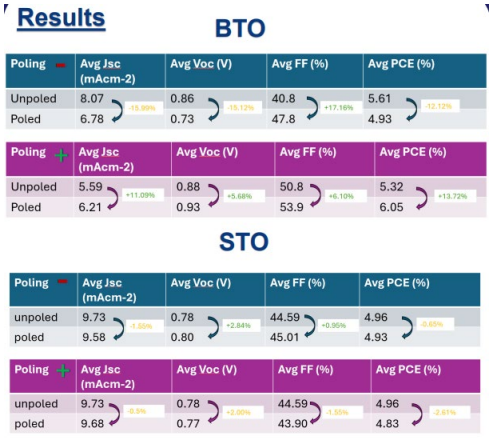

Figure 1: *table summarizing performance of poled and unpoled BTO- and STO-perovskite devices.*

Conclusions

Ferroelectric BTO scaffolds substantially enhance the built-in electric field and Voc when poled. Performance is presently limited by incomplete perovskite infiltration; nonetheless, the use of 5-AVAI and Triton X-100 demonstrates that this bottleneck can be mitigated.

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ERC, QMUL

Enhanced thermoelectric performance of copper iodide films by cesium fluoride dopant

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Abstract: The thermoelectric performance of CuI thin films can be modified by CsF dopant. The doping is achieved by co-evaporation and the power factor can reach a maximum at a proper dopant ratio. The modification is ascribed to the carrier introduction by an abnormal elemental insertion, and the surface morphology can be improved to some extent. Some key parameters and the direct evidence of this elemental insertion are still under investigation.

Keywords: thermoelectric; copper iodide; thin films; transparent semiconductor

Introduction

Thermoelectricity is a strong candidate to overcome the environmental issues caused by our traditional methods obtaining energy from fossil fuels. It witnesses no intermediate energy conversion process (high efficiency), leads to no side products or contamination (corresponding to the Net Zero goal and Paris agreement) and has abundant resources of waste heat from industries. two common parameters evaluating the maximum power and the efficiency of thermoelectric materials are power factor (PF) and figure of merit (zT) which can be expressed as:

$$PF = S^2\sigma$$

$$ZT = \frac{S^2\sigma}{\kappa}T$$

Where S, σ, κ and T are Seebeck coefficient, electric conductivity, thermal conductivity and absolute temperature respectively.

Among the thermoelectric materials, copper iodide (CuI) has a great potential for its high carrier mobility, low thermal conductivity, easier preparing process (in comparison with metallic chalcogenides) and transparent feature. Here, cesium fluoride (CsF) is doped in CuI thin films in various ratio by co-evaporating pre-mixed powder onto quartz-coated glass substrates under vacuum. Up to now, its influence on the thermoelctric parameters, surface morphology, band gaps and phase components of CuI thin films has been characterized.

Results and Discussion

As shown in the figure 1a, σ of CuI film is increased with more CsF doped when the ratio is low, while S drops constantly. They both correspond to our hypothesis of elemental insertion (but not in-situ) which introduces carriers (holes). However, σ falls back afterwards which may result from the over-doped second phase piling up at grain boundaries and hindering carrier migration. The PF has a maximum value of 0.425 mW/mK^2 at 4 at% which is compatible with state-of-art values of published papers on doped CuI-based thermoelectric materials. Meanwhile, CsF can homogenize the CuI grains (shown in Fig. 1b) very efficiently while not causing apparent second phase (shown in Fig. 1c). It narrows the band gap (shown in Fig. 1d) which proves the introduction of impurity energy level.

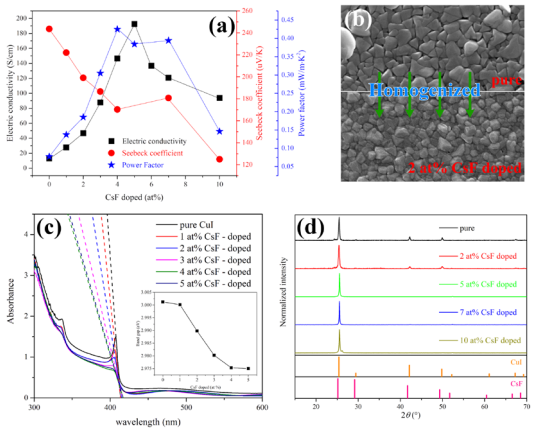

Figure 1. (a) The σ, κ and PF values of CuI with various amount of CsF doped, the (b) homogenized morphology , (c)XRD patterns and (d)UV-vis patterns (with calculated band gaps)of CuI-based thin films.

Conclusions

The co-evaporation with CsF can boost the thermoelectric performance of CuI thin films and the doping level with the best power factor has been found. However, its thermal conductivity remains to measure in the near future. We are looking for directer evidence for the elemental insertion as well.

Acknowledgement

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Volatile analog memristive switching in anodic titanium-tungsten combinatorial library

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Abstract: A combinatorial approach was employed to fabricate anodic titanium-tungsten (Ti-W) thin film library with W content ranging from 3-20 at% to systematically examine the memristive switching behaviour. Electrical characterization revealed consistent analog volatile behaviour across the entire compositional range, most likely governed by an interfacial switching mechanism. The devices displayed clear multi-level switching, enhancing the potential for high-density data storage. Furthermore, they demonstrated consistent endurance up to 10^4 cycles with an excellent HRS/LRS ratio of up to 10^7. Ti-W anodic oxides show potential as tuneable memristors for neuromorphic applications.

Keywords: anodic oxide; memristor; combinatorial analysis; interfacial mechanism

Introduction

As interest in high-density data storage, neuromorphic computing, and sensing technologies continues to rise, anodically grown memristors emerge as promising candidates due to their CMOS compatibility, excellent stability, and simple fabrication [1]. The development of memristors with precisely controlled electrical characteristics requires a systematic technique, which can be achieved by a combinatorial approach. Such methodology allows for high-throughput screening across a wide compositional range on a single substrate. This is a valuable tool for efficient identification of the best-performing alloy composition [2]. This study aims to investigate the impact of varying W content on the switching behaviour of anodically grown Ti-W thin-film memristors.

Results and Discussion

The memristors in this study were fabricated by anodic oxidation of a compositionally graded Ti-W thin-film library. All devices across the gradient exhibit volatile analog resistive switching with consistent endurance up to 10^4 cycles and a HRS/LRS ratio of up to 10^7. While the general switching behaviour remained consistent through the composition spread, subtle variations are observed. Most devices exhibited unipolar switching, but in certain regions some bipolar behaviour is contributing to the hysteresis on the positive part of the I-U sweep. Systematic correlation with W content is currently under investigation. Endurance and retention are uniformly high across the library, with no significant variation as a function of W content. Furthermore, devices demonstrated multi-level switching with several intermediate states. The absence of abrupt SET/RESET transitions together with analog volatile behaviour, suggests an interfacial switching mechanism, rather than a filamentary one.

Conclusions

Volatile analog memristors fabricated from a Ti-W (3-20 at.% W) thin-film alloy exhibit highly consistent switching behaviour, endurance, and retention across the entire compositional spread. Future work will focus on structural and qualitative compositional analysis to better understand and optimize the performance and stability.

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Engineering Protein Assemblies and the Mechanics of Liquid-Liquid Interfaces for Stem Cell Technologies

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Abstract: Cells sense and respond to the mechanical properties of their microenvironment and engineering the mechanical properties of biomaterials is now accepted as a critical design element for tissue engineering and stem cell technologies. Previous work in our group demonstrated the importance of nanoscale mechanics in the regulation of cell adhesion and mechanosensing. Taken to its extreme, we showed that cell adhesion and stem cell phenotype retention is enabled on liquid substrates, including oil microdroplets, and that this phenomenon is mediated by the assembly of mechanically strong protein nanosheets. In this lecture, we will discuss some of the processes and parameters regulating interfacial mechanics of such protein assemblies and their implications for stem cell technologies.

Keywords: liquid-liquid interfaces; microdroplets; protein nanosheets; stem cells; interfacial mechanics.

Introduction

The discovery that cells can adhere, spread and proliferate at the surface of liquids, such as silicone, fluorinated or mineral oils led us to investigate how the interfacial self-assembly of proteins introduced in aqueous phases regulate interfacial mechanics of corresponding liquid-liquid interfaces [1-2]. To study the resulting interfaces, we use a combination of interfacial shear rheology, neutron reflectometry, atomic force microscopy and magnetic tweezer-assisted interfacial micro-rheology. In turn, we investigate how controlling interfacial mechanics enables the control of cell adhesion, but also the maintenance of stem cell phenotype.

Results and Discussion

We show how the design of macromolecular architecture enables the regulation of interfacial toughness and viscoelasticity and how this, in turn, controls the expansion of mesenchymal stem cells. To modulate such mechanical properties, we design polymer and protein assemblies at liquid-liquid interfaces, forming nanosheets with a broad range of mechanical profiles. We demonstrate that the nanosheets assembled display particularly high anisotropy and controlled interfacial shear moduli, viscoelasticity and toughness [3-4]. In turn, cells respond strikingly to such anisotropic mechanics. Indeed, mesenchymal stem cells (MSCs) and induced pluripotent stem cells (iPSCs) are found to adhere to aqueous-oil interfaces stabilised by nanosheets. We find that their adhesion, mediated by the integrin-actomyosin machinery, is regulated by the mechanics of these interfaces and strikingly insensitive to the mechanics of the underlying liquid substrate. In turn, nanosheets are found to stabilise the formation of microdroplets and stable emulsions that support the expansion of MSCs and iPSCs, the retention of their phenotype and promotion of pro-reparative secretory profiles [4-5].

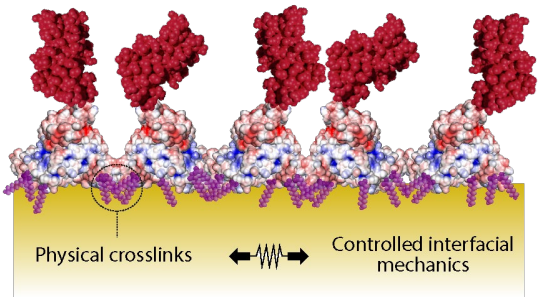

Figure 1: *Engineered protein nanosheets enabling controlled interfacial mechanics and bioactivity.*

Conclusions

Therefore, this works paves the way towards a new range of microcarriers, based on bioactive emulsions (or bioemulsions), for the production of stem cells and their application in regenerative medicine.

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Acknowledgements

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The influence of fluid shear on cell adhesion investigated with photoelectrochemical imaging (PEI)

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Abstract: This study utilized a photoelectrochemical imaging (PEI) sensor with electrolyte-semiconductor (ES) structure. The sensor was constructed using electrodeposited nanocrystalline α-Fe_2O_3 thin films on FTO-coated glass substrates, enabling label-free, non-contact dynamic cell monitoring through backside scanning with a modulated laser beam. Under laminar flow conditions (0.42–1.02 ml/min), the PEI successfully acquired high-resolution images of osteosarcoma (SAOS-2) cell adhesion, quantitatively characterizing cell adhesion strength through photocurrent responses and elucidating the shear stress-mediated cell-substrate interaction mechanisms. This technology provides a high spatiotemporal resolution analytical tool for investigating cellular mechanics in physiologically relevant fluid environments.

Keywords: cell adhesion; fluid shear stress; photoelectrochemical imaging

Introduction

Cell adhesion is a core mechanism that regulates biological processes such as differentiation, migration, and proliferation. While traditional fluorescence microscopy offers nanoscale resolution, its reliance on fluorescent labelling leads to issues like photobleaching[1]. Recent advancements in non-contact imaging technologies, such as light-addressable electrodes leverage the photoelectric effect of semiconductor materials to monitor dynamic cellular behaviours label-free with micron-level resolution[2].

Results and Discussion

The study successfully established a PEI platform for cellular analysis under hydrodynamic conditions. Computational fluid dynamics simulations using Fluent software revealed distinct flow velocity profiles within microchannels at 0.42 ml/min, as illustrated in Figure 1.

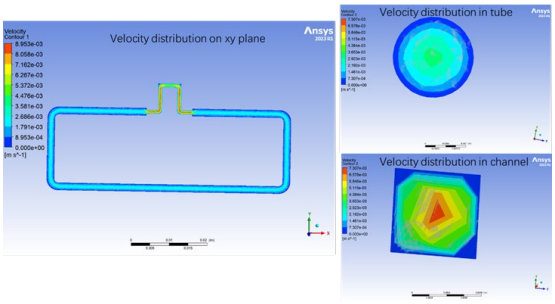

Figure 1: *Fluid local velocity Simulation for fluid system under 0.42ml/min flow rate*

Fluid shear experiments revealed significant photocurrent attenuation at flow rates of 0.42–1.02 ml/min as depicted in Figure 2, with fluorescence microscopy confirming complete detachment of live cells, attributed to localized shear stress exceeding cellular adhesion thresholds.

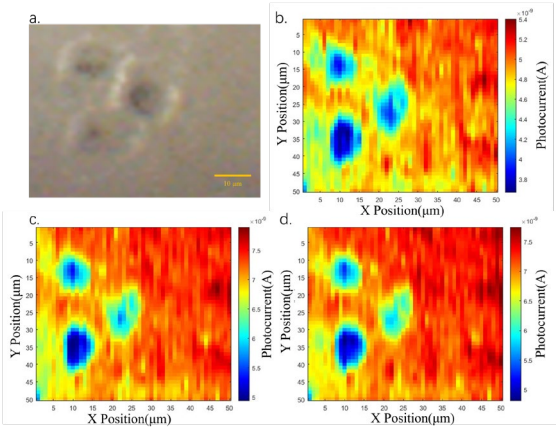

Figure 2: *(a) Optical image of osteosarcoma (SAOS-2); (b–d) Photocurrent images at 0, 0.42, and 1.02 mL/min.*

Future research will integrate experimental data with hydrodynamic simulations to establish a precision-controlled shear stress model, with extensions to targeted drug delivery and stem cell electrophysiology studies.

Conclusions

This study achieves in situ simultaneous observation of Saos-2 cell adhesion dynamics under fluid shear stress, providing a novel high spatiotemporal resolution analytical tool for revealing the regulatory mechanisms of mechanical microenvironment on cell adhesion.

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Co-sputtered Titanium-Europium Thin Films for Biomedical Implants: Fabrication, Structure and Stability

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Abstract: This study focuses on improving Titanium´s (Ti) properties as an implant material. Research has shown that the addition of rare earth elements like Europium (Eu) has the potential to achieve this goal. Co-sputtered Ti-Eu thin films, with a compositional spread have been investigated in terms of their physical properties, band gap changes of their oxides and corrosion resistance. The results revealed electrochemical stability in simulated body fluids across all compositions. At the same time unique structuring of the oxide layer has been observed after anodisation, while crystallographic and bandgap analysis showed interesting changes with composition.

Keywords: implant, thin film, alloy, combinatorial, electrochemistry, rare earth

Introduction

Ti is the material of choice for medical applications especially implants. Nevertheless, continuous research efforts are devoted to further improve its properties. Recent studies have shown that incorporating Eu into Ti´s protective oxide layer can lead to improved cell adhesion while maintaining a high corrosion resistance [1]. This study investigates the interactions between Eu and Ti and their oxides over a wide compositional range. For this purpose, a combinatorial thin film library was deposited via sputtering and their physical and electrochemical properties were examined.

Results and Discussion

In this study Ti-Eu thin films were produced by co-sputtering. A compositional spread ranging from 3 to 20 at.% Eu was achieved. A comprehensive physical analysis was performed on selected compositions. The methods include EDX, XRD, SEM and TEM. Furthermore, ellipsometry was performed on an anodically grown oxide layer of the metal in order to investigate changes to its bandgap. As an example Figure 1 shows a TEM cross-section of the 3 at.% Eu film revealing a well-defined bilayer oxide: an inner region with protruding filaments and minimal Eu, and an Eu-rich outer layer, while Eu remains uniformly distributed in the underlying metal. Localized electrochemical measurements using a Scanning Droplet Cell Microscope (SDCM) revealed a uniform corrosion resistance across the compositional range, yet systematic shifts in the alloy's crystallographic texture were detected along the Eu gradient via XRD.

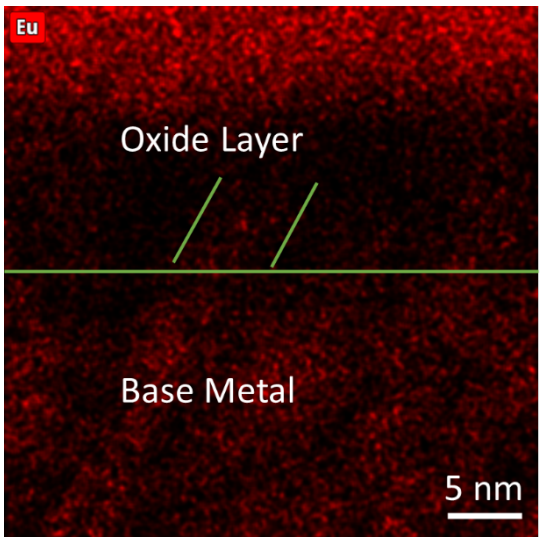

Figure 1: *TEM image of the 3 at.% Eu composition, showing the base metal and the anodic oxide, with Eu coloured in red.*

Conclusions

A Ti-Eu thin film library was co-sputtered and comprehensively characterized by EDX, XRD, SEM, TEM and ellipsometry. It was possible to reveal the formation of a two-layer oxide after anodization. The SDCM measurements confirmed uniform corrosion properties despite changing Eu contents. Simultaneously changes in the crystallography and other oxide properties have been identified along the compositional range. The study suggests good suitability of the films for implant applications and opens new interesting mechanistic research questions.

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Adaptive Oral Multispecies Biofilm Flow Chamber *in vitro* Model

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Abstract: *In vitro* models of oral multispecies biofilms are an important tool in research to advance dental implant safety. In this work, we aimed to develop an adaptive oral multispecies biofilm *in vitro* model able to resemble a dysbiotic biofilm shift under flow conditions to study mechanisms of biofilm growth and diversification and test diagnostic tools, preventive strategies, and treatment options.

Keywords: dental plaque, *in vitro* model, dental implant, dysbiosis

Introduction

26% of dental implants with an implant function time of more than 5 years are affected by peri-implantitis [1]. Therefore, more research is required to treat, understand, and prevent these bacterial infections. For this purpose, *in vitro* models are an important tool to test antibacterial substances, observe mechanisms of biofilm growth, and explore preventive strategies. In the Hannoverian Oral Multispecies Biofilm Implant Flow Chamber (HOBIC) model, a multispecies biofilm is grown under constant flow conditions, simulating salivation in the human oral cavity [2]. With the current cultivation conditions, it exhibits a commensal composition that reflects oral health. The aim of the present study was to advance the HOBIC model to reproduce the pathogenic shift in species composition occurring during peri-implantitis to provide an even more realistic testing system.

Results and Discussion

To obtain the bacterial shift and identify relevant boundary conditions, two different combinations of bacterial species were grown in the HOBIC model and under static control condition, containing *Streptococcus oralis*, *Actinomyces naeslundii*, *Fusobacterium nucleatum*, and either *Veillonella dispar* combined with a *Porphyromonas gingivalis* type strain (commensal model), or *Veillonella parvula* combined with a *P. gingvalis* clinical isolate (pathogenic model). Biofilms were analysed after 3, 6, 10, 15, and 21 days of continuous cultivation.

Live/Dead fluorescence-staining followed by confocal laser scanning microscopy confirmed a stable biofilm growth over 21 days for both species combinations, with increased growth of the pathogenic model. In parallel, whereas the commensal model only showed a diversification of commensal species over time, pathogenic species significantly increased in the pathogenic model, as analysed by qRT-PCR. These differences could also be confirmed on the metabolic level, with the pathogenic model showing higher pH-values and more gingipain protein.

Conclusions

In this work, we were able to develop an adaptive oral multispecies biofilm *in vitro* model that replicates different clinical conditions and can now be used for antibacterial approaches testing.

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A distributed Bragg Reflector interface with high spectral tunability for filter-free fluorescence microscopy

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Abstract: A highly tuneable, filter-free, platform with Distributed Bragg Reflector (DBR) platform for fluorescence spectroscopy/microscopy is presented in this work. The given platform facilitates easier implementation of the fluorescence-based characterization techniques in simplified, portable optical setups for potential point-of-care use. The tuneability of this platform also ensured its easily adaptability to many common fluorescent dyes used for this technique.

Keywords: Fluorescence spectroscopy; Bragg reflector; Alexa Fluor; Ion beam deposition, filter-free microscopy

Introduction

Fluorescence microscopy has been a prominent measurements modality for medical diagnostics [1], scientific research [2], agriculture monitoring [3] and food industry [4] etc. Traditionally, a complex train of indispensable optical components and light sources are used to selectively excite a specific fluorophore bonded to an analyte (molecular labelling). Furthermore, multiple sets of these optical filters are required to for different fluorophore owing to their different excitation and emission spectrum [5]. These also makes remote implementation of this technique, for example, in point of care testing or Tele-Diagnosis very challenging [6].

In this work we present a highly tuneable, DBR platform for filter-free fluorescence spectroscopy /microscopy. The DBR consists of several pairs of high (TiO_2) and low (SiO_2) refractive index (RI) material stacked on top of each other. The design aim was to have very low and a relatively high reflectively of the DBR near the excitation wavelength and emission wavelength respectively of a fluorophore. So, when the platform is used as a substrate for fluorescence spectroscopy only the emitted light from the fluorophore is captured by the detector while the excitation light can be efficiently blocked by the DBR. This platform can also be easily adapted for other fluorophore dyes by changing the film thicknesses of either one or both of its constituent layers.

Results and Discussion

Figure 1 shows the simulated reflection spectrum of the DBR platform designed for Alexa Fluor 532 Dye. With a narrow band led for excitation around 532 nm, the excitation light can be efficiently blocked by the DBR because of the low reflectivity of the DBR around this wavelength. While, the emission from the fluorophore will be reflected back to the detector as the emission spectrum lies in the high reflectivity spectrum of the DBR.

Conclusions

A tuneable DBR is presented in this work as a potential platform for filter-free fluorescence spectroscopy. The DBR platform is flexible and can be adapted to new fluorophore by tunning the constituent layers thickness. The reduced complexity of the fluorescence measurements with this DBR platform, will also facilitate easier integration of this technique for remote measurement schemes.

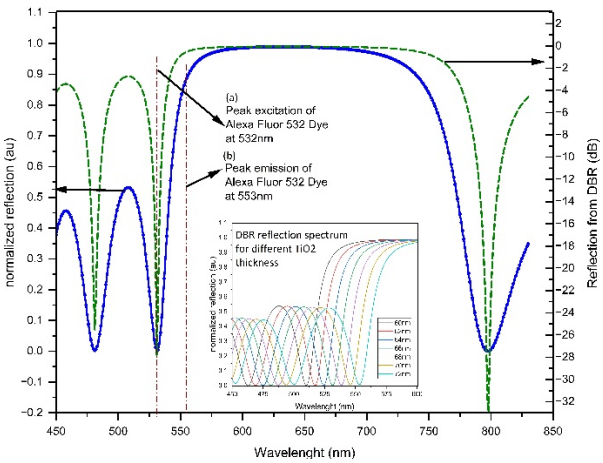

Figure 1: *Reflection spectrum of the DBR platform designed for Alexa Fluor 532 Dye having peak excitation peak at 532nm (a), and emission at 553nm (b).* The *emission spectrum of the Alexa Fluor 532 Dye very efficiently reflects back the DBR while simultaneously blocking the excitation light at 532nm.* ***Inset:*** *Tuneability of the DBR reflection spectrum by tunning the TiO_2 thickness.*

Acknowledgements

The authors acknowledge the support from FLEXCOMPUTE, INC. from providing access to the Tidy3D software for running all the numerical simulations in this work. The authors also thank ZMNT – Central Laboratory for Micro- and Nanotechnology, RWTH Aachen University, for their support in fabrication process. BioeconomieREVIER project no. *031B1134C* (ProtLab2) funded by BMBF.

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Conductive and Biodegradable MIP-Based Biosensor for Real-Time IL-6 Monitoring During Surgical Intervention

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Abstract: Intraoperative monitoring of inflammatory markers can improve surgical outcomes. Traditional ELISA methods are time-consuming, whereas electrochemical impedance spectroscopy (EIS) offers rapid analysis within 3 minutes across a 1 Hz–100 kHz range. This study presents a conductive, biocompatible, and biodegradable molecularly imprinted polymer (MIP) for selective detection of biomarker interleukin-6 (IL-6), with a detection limit of 290 pg/mL. Degradation was monitored via EIS and FTIR analysis identified a critical potential of 0.205 V, below which complete depolymerization occurred. These results demonstrate the feasibility of biodegradable MIPs as fast, reusable biosensors for real-time inflammation monitoring during surgical procedures.
Keywords: Cochlear implant, electrochemical polymerization, MIPs, electrochemical degradation

Introduction

The ability to monitor inflammatory biomarkers in real time during surgical procedures offers significant potential for improving intraoperative decision-making and patient outcomes. Among these biomarkers, IL-6 plays a central role in mediating inflammatory responses and is commonly elevated in various pathological conditions [1]. Rapid detection of IL-6 could therefore provide valuable clinical insight, particularly in time-sensitive surgical contexts [2]. Conventional detection methods such as ELISA are sensitive and reliable but are limited e.g. by labour-intensive protocols and long testing times. These restrictions make use in surgical environments difficult. EIS has emerged as a rapid and label-free alternative, capable of delivering results within minutes. When combined with MIPs, which provide high specificity through template-induced recognition sites, EIS becomes a powerful tool for biosensing applications [3]. In this study, conductive MIP and non-imprinted polymer (NIP) films based on PEDOT: PSS were electrochemically deposited. IL-6 epitope was used as the template due to the IL-6 high cost.

Method

PEDOT:PSS was electrochemically deposited using galvanostatic. To evaluate MIP functionality, EIS were conducted in phosphate-buffered saline (PBS) with and without different IL-6 concentrations. Cross-selectivity was assessed by using human serum albumin (HSA) interleukin-9 (IL-9) and interleukin-1ß (IL-1ß). Additionally, EIS was also realized in real in-vivo samples. However, as PEDOT is non-biodegradable, its degradation was induced electrochemically by modulating the applied potential during extended EIS cycles. Additionally, PBS containing the resulting monomeric and oligomeric fragments was subjected to a biocompatibility test and FTIR.

Results and Conclusions

MIP exhibited a measurable change in impedance upon exposure to IL-6 at 290 pg/ml and higher, while NIP showed no response. Specificity was further validated by the absence of impedance response to HSA, IL-9 and IL-1ß. Although detection at clinically relevant levels (~2 pg/ml) in real in-vivo sample remains a challenge, results suggest that optimizing the epitope-to-monomer ratio could improve sensitivity. However, decreasing potential correlated with increased monomeric degradation, with complete deploymerization below 205 mV yielding renally clearable monomers (figure 1). FTIR analysis confirmed the identity of degradation products, and biocompatibility testing demonstrated high biocompatibility. Overall, this work presents a conductive, biocompatible, and degradable MIP platform with selective analyte recognition. Moreover, MIPs detection during surgical procedures can be used to synthesise patient-specific nanoMIPs suitable for real-time monitoring on an AIMD.

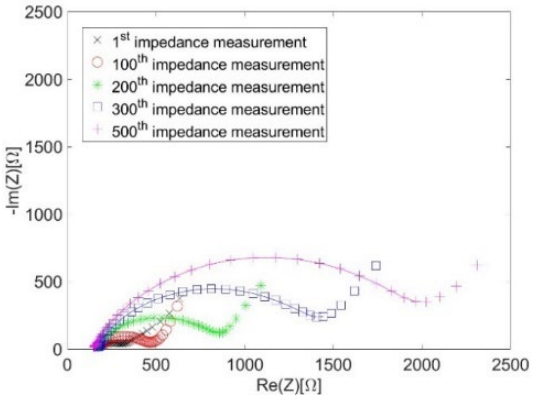

Figure 1: *Nyquist plot for electrical degradation*

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3D Printing of Scaled Neural Implants: Additive Fabrication Tailored to Rodent Skulls

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Abstract: This work presents a fully additive manufacturing strategy for active implantable medical devices (AIMDs) tailored to rodent skulls. Using 3D printing with conductive epoxy paste and medical-grade silicone, we successfully fabricated a flexible, multi-layer implant containing up to 19 electrodes. A dual-layer design compensates for limited wiring space, allowing for tighter line spacing and improved signal routing.

Keywords: neural implants; conductive paste; medical silicone; 3D printing; rodent model

Introduction

Additive manufacturing of implantable medical devices (AIMDs) offers a promising pathway for highly customizable, flexible neural interfaces. Traditional microfabrication techniques are often time-consuming, non-adjustable to individual needs and expensive, motivating the exploration of direct 3D printing of conductive and insulating materials. Our work focuses on the development of a flexible multi-electrode implant fitting the special anatomic features and very limited space of the rodent skull, fabricated entirely via a layer-by-layer 3D printing process using conductive epoxy paste (Elecolit-3648) and silicone (Sylgard-184). Furthermore, water-soluble polyvinyl alcohol (PVA) was used as a more biocompatible option for sacrificial layers and supporting structures during the printing process.

Results and Discussion

The manufacturing process features two main materials. Sylgard-184, a medical-grade silicone that serves as both insulation and flexible carrier layer as well as Elecolit 3648 used for the conductive elements of the implant.

White-light interferometry was used to derive suitable printing parameters for each material allowing printed layer thickness of ~25–30 µm, enabling precise stacking.

The 3D-printing process employs a 3D-bioplotter system (EnvisionTec) to deposit conductive traces with a minimum line width of 250 µm using a 30GA cannula. For the silicone lines a 200µm resolution was accomplished. Each functional layer (wiring, insulation) was successively deposited.

Due to the very limited space on the skull (~30x70mm), a two-layer architecture was introduced, doubling the available wiring area without compromising implant flexibility.

The PVA pre-coated glass substrates allowed a stress-free implant release using only water. Compared to conventional sacrificial layers which are removed with aggressive solvents or developers, the use of PVA enables the removal of sacrificial and support layers without additional chemical input simply by water and thus promotes biocompatibility.

***Figure 1:** The multi-electrode implant on glass substrate and fitted on the skull*

Conclusions

The presented approach enables fast, scalable, and flexible production of rat-scale neural implants using entirely additive processes. Although yield and resolution require further optimization, the technique holds promise for experimental neurotechnology, particularly in high-throughput animal studies.

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Acknowledgements

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InToSens (InflamatoryToxinSensor) – iGEM- Project 2020

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Abstract: Implantitis, a difficult-to-detect inflammation in implants often caused by biofilms, can lead to severe complications. We developed a sensor using engineered cells that respond to bacterial toxins via the NF-κB pathway, expressing MagA for MRI visualization and Gaussia Luciferase for detection in body fluids. *In vitro* tests confirmed reporter protein expression and identified the IL6 promoter as suitable for toxin-induced activity. A microfluidic chamber for characterizing magnetic particles was also developed, showing separation based on magnetic field strength, with future adjustments needed for analyzing MagA-expressing cells.

Keywords: implantitis; biofilm; intestinal epithelial cells; lipopolysaccharides; synthetic biology

Introduction

Implantitis, an implant-associated inflammation often caused by bacterial biofilms, is difficult to detect early and can lead to severe complications like implant loss and sepsis. With genetically engineered intestinal epithelial cells a sensor was developed that responds to bacterial toxins by activating the NF-κB pathway [1]. This activation drives the expression of two reporter proteins: MagA, allowing MRI visualization of biofilm formation [2], and Gaussia Luciferase, secreted and detectable in bodily fluids [3] for enhanced sensitivity.

Results and Discussion

In vitro expression of the reporter proteins, MagA, visualized with a fluorescent tag showing membrane localization, and Gaussia Luciferase, detected in supernatant, was successfully reported in HeLa cells, confirming secretion and activity. Several promoters were tested for LPS-inducible activity and the IL6 Promotor was found to be the most suitable one.

A microfluidic chamber was also designed and tested to characterize magnetic particles, intending it for future analysis of their MagA-expressing cells. Using magnetic beads and iron microparticles, the chamber's ability to separate particles based on magnetic field strength was demonstrated.

It was observed that larger iron microparticles were more easily influenced by the magnetic field than smaller magnetic beads. Adjustments to the chamber and stronger magnetic fields will be needed for analyzing their MagA-expressing cells, which contain smaller magnetic nanoparticles.

Conclusions

The results show that the sensor can be applied to detect the bacterial endotoxin LPS *in vitro*, which is present in all biofilms containing gram negative bacteria. This demonstrates a first proof that the sensor concept is likely to work in a relevant context.

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Acknowledgements

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Adhesion forces of *Candida albicans* to polymeric materials

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Abstract: *Candida albicans (C. albicans)* adhesion to polymeric surfaces is a key factor in denture-related stomatitis. This study analyzed adhesion forces on polyvinyl chloride (PVC) and polytetrafluoroethylene (PTFE) using single-cell force spectroscopy. The results showed that adhesion forces are influenced by both saliva and surface properties, such as roughness and hydrophobicity. The findings highlight the role of surface characteristics in microbial adhesion. Understanding these interactions can guide the development of anti-adhesive denture materials, potentially reducing the risk of denture-related infections and improving oral health for denture wearers in the future.

Keywords: *Candida albicans,* atomic force microscopy, single-cell force spectroscopy, polymeric prosthesis material, roughness

Introduction

Denture-related *Candida* stomatitis is an inflammatory condition of the oral mucosa beneath removable dental prostheses, primarily caused by the oral fungus *Candida albicans* [1]. A critical factor in the development of these material-associated infections is the adhesion and subsequent biofilm formation of *C. albicans* on polymeric surfaces [2]. However, the underlying mechanisms governing the adhesion of *C. albicans* on different polymeric materials remain incompletely understood. This study aims to investigate these biophysical processes on a single cell level.

Results and Discussion

Material properties were analysed using confocal laser scanning microscopy (CLSM), while the adhesion forces of single cells were measured via single-cell force spectroscopy (SCFS) [3] on PVC and PTFE surfaces, with and without artificial saliva. Surface hydrophobicity and roughness, as well as saliva, significantly influenced *C. albicans* adhesion. Hydrophobic, rough surfaces (PTFE 0.2 µm) exhibited significantly higher adhesion forces and adhesion points than non-hydrophobic PVC. In PVC samples, adhesion behaviour strongly correlated with surface roughness [**Figure 1**].

Conclusion

In the present investigation, a range of behaviours exhibited by *C. albicans* cells with regard to adhesion forces on various polymeric materials were elucidated. The results may facilitate the development of innovative denture materials to reduce *C. albicans* adhesion and thereby the prevalence of stomatitis in future.

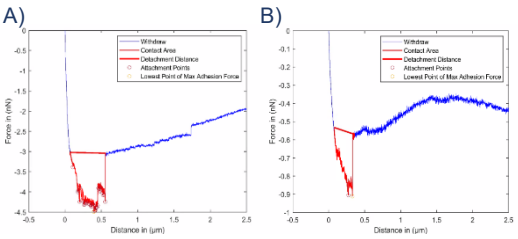

Figure 1: Exemplary force-distance curves
The adhesion points and maximum adhesion force of C. albicans on PTFE (roughness: 0.2 µm, A) and PVC (roughness: 0.2 µm, B) are shown.

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Acknowledgements

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Tracking cell migration by cellular force footprint recorded with a mechano-optical biosensor

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Abstract: Conventional cell migration assays require time-lapse imaging of live cells to trace cell migration paths, consequently demanding cumbersome hardware setup and suffering from low data throughput. In this work, I developed an assay named Tracking Cells by Footprint (TCF) based on a mechano-optical biosensor that irreversibly becomes fluorescent when sensing local cell adhesive force. Cell migration paths are visualized and recorded as fluorescent footprints on glass or elastic substrates coated with such biosensor. From the footprints, cell migration ranges, speeds and persistence are analysed and quantified without the need of time-lapse imaging.

Keywords: Mechano-optical biosensor, DNA sensor, cell migration, cellular force

Introduction

Cell migration is an essential process throughout life from embryonic development to apoptosis [1]. To study cell migration, time-lapse imaging is typically performed to continuously monitor the cell locations However, live cell migration assay with time-lapse imaging requires a cumbersome hardware setup and has intrinsic difficulty in producing data in high throughput. To address these technical challenges, we developed track cells by footprint to record cell migration tracks as cellular force fluorescent footprints. In a typical TCF assay, cell culture surfaces are homogeneously coated with a mechano-optical biosensor, which is initially dark but can be activated to fluoresce by integrin-transmitted cell adhesive force. The mechano-optical biosensor used in this assay is integrative tension sensor previously developed in our lab. Briefly, ITS is a double-stranded DNA or a DNA/PNA hybrid duplex labelled with a pair of quencher and fluorophore and equipped with a RGD peptide ligand targeting integrin. Immobilized on a surface, the ITS becomes fluorescent when the dsDNA or the DNA/PNA duplex is mechanically disassociated by the force transmitted by integrin-RGD ligand bonds. Previously, ITS was mainly used to study cell adhesive force and force-structure interplay in adherent cells [2]. Here, ITS is adopted to record cell migration tracks in the TCF assay.

Results and Discussion

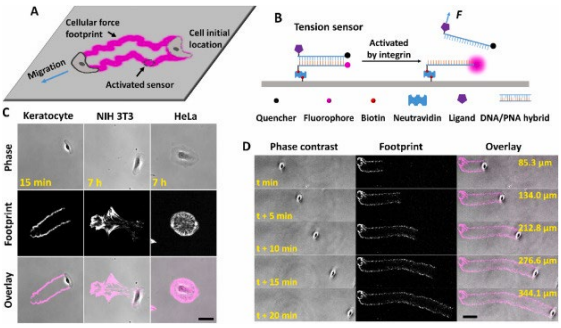

Figure 1: *Reporting cell migration paths by cell footprint recorded by mechano-optical biosensor. (A) The principle of the TCF (Track Cells by Footprint) assay. A cell leaves 'footprint' by activating tension sensor (ITS), a mechano-optical biosensor, to fluoresce along the migration path. (B) ITS consists of a DNA/PNA hybrid decorated with a pair of quencher and fluorophore and a ligand (RGD). If the PNA/DNA hybrid is ruptured by the cellular force transmitted by integrins, the originally quenched fluorophore becomes fluorescent. (C) Footprints of fast migrating cells (keratocytes, 15 min), slow migrating cells (NIH 3T3 fibroblasts, 7 h) and static cells (HeLa, 7 h) on the TCF platform. (D) Time-series images of keratocyte footprint developed in 20 min. The cell migrated for 48.7, 127.5, 191.3, and 258.8 µm in 5, 10, 15 and 20 min, respectively. Scale bars: 50 µm.*

Conclusions

We developed a TCF assay to evaluate cell motility by cellular force footprints recorded on a mechano-optical biosensor ITS. The TCF platform coated with such biosensor converts cell adhesive force to permanent fluorescent mark on a surface, hence recording cell migration tracks as fluorescent footprints. The spatial resolution of force imaging obtained by ITS was previously demonstrated as 0.4 µm, which is sufficient for tracking the migration of small mammalian cells or cell fragments.

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Acknowledgements

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PCB-Integrated 3ω Sensor with Suspended Microwires for Thermal Measurements

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Abstract: A 3ω thermal conductivity sensor was developed using a freely suspended gold wire integrated into a microfluidic compartment on a printed circuit board. 3ω voltage signals, based on temperature oscillations at 2ω, were measured in ethanol-water mixtures and showed clear dependence on thermal conductivity. While comparison with planar sensors is ongoing, the wire-based design shows potential for improved sensitivity and future electrochemical integration for biochemical sensing.

Keywords: Sensor; 3ω principle; Thermal waves; Hot-wire

Introduction

The 3ω method works by passing an AC current through the wire, which heats it and causes its temperature to oscillate at twice the frequency of the current. These temperature changes cause the wire's resistance to vary, creating a voltage signal at three times the original frequency (3ω). The strength of this 3ω signal depends on how quickly heat moves away from the wire into the surrounding liquid. By measuring this signal, the thermal conductivity of the liquid can be accurately determined.

Results and Discussion

The experimental setup involved the fabrication of a hot-wire thermal conductivity sensor using a freely suspended gold wire integrated into a microfluidic compartment on a PCB. Ethanol-water mixtures with varying concentrations were introduced into the channel, and 3ω signals were measured using a lock-in amplifier across a range of frequencies. Based on thermal wave oscillations at 2ω generated by Joule heating, the resulting 3ω voltage signals were analyzed to assess the thermal interaction between the wire and surrounding fluid (Eq. 1).

$$|U_{3\omega}| = \frac{1}{2} R_0 I_0 \beta |T_{2\omega}| \qquad \text{Eq. 1}$$

Clear distinctions in thermal response were observed, with higher ethanol content resulting in higher 3ω voltage amplitudes, consistent with ethanol's lower thermal conductivity compared to water. A Bessel function-based model was used to fit the frequency-dependent data, enabling the extraction of thermal conductivity values from the experimental measurements.

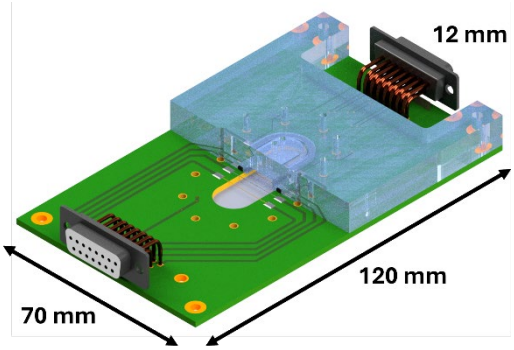

Figure 1: *PCB-integrated 3ω sensor with suspended microwires*

Conclusions

This platform allows for sensitive, label-free characterization of fluid thermal properties in small volumes. Future work may explore biochemical surface modifications and integration of reference and counter electrodes to extend the sensing capabilities toward the detection of biochemical interactions.

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Acknowledgements

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Spontaneous cell detachment under thermal stimulation: A label-free pharmacological approach for assessing antifungal drug activity

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Abstract: Efficient and real-time monitoring of antimicrobial efficacy is essential for pharmacological research and clinical decision-making, yet the development of novel techniques that are rapid, cost-effective, and easy to implement remains essential to overcome the limitations of conventional assays. Hereby, we propose a sensitive, label-, and receptor-free method based on the modulation of spontaneous cell detachment kinetics by drugs.

Key words: Cell-based biosensor, pharmacological drug-testing, spontaneous cell detachment, antimicrobial resistance, antifungal drugs

Introduction

The increasing threat of antimicrobial resistance and the growing complexity of microbial infections highlight the urgent need for new methods to evaluate drug efficacy. Traditional assays, such as disc diffusion, and agar dilution, or more advanced time-kill tests and flow cytofluorometric methods often rely on labor-intensive/time-consuming protocols that may not accurately reflect dynamic cellular responses.[1] Therefore, innovative techniques that are faster, cost-effective, and capable of capturing real-time or functional cellular changes are essential for advancing pharmacological research and predicting therapeutic outcome. Here, we exploit the spontaneous cell detachment effect from a temperature gradient reported in reference 2 to characterize the response of two antifungal drugs on *C. albicans* and *S. cerevisiae*.

Results and Discussion

S. cerevisiae and *C. albicans* Tansir 082 were treated with two drugs, miconazole and ciclopirox. Spontaneous detachment monitoring was performed for a heating temperature of 27 ºC (closer to room temperature as well as the optimum growth temperature of 30 ºC). To allow for monitoring the drug effect on cell growth (ground proof), measurements were also performed for drugs on cells in culture-rich medium. For *S. cerevisiae*, spontaneous detachment time, t_d, is sensitive to as low as 1% miconazole and completely suppressed by concentrations of ≥75%. Also, ciclopirox concentrations of 0.2% caused significant lengthening of spontaneous detachment time, with no detachment for concentrations of ≥ 1%. Likewise, low drug concentrations of similar range also increase the spontaneous detachment time of *C. albicans* compared to drug-free medium, with a total suppression for ≥ 50% miconazole and 10% ciclopirox. Finally, we showed that in the presence of culture medium, the drug-modulation of t_d, as well as cell proliferation time, t_p, can be monitored simultaneously, allowing to correlate the new method with conventional cell culture techniques.

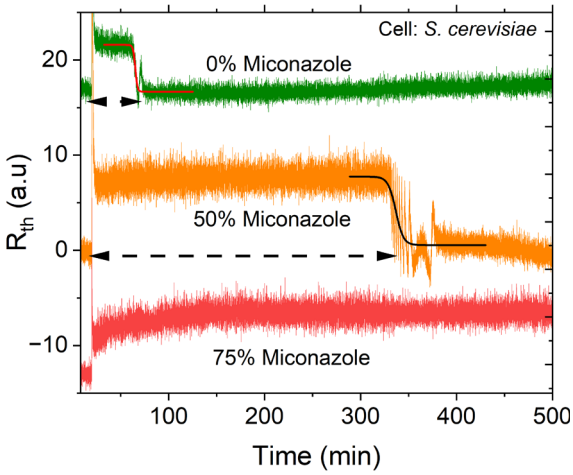

Figure 1: Modulation of spontaneous detachment of S. cerevisiae by anti-fungal drug, miconazole.

Conclusion

Spontaneous cell detachment responds sensitively to anti-fungal drugs, providing a new strategy for pharmaceutical assessment of drug efficacy.

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Acknowledgement

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“Nature” in action – beeswax and carnauba wax as encapsulation materials for bioresorbable temperature sensors?

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Abstract: Beeswax and carnauba wax have been tested as natural encapsulation materials for future implantable, magnesium-based resistance temperature detectors (RTDs) onto a polylactic acid (PLA) substrate. Goal of this study was to expand the lifetime of the fully bioresorbable RTD to at least 72 hours. The sensor performance was examined at a temperature range between 30 °C and 43 °C under both ambient air and tissue-like conditions (inside a hydrogel).

Keywords: polylactid acid, temperature sensor, magnesium alloy, bioabsorbable, encapsulation materials

Introduction

Implantable, bioresorbable sensors are attractive for the real-time observation during the postoperative healing process, especially during the crucial first 72 hours [1]. With magnesium as material for temperature sensing, such a long service-time can only be achieved by utilizing bioresorbable encapsulation materials [2]. These materials are intended to slow down the degradation process without affecting the sensor functionality. In this work, we investigated bioresorbable materials provided by nature, that is beeswax (BW) and carnauba wax (CW), as encapsulation layers for a biocompatible and biodegradable Mg-based RTD, previously developed in our group [3].

Results and Discussion

A meander-shaped Mg-based RTD was deposited onto PLA and encapsulated with the biocompatible and bioresorbable materials BW and CW. The sensor performance and lifetime were characterized under ambient air and tissue-like (inside a hydrogel) conditions in the temperature range between 30 °C and 43 °C.

Figure 1 shows exemplary sensor signals under ambient air conditions of the Mg-based RTDs for the two encapsulation materials BW and CW. Under tissue-like conditions, only the CW-encapsulated RTD could reach the targeted 72 h service-time, however, with corrosion-induced drift effects visible in the measurement signal.

Conclusion

The encapsulated magnesium-based resistors were successfully characterized under hydrolysis-free and tissue-like conditions. For the measurement under ambient air conditions the RTDs of both encapsulation materials demonstrated distinct temperature steps, resulting in a temperature coefficient of about 0.003 °C^{-1}. Measurements under tissue-like conditions showed that BW was no longer functional for use above 35 °C at humid conditions (hydrogel).

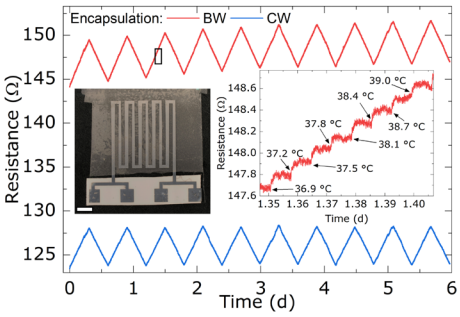

Figure 1: *Resistance over time measurements for exemplary Mg-based RTDs with the “natural” encapsulation materials beeswax and carnauba wax on a bioresorbable PLA substrate between 30 °C and 43 °C in 0.3 °C steps under ambient air conditions. On the right, a magnification of a section of the third heating cycle of the BW-encapsulated Mg-based RTD is shown. The picture (left) presents an exemplary BW-encapsulated Mg-based RTD. The white bar corresponds to 2 mm.*

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Hybrid Flexible and Stretchable Epidermal Electronic System for Cardiac Monitoring

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Abstract: This work presents a skin-close, hybrid Epidermal Electronics System (EES) for cardiac monitoring. Combining flexible and stretchable materials, it integrates gold electrodes for electrocardiography (ECG), a 3-axis accelerometer for seismocardiography (SCG), and a temperature sensor. Data is processed and transmitted via Bluetooth Low Energy (BLE). The modular design ensures versatility, while the small form factor provides comfort and high signal quality, enabling accurate and real-time cardiac health monitoring. Additionally, systolic time intervals (STI) are extracted from the measurements, offering valuable insights for cardiac diagnosis.

Keywords: Epidermal Electronics System (EES); Cardiac monitoring; Electrocardiogram (ECG); Seismocardiogram (SCG); Bluetooth Low Energy (BLE).

Introduction

Cardiac monitoring is essential for early detection and management of heart conditions, yet conventional devices are often bulky and uncomfortable, limiting patient compliance. This project aims to develop an advanced monitoring system capable of measuring ECG and SCG simultaneously [1], allowing for accurate STI extraction, which provides insights into cardiac function, enabling the detection of conditions such as heart failure and valve disorders. Building on our earlier work [2], this system offers enhanced integration, modularity, and functionalities. The project is ongoing, and recent results, including STI analysis, are presented.

Results and Discussion

The EES comprises a flexible circuit module based on polyimide (PI) and a stretchable electrode module made from Flexdym™. The circuit module was fabricated using a cleanroom microelectronics process, including photolithography, evaporation, and electroplating, ensuring precise patterning and high-quality connections. The stretchable module was produced via a screen-printing process, providing excellent elasticity and adaptability. Both modules were then interconnected using magnetic snaps, enabling easy assembly and separation.

As a prototype, a flexible Printed Circuit Board (PCB) based on 50-µm PI and 35-µm copper has been designed.

Figure 1: *A schematic of the hybrid and modular design concept.*

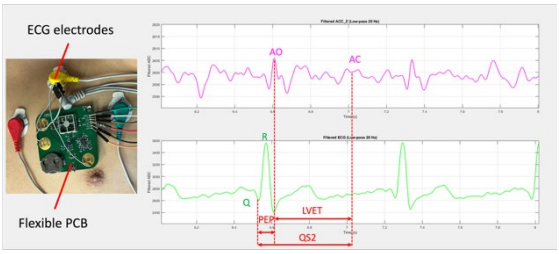

Figure 2: *Left: Measurement setup with the prototype PCB. Right: A section of the measured SCG traces (top) and ECG traces (bottom) signals, highlighting key waveform components—Aortic Opening (AO) and Aortic Closure (AC) in SCG, and the QRS complex in ECG—along with the Systolic Time Interval (STI) parameters: Pre-Ejection Period (PEP), Left Ventricular Ejection Time (LVET), and Q to Second Heart Sound Interval (QS2).*

Conclusions

In this project, a proof-of-concept EES with a thin-film electronics design was demonstrated through successful prototyping. The next phase in our project will focus on fabricating and assembling both flexible and stretchable modules, further advancing the functionality and integrity of the EES.

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Acknowledgements

Funding came from the CORNET project “Hybrid E-Tattoo: a platform for sensor fusion of smart textiles and skin adhesives for the next generation of smart wearables” (IGF 351 EN) and from the RWTH Aachen University.

Development of a Biochip for Dissection of Multivalent Atherosclerosis Signalling

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Abstract: Atherosclerosis is a chronic inflammatory condition wherein the stiffness of the cardiac extracellular matrix (ECM) increases with disease progression. Mechanosensitive cells, such as vascular smooth muscle cells (vSMCs), produce intracellular chemical signals in response to this stiffening, instigating phenotypic switching and potentially atherosclerotic plaque development. Transmembrane proteins, called integrins, mediate this signalling by binding to proteins and through crosstalk with other receptors, including proteoglycan binding receptors. The contribution of this crosstalk to mechanosignalling is unknown and so this study aims to examine modulation of adhesion properties and integrin activation resulting from integrin crosstalk with proteoglycan receptors in vSMCs.

Keywords: mechanotransduction, DNA origami, atherosclerosis, nanolithography

Introduction

Integrins are essential in the maintenance of a functional vascular system by mediating ECM adhesion via interactions with ECM ligands, including laminin, collagen and fibronectin[1]. Integrin dysfunction can disrupt cell adhesion and influence vascular remodelling in cardiovascular diseases such as atherosclerosis[1]. Therefore, understanding the underlying signalling mechanisms essential for the development of novel therapies in the treatment of atherosclerosis. vSMCs express several β1 integrins which are implicated in the phenotypic switching from a contractile cell type to foam cell and development of a fibrous plaque characteristic of atherosclerosis[2].

Results and Discussion

We present a biomimetic platform utilising the highly versatile and customisable DNA origami. This nanotechnology may be used to produce surfaces with nanoscale resolution and precise control over immobilised ligand spacing at the single-molecule level. Using this platform, we investigate the role of integrin-receptor crosstalk in mechanosensation and arterial disease. DNA origami was functionalised with different numbers of Arg-Gly-Asp Acid (RGD) peptides, a β1 aptamer and/or the proteoglycan chondroitin sulfate. When vSMCs were plated onto the ligand-decorated DNA origami, confocal microscopy analysis determined that an inter-ligand spacing of ~40 nm caused an increase in cell spreading and adhesion formation. Additionally, simultaneous engagement of the β1 aptamer with chondroitin sulfate enabled the examination of adhesion formation, phosphotyrosine expression, and cell spreading due to integrin-receptor crosstalk.

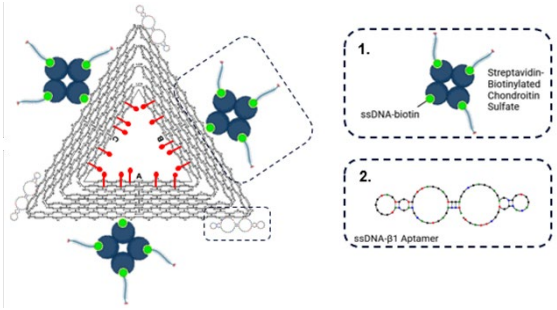

Figure 1: *Schematic of multivalent functionalised DNA origami utilised in vascular smooth muscle cell-adhesion investigations.*

Conclusions

Our study highlights the importance of precise nanoscale arrangement of integrins and ligands required for the integrin-dependent biological activities of vSMCs, providing novel insights into their integrin adhesions during atherosclerosis. Our platform has great potential in cardiovascular research and in the development of novel therapeutics by providing a highly customisable method for examining integrin-ligand interactions at the molecular level.

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Bioactivity at the Interface: Investigating the Responses of Human Cells to Bioresorbable Biomaterials

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Abstract: The nature of the response of human cells at the host–material interface is crucial to the biological performance of bioresorbable biomaterials in musculoskeletal repair, affecting both tissue regeneration and resorption. This study examined human mesenchymal stem cells (hMSC) and monocyte-derived osteoclasts responses when directly incubated on two biomaterials: a bioresorbable polymer and a bioresorbable polymer – bioactive ceramic composite. The composite supported increased hMSC colonisation and mineralisation. Additionally, Scanning Electron Microscopy (SEM) revealed that osteoclasts created pits on the composite, indicating active resorption. These findings suggest that the composite provides a bioactive interface that allows both regenerative activity and resorption, essential for effective musculoskeletal repair.

Keywords: composites; human mesenchymal stem cells; monocytes; cell-surface interfaces; biomaterials

Introduction

Bioresorbable composites are mechanically well-characterised, yet the responses of human cells to these materials remain underexplored [1]. Understanding cell interactions with biomaterial surfaces is vital for developing effective scaffolds for regeneration and resorption [2]. This study elucidates the behaviour of human mesenchymal stem cells and monocyte-derived osteoclasts at the surface of a bioresorbable polymer–ceramic composite versus a bioresorbable polymer control, providing key insights into the design of functional biomaterials for effective musculoskeletal repair.

Results and Discussion

Bioresorbable polymers and bioresorbable polymer – bioactive ceramic composites were fabricated via injection moulding and 3D printing and then seeded separately with either human mesenchymal stem cells (hMSC) or human monocytes (hM) to assess the biomaterials capacity to support both regenerative and resorptive cell colonisation and differentiation for 14 and 21 days. The composite promoted greater levels of hMSC proliferation and mineralisation (latter indicating potential osteogenic differentiation), confirmed by toluidine blue and Alizarin red staining (Figure 1a), and supported fusion of hM into mature multi-nucleated osteoclast-like cells observed to be actively resorbing material, (Figure 1b). These findings suggest that the composite may promote both regenerative and resorptive activities, indicating its potential to serve as a bioresorbable material that can be resorbed through the physiological bone remodelling processes and so facilitate coupled dynamic tissue integration.

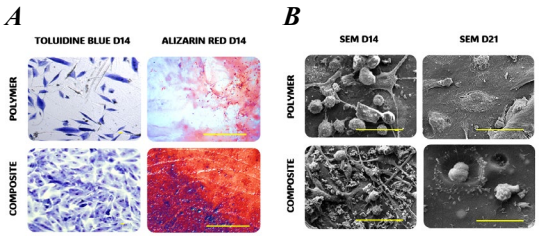

Figure 1: *(A) Optical microscopy following toluidine blue and Alizarin red staining to assess hMSC colonisation and mineralisation, respectively. Scale bar = 100 µm. (B) Scanning electron microscopy to confirm hM fusion and multi-nucleated osteoclast-like cell resorptive activity. Scale bar =50 µm.*

Conclusions

The bioresorbable polymer-ceramic composite creates a biologically active interface that facilitates colonisation and mineralisation driven by hMSCs and the fusion of hM into multinucleated osteoclast-like cells capable of resorbing the composite. This dual functionality highlights the significance of interfacial bioactivity in the design of scaffolds for musculoskeletal regeneration.

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Acknowledgements

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Microfluidic Environment Modulates Human Mesenchymal Stromal Cell Response to Orthobiologic Porous Synthetic Bone Graft Substitutes

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Abstract: In order to verify whether fluid flow affects cell behaviour at the cell-biomaterial interface when incubated on 3D scaffolds with hierarchical porous architectures, human mesenchymal stromal cells (hMSC) were cultured on porous silicate substituted hydroxyapatite bone graft (Inductigraft™) under static and perfused conditions. Markers for cell proliferation, osteogenic capacity, and scaffold-media ion exchange were monitored over 28 days. The introduction of fluid flow within the perfusion system significantly increased cell proliferation and osteogenic activity as compared to static culture, and was coupled with elevated levels of silicon ion release in the cell culture media, demonstrating that fluid flow alters cellular behaviour and biomaterial-media interactions at the scaffold interface. These findings highlight the importance of microfluidic environment when screening hMSC responses to 3D scaffolds with hierarchical porous architectures.

Keywords: silicate-substituted hydroxyapatite, mesenchymal stromal cells, cell-biomaterial interfaces

Introduction

Silicate substituted hydroxyapatite (SiHA) has been shown to enhance bioactivity and support osteoinduction *in vivo*, supporting significantly greater levels of *de-novo* bone volume and coverage (biomaterial-bone contact) as compared to stoichiometric HA on implantation in an ectopic site [1]. This effect has alternatively been hypothesised to be linked to niche environment modulation via silicate ion release [2] and tuning physio-chemical characteristics at the biomaterial-host interface [3], in turn driving development of the protein-material interlayer and subsequent cell-interlayer-interface interactions [4]. The level of strut porosity was also found to be a dominant factor in the ability of the scaffolds to support osteoinductive behaviour [1]. However, studies into the mechanisms of action behind these phenomena within hierarchical porous scaffolds using 2D static *in vitro* methods have been unsuccessful. While it has been postulated that dynamic culture better mimics the native *in vivo* environment, and is thus required in any *in vitro* model to evaluate porous scaffold performance, further investigation is needed to verify how flow conditions influence cell interactions with complex biomaterials to optimise perfused bioreactor screening strategies.

Results and Discussion

Bone marrow derived hMSC were incubated on 450 µg Inductigraft™ granules (n≥5 per condition) under perfused (PC) and static culture (SC) for 7, 14 and 28 days. Under PC, cell proliferation, as monitored by total DNA, was significantly higher than SC at all timepoints ($P<0.05$); increasing to 10-15 µg at day 28 for PC, plateauing at 1-2 µg for SC after day 14. Alkaline phosphatase activity (ALP), a marker of osteogenic differentiation, peaked at 9-10 µmol/min/mL in PC at day 14, but plateaued at only 1-2 µmol/min/mL in SC. Furthermore, Si ion release into cell culture media was only detected in PC. These results demonstrate that PC was required to support patterns of proliferation and differentiation in hMSC incubated on porous scaffolds more reflective of those observed *in vivo*. Furthermore, it encouraged ion exchange at the material-media interface suggesting that PC is necessary to replicate conditions required to facilitate hMSC response via multiple mechanisms as is likely to occur *in vivo*.

Conclusions

Fluid flow introduced through PC strongly affects the pattern of hMSC response and was required to support material-media interfacial ion exchange. This underlines the importance of microfluidic environment when screening hMSC responses to 3D scaffolds with hierarchical porous architectures.

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Acknowledgements

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Long-acting Therapeutics Enabled by Nanomedicines

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Abstract: Long-acting drug formulations offer the potential to improve treatment adherence for chronic conditions. This presentation will introduce foundational concepts in nanomedicine and explore how solid drug nanoparticles and responsive nanogels can be engineered to create injectable, in situ forming implants (ISFIs). These systems offer controlled, long-term drug release while minimising patient burden. Recent advances in formulation and characterisation will be highlighted, along with prospects for clinical translation.

Keywords: nanomedicine; drug delivery; long-acting injectables; nanogels; in situ forming implants

Introduction

Poor adherence to medication is a major challenge in the management of all long-term conditions contributing to avoidable healthcare costs and poorer patient outcomes [1]. Long-acting injectable drug delivery systems have emerged as a promising solution to reduce the reliance on daily self-administration and improve therapeutic coverage [2]. Nanomedicine offers tools to achieve this by engineering formulations that can deliver drugs over extended periods with minimal intervention. This talk focuses on two complementary strategies developed in our group: solid drug nanoparticles (SDNs) and nanogel-based in situ forming implants (ISFIs). These systems aim to address patient adherence and offer tuneable, sustained release for poorly soluble and highly potent drugs.

Results and Discussion

Our ISFI platform is based on the co-formulation of SDNs and thermoresponsive nanogels that transition from a fluid to a depot upon injection. [3-5] The nanogels, based on poly(N-isopropylacrylamide), undergo volume phase transition at physiological temperatures, and their aggregation behaviour is finely tuned through ionic strength and particle size.

SDNs of drugs like lopinavir and rapamycin were prepared using emulsion-templated freeze-drying, enabling high drug loadings (up to 70%) and redispersibility. The ratio of SDN to nanogel and injection conditions were shown to affect implant structure and function. We observed that increasing the nanogel content reduces the burst release and prolongs the release tail. These findings suggest that formulation can be rationally designed for tailored therapeutic profiles.

In preclinical models, co-injection of nanogels and SDNs led to depot formation with extended drug release and reduced peak concentrations compared to SDNs alone. These results demonstrate how material structure influences depot morphology and pharmacokinetics.

Conclusions

Our work demonstrates that combining SDNs and dual-responsive nanogels enables the formation of injectable depots that support sustained, long-acting drug delivery. The modularity of the system allows for tailoring of release profiles through control over nanogel properties and formulation ratios. This approach is a promising route to address adherence-related challenges associated with long-term oral drug administration and is now being further developed through the UK's Hub for Advanced Long-acting Therapeutics (HALo).

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Particle Imprinted Polymers for Bacteria Detection

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Abstract: Surface imprinted polymers (SIPs) offer a selective, robust platform for bacterial detection, but using whole bacteria as templates complicates fabrication, requiring specialized facilities and time-consuming handling. This work explores microparticles as synthetic mimics of *S. aureus* and *E. coli*, aiming to replicate both bacterial shape and surface functionality. By imprinting these particles in PDMS and polyurethane layers, we plan to create binding cavities with distinct shapes and properties. This approach aims to simplify SIP fabrication, enhancing reproducibility and enabling future development of practical biosensors for bacteria detection.

Keywords: surface-imprinted polymers, bacteria detection, microparticles, PDMS

Introduction

Reliable bacterial detection is essential for public health, food quality, and the environment[1]. Surface imprinted polymers (SIPs) offer a robust platform by forming selective binding cavities on a polymer surface[2]. However, using live bacteria as templates makes the process labor intensive and requires special facilities. As an alternative, we use microparticles to mimic bacterial morphology and surface properties. This strategy simplifies fabrication and improves reproducibility, focusing on *S. aureus* and *E. coli* as target models. By using PDMS and polyurethane polymer layers, we aim to develop robust SIPs for practical bacterial sensing applications.

Results and Discussion

To mimic spherical *S. aureus*, 1 µm polystyrene (PS) microparticles were used for imprinting. However, strong non-specific adhesion of *S. aureus* to PDMS showed the need for another polymer. Polyurethane (PU), known for reduced bacterial adhesion, was chosen as an alternative. In parallel, cylindrical deformation of PS microparticles was investigated to mimic *E. coli*. This was done using polyvinylpyrrolidone (PVP) as a plasticizer combined with magnetic stirring[3]. Partial deformation was achieved with carboxyl- and sulfate-functionalized PS particles (PS_CS). Work is ongoing to improve yield by using lower-molecular-weight PVP and testing other particles, including amine-functionalized PS and PMMA.

Removing PS microparticles with different surface functionalities from PDMS has proven difficult. Only the amine-functionalized particles with a dyed core could be successfully washed off using THF. For the negatively charged PS_CS particles, incubation in 1 M NaOH was the most effective method, although it required stainless steel substrates to resist corrosion. With further optimization of this removal process, we aim to evaluate how *E. coli* binds to cavities with different morphologies.

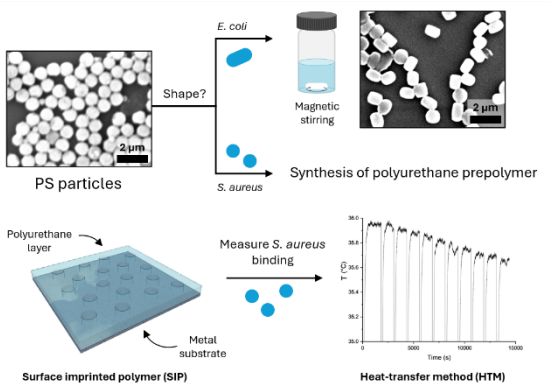

Figure 1: *SIP formation using microparticles that mimic bacteria shapes. Binding of bacteria to the SIP is measured with HTM.*

Conclusions

This work introduces a novel strategy for imprinting fabrication using synthetic microparticles acting as bacteria mimics. The substitution of bacteria with synthetic templates could significantly improve the practicality, safety, and reproducibility of surface-imprinted polymers for bacteria detection. Preliminary findings demonstrate successful particle deformation, indicating the use of microparticle templates for a wider range of bacteria morphologies.

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Acknowledgements

This work was supported by Maastricht University and the Sensor Engineering Department.

Towards a novel SIP-based diffraction grating chip for label-free detection of *Escherichia coli*

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Abstract: Usually, the detection and identification of bacteria, in e.g., environmental or clinical samples, are carried out using conventional bacterial diagnostic or molecular biological methods, which require appropriately trained laboratory personnel. Cultivation of the microorganisms in the laboratory is essential for the application of most of these methods. In contrast, here we developed a novel diffraction grating sensor chip using a SIP (surface imprinted polymers)-based receptor layer for biosensing applications with periodic cavities that offers a rapid way of quantitatively detecting of non-cultivated bacteria in aqueous environment.

Keywords: biomimetic surface imprinted polymers; diffraction grating; label-free detection of *E. coli K12*

Introduction

Increasing mobility, the globalization of food trade and a continuously growing world population are leading to an ever faster spread of infectious diseases, often triggered by pathogenic bacteria. Food contaminated with pathogenic microorganisms can lead to a variety of different diseases, from harmless gastrointestinal illnesses to cancer [1]. Pathogenic bacteria therefore pose major challenges for the public health system. The detection and identification of bacteria, e.g., in food, are usually carried out using conventional bacterial diagnostic methods or advanced molecular biological methods, both of which require appropriately trained laboratory staff. Usually, these methods are time-consuming and cultivation of the microorganisms in the laboratory is essential for the application of most of these methods. Therefore, novel detection methods are required to detect, identify and monitor these bacteria [2].

The developed sensor chip could eliminate the need for additional functional layers for signal transduction. Hence, this concept could offer a cost-effective alternative for bacteria detection. Based on this type of new receptor layer for biosensing application, an optical method, rooted on diffraction gratings, was developed for rapid detection of *E. coli*.

Results and Discussion

The developed diffraction grating sensor chip in combination with a biomimetic SIP receptor layer with periodically imprinted cavities delivered promising results in preliminary experiments. Hence, for different *E. coli* cell concentrations in comparison to cell-free samples in PBS a shift in relative intensity due to the number of captured cells was observed.

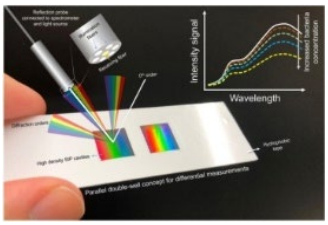

Figure 1: *Diffraction grating rooted on SIP-based receptor layer for rapid detection of E. coli.*

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This work was partially financed by the European Union and the German Federal Ministry of Education and Research (Project number: 03F0902A) in the frame of ARENA financed under the 2020 AquaticPollutants Joint call of the AquaticPollutants ERA-NET Cofund (N°869178).

Non-Invasive Glucose Detection Using Electroactive Molecularly Imprinted Polymers (eMIPs) for Wearable Sensor Applications

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Abstract: Diabetes diagnosis currently relies on invasive, costly, and unstable enzymatic methods. We report on electroactive polypyrrole (PPy)-based molecularly imprinted polymer nanoparticles (eMIPs) as robust, low-cost, and enzyme-free alternatives for glucose sensing. Fabricated by drop-casting onto disposable screen-printed electrodes (SPEs), eMIPs sensors accurately detected glucose over a wide range (1 µM-10 mM) with a low detection limit of 26 nM. The eMIPs also sensor showed high specificity and selectivity, and showed a strong correlation (> 0.93) with clinical test results.

Keywords: electroactive molecularly imprinted polymer nanoparticles (eMIPs), screen printed electrode (SPEs), conductive polymers, Polypyrrole (PPy)

Introduction

Diabetes mellitus is a chronic metabolic disorder affecting over 537 million adults globally, often leading to serious complications. Conventional glucose monitoring methods are invasive, enzyme-based, and suffer from high cost and limited stability, reducing patient compliance. Molecularly imprinted polymers (MIPs) offer a promising alternative due to their low cost, high stability, reusability, and excellent selectivity for target molecules [1,2]. In this work, we developed a PPy-eMIPs sensor on SPEs for rapid (<30 s), sensitive, and selective electrochemical detection of glucose, enabling next-generation non-enzymatic monitoring for diabetes management.

Results and Discussion

Dynamic light scattering measurements and transmission electron microscopy of th eproduced eMIPs showed an average particle size of 91 ± 0.9 nm and 63 ± 11 nm respectively. Then, eMIPs functionalized SPEs were incubated with glucose (1 µM to 10 mM) for 5 min and cyclic voltammograms (CV) were recorded. CV results observed the linear decrease in current with increasing concentration of glucose (**Figure 1a**). eMIPs sensor was found to be highly selective as no significant change in current was observed in the presence of interferents (**1b**). Similarly, no change in current in the presence of NIPs, confirmed the high specificity of the eMIPs sensor (**1c**). Glucose concentration (mM) obtained with eMIPs sensor demonstrated no significant difference (>0.95) compared to Roche blood analyser results (**1d**).

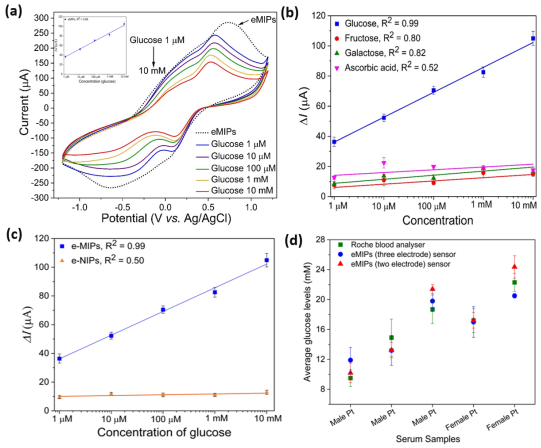

Figure 1: *CV of* ***(a)*** *eMIPs in the presence of glucose (1µM-10mM)* ***(b)*** *Selectivity and* ***(c)*** *specificity of eMIPs sensor.* ***(d)*** *Comparison of our eMIPs sensor with Roche blood analyser*

Conclusions: This is the first report demonstrating a facile and scalable method for fabricating PPy-based eMIPs sensors for glucose detection in real diabetic samples. Due to their versatility and adaptability to virtually any target, eMIPs offer a promising platform for multi-biomarker sensor applications.

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Acknowledgements Authors would like to thank Northern Accelerator grant (NACCF248) for funding this project and MRC research grant (MR/Y008421/1).

Development of Molecularly Imprinted Polymers as an Indirect Sensing Approach for Spore-Forming Bacteria Detection

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Abstract: Dipicolinic acid (DPA) is a biomarker predominantly found in bacterial spores, where it contributes significantly to their heat resistance. Detecting DPA enables the indirect identification of contamination by spore-forming bacteria in food products. In this study, Molecularly Imprinted Polymers (MIPs) were synthesized using (vinylbenzyl)trimethylammonium chloride as the functional monomer for selective DPA recognition. Rebinding experiments demonstrated selective binding to DPA. These findings support the potential of DPA-imprinted MIPs as recognition elements for rapid, real-time monitoring of bacterial spores in food safety applications.

Keywords: molecularly imprinted polymers; dipicolinic acid; spore detection; biosensors; food safety

Introduction

The presence of heat-resistant bacterial spores, such as those from *Bacillus cereus*, presents a major challenge to food safety. Dipicolinic acid (DPA), which accounts for ~10% of spore dry weight, is a key factor in their resistance to wet heat [1-2]. Molecularly Imprinted Polymers (MIPs) offer a robust and selective method for detecting small molecules such as DPA [3]. This work describes the synthesis and evaluation of DPA-specific MIPs aimed at the indirect detection of spore-forming bacteria.

Results and Discussion

MIPs were synthesized using (vinylbenzyl)trimethylammonium chloride as a positively charged functional monomer, ethylene glycol dimethacrylate (EGDMA) as crosslinker, and AIBN as initiator. Triethylamine (TEA) was included to facilitate DPA deprotonation during polymerization. Post-polymerization, Soxhlet extraction with MeOH:AcOH (1:1) and NaOH/water washes effectively removed residual template and base. Rebinding tests in aqueous DPA solutions showed that MIPs outperformed non-imprinted polymers (NIPs) across three repetitions. These results highlight the potential of these polymers as the recognition element in biosensors for food safety monitoring.

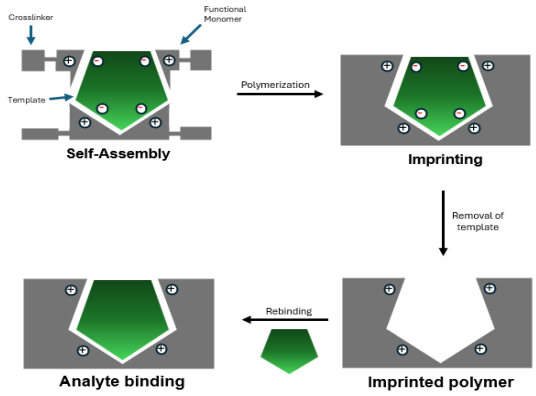

Figure 1: *Schematic representation of MIP synthesis and DPA rebinding.*

Conclusions

The developed MIPs exhibit promising selectivity toward DPA, supporting their application in the indirect detection of bacterial spores in food matrices. Future work will focus on integrating these polymers into thermal or impedance-based biosensing platforms for real-time detection of contamination in food samples.

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Development towards a novel screening method for nipecotic acid bioisosteres using molecular imprinted polymers (MIPs) as alternative to *in vitro* cellular uptake assays

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Abstract: The development of radioligands targeting GABA transporter 1 (GAT1) is highly desired to allow for better diagnosis and treatment of CNS diseases. To increase the brain-uptake of GAT1 radioligands, the use of nipecotic acid bioisosteres is a promising strategy. In order to screen these isosteres for their binding to GAT1 in a time- and cost-effective manner, this research aims to develop a molecular imprinted polymer (MIP) that mimics the natural binding site of GAT1 and can act as an alternative screening tool to the current cellular-based assays. To that end, nipecotic acid MIPs were developed and analysed using electrical impedance spectroscopy (EIS).

Keywords: nipecotic acid, bioisostere, molecular imprinted polymer, electropolymerization

Introduction

The development of radioligands targeting GABA transporter 1 (GAT1) is highly desired in order to improve treatment and diagnosis options for CNS diseases, such as epilepsy, Alzheimer's disease, and schizoprenia. Therefore, several nipecotic acid-based radioligands have been tested, but suffer from low brain uptake due to the zwitterionic behaviour of the nipecotic acid group (Figure 1) [1].

To develop more viable GAT1 radioligands in the future, the use of nipecotic acid bioisosteres is a promising strategy to increase brain uptake [1]. However, this requires knowledge on the binding of these isosteres to GAT1. To obtain this information and screen isosteres for their affinity to GAT1, a nipecotic acid imprinted polymer was developed with a view to generating an artificial mimic of the GAT1 binding site (Figure 1). It is expected that bioisosteres that bind well to the MIP should also bind well to GAT1 and therefore could function as viable isosteres for use in GAT1 radioligands.

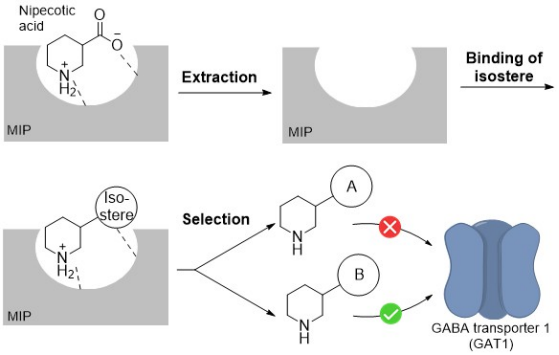

Figure 1: *Schematic overview of the screening of nipecotic bioisosteres using MIPs. After synthesis, nipecotic acid is extracted and the binding of isosteres is evaluated. Well-binding isosteres are expected to bind to the natural GAT1 as well.*

Results and Discussion

Nipecotic acid MIPs were synthesized through electropolymerization of *ortho*-phenylenediamine (oPD) by cyclic voltammetry (CV) [2]. After optimization of the generated receptor layer by varying the scan rate and number of CV cycles, an optimized MIP with an average imprinting factor of 2.6 was obtained. To evaluate whether the generated MIP could be used as artificial GAT1 mimic, selectivity studies were conducted using electrical impedance spectroscopy (EIS). It was found that the substrate carboxylic acid group played a more important role in binding than the amine group, while both are crucial for binding in GAT1 [3].

Conclusions

Despite the successful synthesis of a nipecotic acid MIP, it was found that the developed MIP did not exhibit all the major binding interactions that can be seen in the natural GAT1 binding site. This shows that efficient mimicking of dynamic natural receptors and remains difficult, and smart monomer and template selection are critical in the process.

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Towards molecularly imprinted polymers for sensing 1-OH pyrene

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Abstract: Since exposure to polycyclic aromatic hydrocarbons, like benzo[a]pyrene, is linked to multiple diseases like cancer, there is urgent need to detect them and their metabolites like 1-OH pyrene in a reliable and easy manner. Employing molecularly imprinted polymers (MIPs) promises to enable highly specific, rapid and accurate detection even outside of a laboratory environment. By developing a conductive MIP, a rapid and easy way of detection using electrochemical impedance spectroscopy is enabled, which can be integrated into a user-friendly and portable device. Herein, we present the progress in developing a MIP-based electrochemical sensor for detecting 1-OH pyrene.

Keywords: molecularly imprinted polymers; electrochemical sensing; polycyclic aromatic hydrocarbons

Introduction

It is well known that fumes emitted from combustion processes contribute to several severe illnesses, including cancer [1]. This is in part due to the presence of polycyclic aromatic hydrocarbons (PAHs) in these emissions [1]. In order to assess the exposure of individuals to these harmful substances, the concentration of benzo[a]pyrene metabolites such as 1-hydroxy pyrene (1OHP) is measured in urine, usually via gas-chromatography [2]. However, despite recent advances in measurement techniques, extensive equipment, sample processing and trained personnel are still needed [3]. To enable rapid, simple and affordable assessment of the extent of PAH exposure close to the point of care, a different approach is needed. Electrochemical sensors based on molecularly imprinted polymers (MIPs) are promising in this regard due to their high specificity, sensitivity and low cost [4, 5]. So far, there is only limited work on employing MIPs for sensing PAH metabolites [6,7]. In this work, we present the progress towards developing a MIP-based electrochemical sensor for detecting 1OHP.

Results and Discussion

Imprinted polymers were manufactured on screen-printed carbon electrode from a 1:1 mixture of dimethyl sulfoxide and 0.5 M aquatic potassium chloride using chronoamperometry A significant challenge in MIP development is keeping electroactive analyte species stable while conducting electropolymerization. As 1OHP gets oxidized at potentials as low as $0.7V_{SHE}$, polymerization needs to be conducted at potentials below this value. As pure pyrrole polymerized only at around $0.85V_{SHE}$ in the used solution, dopamine hydrochloride was added to the polymerization solution, through which the polymerization potential could be lowered significantly [8]. Current investigations aim at lowering the oxidation potential even further to enable reliable polymerization without electrooxidation of 1OHP. The template is subsequently removed with ethanol. Sensing is conducted using electrochemical impedance spectroscopy, measuring the impedance increase associated with specific binding of the analyte to the polymer. Preliminary results appear promising and indicate potential for successful application in an electrochemical sensor. Further results will be presented at the conference.

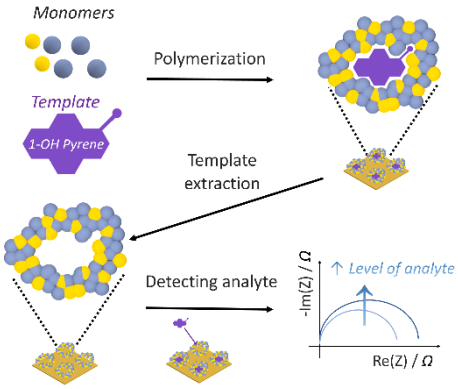

Figure 1: *MIP synthesis and sensing principle.*

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Acknowledgements

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Optimising Clinical Management of Parkinson's Disease via Innovative Sensing

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Abstract: Parkinson's disease is commonly treated with levodopa, but its short half-life and fluctuating levels in patients often lead to inconsistent symptom control. This work focuses on developing an electrochemical sensor to detect levodopa concentrations using screen-printed electrodes combined with molecularly imprinted polymers. The sensor is designed to improve selectivity and sensitivity toward levodopa in complex biofluids. Preliminary results showed a limit of detection in the low micromolar range with a fast response time. The aim is to contribute to future solutions for more personalised treatment strategies through improved monitoring of medication levels.

Keywords: Electrochemical biosensor, Molecularly imprinted polymer nanoparticles (nanoMIPs), Parkinson's Disease, Screen Printed Electrodes (SPE), Square wave voltammetry

Introduction

Levodopa remains the most effective treatment for managing motor symptoms in Parkinson's disease, a progressive neurological disorder affecting millions worldwide[1]. However, due to its short half-life and variable pharmacokinetics, patients often experience fluctuating symptom control. It can severely impact quality of life, leading to both motor and non-motor complications. Globally, Parkinson's disease is estimated to affect 9 million people, with numbers expected to rise due to an ageing population.

Results and Discussion

Electroactive nanoMIPs were synthesised using a free-radical polymerisation method with L-tyrosine as a dummy template to mimic levodopa's structure. Pyrrole was used as the functional monomer, forming a conductive matrix capable of recognising levodopa via shape and interaction-specific cavities. The synthesised MIPs were deposited onto screen printed electrodes to create a disposable sensing. Cyclic voltammetry (CV) measurements in Figure 1 revealed an increase in the change of current with rising levodopa concentrations, demonstrating sensor responsiveness and reproducibility.

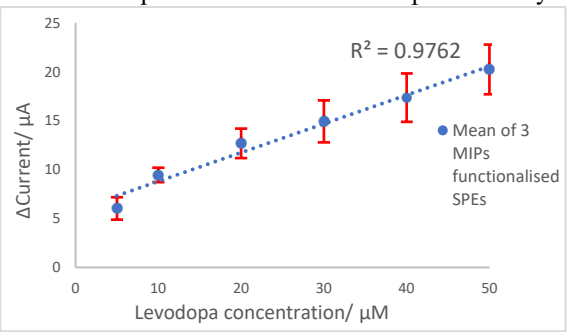

Figure 1: *CV responses of MIP-functionalised SPEs at varying levodopa concentrations (PBS, pH=7.4)*

To enhance sensitivity and achieve a faster electrochemical response, square wave voltammetry (SWV) was also employed. A subtraction method was applied to each curve to extract the relative change in current. These values were then used to generate the corresponding dose-response curve. Figure 2 shows representative SWV curves, demonstrating the change in current upon binding of levodopa to the nanoMIP-functionalised surface.

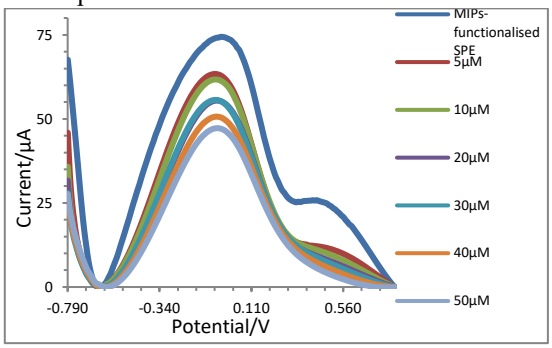

Figure 2: *SWV calibration curves showing the decreasing current of MIPs-functionalised SPEs detecting levodopa in PBS, pH=7.4 (responding time within 20 seconds)*

Conclusions

This study demonstrates a viable approach for the electrochemical detection of levodopa using pyrrole-based MIP sensors. The system reveals potential for further development toward real-time and wearable applications. Future efforts will focus on improving integration and testing in biofluidds for personalised Parkinson's disease management.

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Quantifying Perfluorooctanoic Acid: A MIP-Based Impedimetric Sensor Approach

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Abstract: This study presents the development of an innovative electrochemical biosensor with molecularly imprinted polymers (MIPs) prepared on a carbon screen-printed electrode (C-SPE) using a novel ammonium based monomer for the detection of perfluorooctanoic acid (PFOA). The MIP biosensor obtained shows a good linear response within the concentration range of 0.1 pM to 100nM.

Keywords: electrochemical; molecularly imprinted polymers; perfluorooctanoic acid

Introduction

Polyfluoroalkyl substances (PFAS) have been under increased scrutiny in recent years due to their ability to bioaccumulate in animals and resistance to deterioration. The need for expensive equipment, lengthy processing times, and specialized personnel limits the broader use of current detection techniques, so this increases the need for rapid, accurate, reasonably priced, and easily accessible PFAS detection [1]. MIP biosensors present themselves as an alternative detection method with higher stability and robustness, with the ability to mimic the behavior of natural biomolecules [2]. This research aims to functionalize a C-SPE with a MIP and to use Electrochemical Impedance Spectroscopy (EIS) as a readout technique, making it more straightforward to integrate with hardware and software systems since the goal of this strategy is to create a highly selective, fully operational device with enhanced detection capabilities.

Results and Discussion

We were able to obtain a successful electropolymerization of the ammonium based monomer through Cyclic Voltammetry (CV), and the CVs performed after this presented a clear difference in current between MIP and non-imprinted polymers (NIP). The removal method was also optimized so that we could remove the target (PFOA) without damaging the cavities, so these could be available for future rebinding. After optimization, the analytical performance of the sensor was evaluated by recording calibration curves with the EIS technique. As expected, the absolute impedance decreased with the PFOA concentration, presenting a linear response between 0.1pM and 100nM while the NIP did not respond.

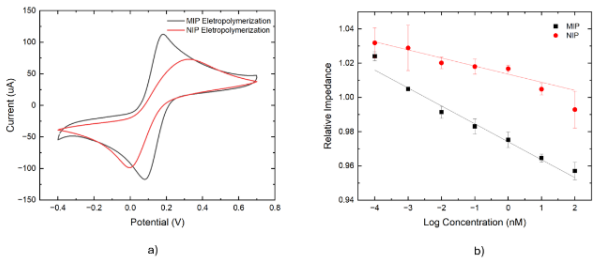

Figure 1: *CVs of MIP and NIP after electropolymerization (a) and respective calibration curves (b).*

Conclusions

This research presents one of the first impedimetric MIP biosensors PFOA detection. The incorporation of the novel electropolymerized monomer enables the development of a highly sensitive biosensor since it presents a clear interaction with the target. Overall, the biosensing device exhibits remarkable potential in terms of sensitivity, selectivity, and reproducibility.

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Step towards in-vivo inflammation sensing in cochlear implant with nanoMIPs in biodegradable layer

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Abstract: Chronic inflammation significantly impairs the long-term performance of cochlear implants (CIs). To enable real-time monitoring of inflammatory biomarkers, we immobilised a conductive, biocompatible, and biodegradable nano-scale molecularly imprinted polymer (nanoMIP) in a chitosan layer for the selective detection of biomarker interleukin-6 (IL-6). NanoMIPs exhibited high sensitivity, detecting IL-6 at concentrations as low as 2 pg/mL in in-vivo perilymph samples. Cross-selectivity studies demonstrated a 10:1 suppression ratio against common perilymph constituents. The nanoMIP-based sensing layer is fully compatible with existing CI-integrated electronics and is designed to degrade post-monitoring, allowing the release of sensory electrodes for resumed stimulation without additional surgical intervention.

Keywords: Cochlear implant, spraycoating, nanoMIPs, chitosan

Introduction

CIs are neuroprosthetic devices that utilize micro-electrode arrays to restore auditory perception by delivering stimulation to the cochlea. However, signifycant proportion of CI patients suffer a loss of CI function shortly after implantation due to inflammatory reactions [1]. Early inflammation detection is essential for timely intervention and minimizing long-term damage. NanoMIPs offer a promising solution for in-situ detection of inflammatory biomarkers (IL-6) [2, 3]. For long-term compatibility, nanoMIPs integrated into CI electrodes should degrade after the acute inflammatory phase. In this study, nanoMIPs were immobilized within a chitosan matrix and deposited onto electrodes via spray-coating, with non-imprinted polymer (NIP) controls prepared under identical conditions without nanoMIPs. IL-6 epitope fragments were used as cost-effective templates with preserved specificity.

Method

NanoMIPs and chitosan were co-dissolved in 2% acetic acid and applied to electrode surfaces via spray-coating. Electrochemical impedance spectroscopy (EIS) was used to evaluate target recognition in phosphate-buffered saline (PBS) with and without IL-6 (with varying concentration). Additionally, cross-selectivity was assessed by using human serum albumin (HSA), interleukin-9 (IL-9), and interleukin-1β (IL-1β). EIS was also performed in in-vivo perilymph to validate sensor performance under physiological conditions. To assess degradation behaviour, nanoMIP-chitosan films were incubated in water at 37 °C for a duration of four weeks. EIS were realized weekly to monitor functional integrity over time. Finally, biocompatibility of the nanoMIP system was evaluated.

Results and Conclusions

NanoMIP sensor exhibited a significant impedance change upon exposure to IL-6 at concentrations ≥29 pg/mL, whereas the NIP showed no detectable response. Specificity was confirmed by the absence of signal in the presence of HSA, IL-9, and IL-1β (figure 1). Notably, IL-6 was successfully detected in in-vivo perilymph samples at diagnostically relevant levels as low as 2 pg/mL. Additionally, variation in the chitosan:nanoMIP ratio revealed that higher chitosan content slowed degradation, reducing nanoMIP release. In contrast, lower ratios increased surface exposure of fresh nanoMIPs, enhancing binding site availability. Finally, biocompatibility assays confirmed that nanoMIPs are non-cytotoxic and safe for biomedical applications.

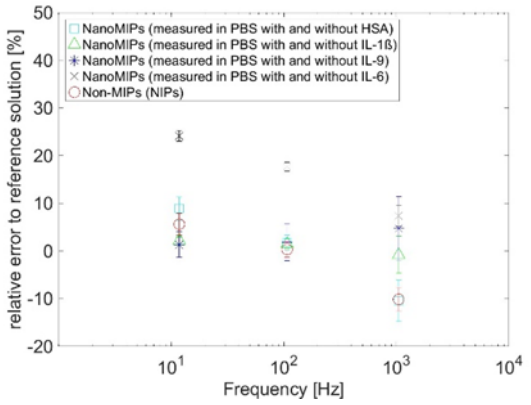

Figure 1: *nanoMIPs: Relative impedance error between PBS with and without HSA, IL-1β, IL-9 and IL-6*

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Gold Screen Printed Electrodes with Spore-Imprinted Polypyrrole for *Fusarium oxysporum* Spore Detection

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Abstract: Fungal outbreak prevention in greenhouse agriculture is energy-intensive due to continuous climate control aimed at suppressing pathogens. This study presents the development of an electrochemical sensor for *Fusarium oxysporum* spores, based on gold screen-printed electrodes modified with surface-imprinted polypyrrole. By enabling real-time spore concentration monitoring, the sensor provides a promising route toward more energy-efficient and targeted disease management in controlled horticultural environments.

Keywords: surface-imprinted polymers, *Fusarium oxysporum*, electrochemical sensor, screen-printed electrodes

Introduction

In the Netherlands, greenhouse cultivation spans 9,688 hectares and consumes approximately 106.8 petajoules of energy annually, with heating comprising 74% of this energy demand [1]. A primary driver of this energy use is the need to mitigate fungal infections, which consistently threaten crop productivity. To suppress fungal proliferation, greenhouses maintain low relative humidity through frequent heating and ventilation cycles [2]. Real-time monitoring of fungal spore concentrations is a promising approach to reduce the need for such interventions, thereby lowering overall energy consumption. This study introduces the development of a fungal spore sensor utilizing gold screen-printed electrodes functionalized with surface-imprinted polymers (SIPs).

Results and Discussion

In this project, SIPs were synthesised by electropolymerisation of 0.05 M pyrrole in 0.1 M lithium perchlorate on Au electrodes within a potential window of 0 to 1 V. Following the methodology adapted from Lahcen et al. [3], the polymer was constructed through a three-step process. Initially, 4 electropolymerisation cycles were performed in the absence of spores using a monomer solution at pH 6.1. Subsequently, 4 additional cycles were conducted in the presence of 12.5×10^6 CFU/mL of fungal spores (pH 5) for the SIP. The non-imprinted polymer (NIP) was prepared identically but without spores. A final set of 4 cycles was run in PBS (pH = 7) to remove unreacted monomer. Preliminary chronoamperometric analysis revealed a stronger binding response of the SIP compared to the NIP, suggesting effective imprinting and the potential for selective spore detection.

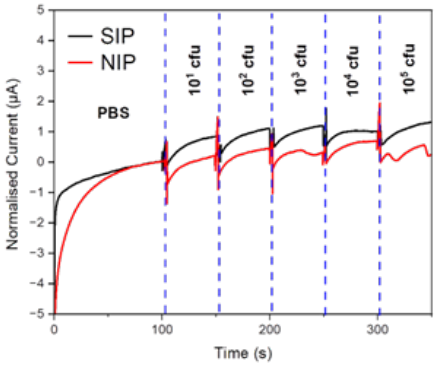

Figure 1: *Chronoamperometric rebinding analysis at a constant potential of 200 mV.*

Conclusions

Preliminary results highlight the potential of the SIP-based sensor for the selective detection of *F. oxysporum* spores. Further research is required to advance the optimization and validation of a reliable fungal spore sensor.

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The authors are grateful for funding of the project "ENERGLIK (Int6B003)" by the European Regional Development fund of the E.U. through Interreg via Flanders-the Netherlands.

Troponin I biomarker sensing from clinical patient samples using molecularly imprinted nanoparticles as recognition elements

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Abstract: Measurements of cardiac troponins are critical in the diagnosis of patients with heart attack. At current, troponin levels are measured with immunoassays, which are expensive and have a long turnaround time (~2h) due to the need for sophisticated lab equipment. We present an alternative portable and low-cost sensor platform that can facilitate rapid detection of troponin (~30 min) by using molecularly imprinted polymer nanoparticles as synthetic recognition elements. Proof-of-concept will be provided via analysing serum samples of patients with confirmed heart attack with our novel sensor platform and benchmarked against current state-of-the-art.

Keywords: molecularly imprinted polymer nanoparticles (MIPs), cardiac troponin, heart attack, thermal analysis

Introduction

Cardiac troponin I (cTnI) is a critical protein biomarker for heart attack diagnosis. This study presents a thorough analysis of a novel biosensing utilizing molecularly imprinted polymer nanoparticles (nanoMIPs) for detection of cTnI in clinical patient serum samples post myocardial infarction. The methodology based on the heat-transfer method approach offers faster measurements than the current gold standard and sample volumes equivalent to a single blood drop.

Results and Discussion

The nanoMIPs were incorporated into low-cost screen-printed electrode (SPEs) and were subsequently slotted into a home-made thermal device. The change in thermal resistance (R_{th}) was then linked to the concentration of cTnI in the sample as binding to the pores of the nanoMIPs impacts on the thermal resistance.

Biomarker binding at peak cTnI levels shows that the performance of our sensor is platform is comparable to a high-sensitivity ELISA, accurately identifying patients with elevated cTnI levels (R^2 = ~0.9). Furthermore, comparison with an establish patient database demonstrates robust correlations between our cTnI concentrations and clinical parameters (R^2 = 0.86).

However, it is worth noting that there were differences between the results obtained with the ELISA assay and our thermal sensing platform, particularly at longer time points. This could perhaps be attributed to the fact that these recognition elements bind to different parts of the troponin complex.

a)

cTnI Concentration Variable	CAPRI Variable	Pearsons Correlation	P Value	Significance (2-tailled)
Value at t=90min (Log)	cTnT Concentration Percent Change (Linear)	0.812	**, P ≤ 0.005	0.008
Peak Value (Log)	Infarction Size Percent Change (Linear)	-0.806	**, P ≤ 0.005	0.009
Absolute Change (Log)	Infarction Size Percent Change (Linear)	-0.783	*, P ≤ 0.05	0.013
Percent Change (Log)	Infarction Size Absolute Change (Linear)	-0.767	*, P ≤ 0.05	0.016
Value at t=90min (Linear)	cTnT Concentration Percent Change (Linear)	0.714	*, P ≤ 0.05	0.031
Percent Change (Log)	Infarction Size Percent Change (Linear)	-0.671	*, P ≤ 0.05	0.048

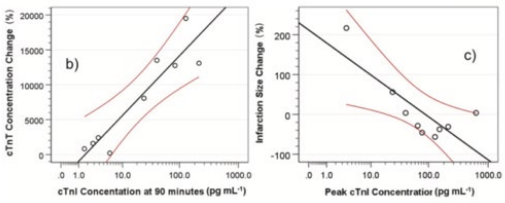

Figure 1: (a) Table of the most significant correlations between measured cTnI concentrations and CAPRI variables **(b)** correlation between cTnI and cTnT concentration **(c)** correlation between peak cTnI concentration and infarct size

Conclusions: This underscores the potential of nanoMIP sensors for sensitive cTnI detection, providing insights into post-heart attack biomarker levels. Furthermore, our methodology presents the additional benefits of being low-cost and portable enabling measurements at time and place of patients. Consequently, it holds the potential to become a vital part of the diagnostic pathway for heart attack diagnosis, ultimately reducing healthcare costs and improving patient outcomes.

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Optimization of a microfluidic channel system with integrated MIPs for intraoperative inflammation detection

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Abstract: Real-time monitoring of inflammatory biomarkers during surgical procedures offer the potential to significantly improve postoperative outcomes. Electrochemical impedance spectroscopy (EIS) presents a rapid and sensitive analytical technique (< 3 min) across a frequency spectrum of 1 Hz to 100 kHz, offering advantages over conventional enzyme-linked immunosorbent assays (ELISA). To address the requirement for minimal invasive sampling, we integrated a microfluidic channel systems capable of analyzing small-volume biological fluid, such as perilymph. In this study we developed a microfluidic system incorporating molecularly imprinted polymer (MIP) sensors for reliable and sensitive intraoperative detection of cytokines (e.g., Interleukin-6) using EIS.

Keywords: Microfluidics, MIP, EIS, Inflammatory Biomarkers, Intraoperative Diagnostics

Introduction:

MIPs, acting as synthetic receptors, exhibit high selectivity for specific inflammatory biomarkers, including cytokines (e.g., IL-6 and IL-9), and are employed as single-use sensors [1]. Further, MIPs are gaining increasing prominence in medical technology due to their capacity for sensitive, specific, and rapid real-time measurement of inflammatory markers. This facilitates enhanced monitoring of implant integration and has the potential to improve long-term patient quality of life [2]. However, the detection of low analyte concentrations (e.g., IL-6 at ~20 pg/ml) necessitates high sensor sensitivity [3]. Moreover, limitations in available sample volumes, such as a maximum of 4 µl of perilymph, pose challenges for EIS. In this study, we developed a microchannel system designed to accommodate minimal sample volumes for electrochemical polymerization. MIPs and non-imprinted polymers (NIPs) were deposited onto electrodes within the microchannel, and the sensor performance was evaluated using EIS.

Methods:

To investigate the suitability of minimal sample volumes for electrochemical polymerization and EIS, the electrode surface was wetted with varying liquid volumes (10 µl to 50 µl). Initially, a PDMS-based liquid reservoir was fabricated to optimize handling of small volumes (figure 1). To ensure that the electrode surface remained uncovered during the molding process, stamps with different geometries and shapes were designed. However, based on these experiments, the microchannel system dimensions (height and width) were subsequently determined. Conductive MIPs and NIPs based on PEDOT were synthesized galvanostatically within the microchannels. MIPs functionality was evaluated by EIS in phosphate-buffered saline under varying concentrations of IL-6 to assess sensor performance in the presence and absence of the target analyte.

Results:

To minimize system impedance and enhance signal quality for electrochemical detection, the free electrode surface area, delimited by PDMS, was optimized to a volume of approximately 50 mm³. This modification resulted in impedance values within the range of Ω to kΩ. Based on these result, the micro channel system was optimized. MIP sensors exhibited a specific impedance change in response to the presence of inflammatory markers. Overall, measurement accuracy was improved, highlighting the potential for early detection of intraoperative inflammation.

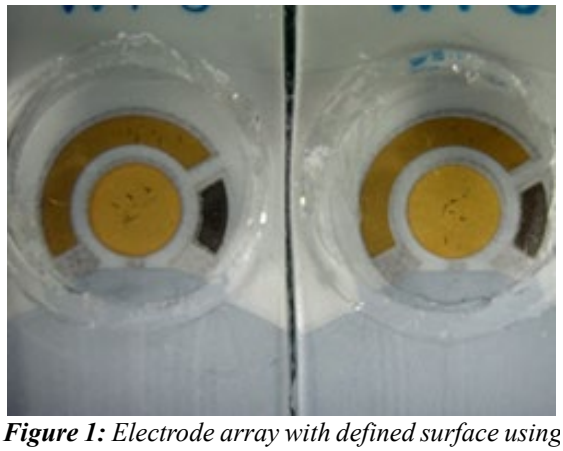

Figure 1: *Electrode array with defined surface using PDMS*

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Acknowledgements: This study is funded by the "Cluster of Excellence Hearing4All" (EXC2077).

Visual Sensor for Sinapic Acid via Bio-Based Molecularly Imprinted Polymers and Cu(II) Complexation

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Abstract: Different growing conditions can severely impact the antioxidant content of crops resulting in changes of associated health benefits. Therefore, a naked-eye sensor for the antioxidant sinapic acid was developed using bio-based molecularly imprinted polymers (MIPs) as recognition layer and Cu^{2+} displacement and complexation as visual readout. The MIP composition was optimized by screening fossil- and bio-based monomers, as well as their combination with deep eutectic solvents. The visual detection was optimized for rebinding and complexation time and MIP mass. The sensor was characterized for its dose-response, selectivity towards structural analogues and applicability in real-life samples.

Keywords: molecularly imprinted polymers, sinapic acid, deep eutectic solvent, visual sensor, metal complexes

Introduction

The detection of antioxidants in fruits and vegetables is vital due to their associated health benefits [1]. Currently used techniques like high-performance liquid chromatography (HPLC) require time, personnel and lab-bound sophisticated equipment. An alternative are MIPs, which are synthetic materials with target-specific cavities. Mostly, fossil-based monomers are used in their synthesis, but bio-based monomers are more currently employed due to their beneficial impact on the environment [2]. Visual sensors provide an easily understandable response. A sensor for Cu(II) based on its complexation with the antioxidant sinapic acid in acetonitrile-water has been previously developed [3]. In this work, the principle was inverted in order to detect sinapic acid. MIPs were used to extract the antioxidant from complex samples and consequently displaced by a Cu(II)-solution to detect the colourful complex.

Results and Discussion

In the first step, the influence of monomer was investigated by screening fossil-based methacrylic acid and bio-based itaconic and aconitic acid. The monomers were combined with choline chloride to form deep eutectic solvents to further improve the environmental friendliness. The optimized MIP showed an IF of 2.33, high thermal stability and low particle sizes around 2.5 µm. these MIPs were implemented as recognition element in the visual sensor. The sensor was optimized by investigating the kinetics of rebinding and of complexation, and the optimal amount of polymer needed. In short, 20 mg of polymer are necessary which show binding saturation after 35 min., followed by a complexation time of 4 min. to generate the visual response. The sensor was further characterized by its dose-response to sinapic acid and a LOD of ~0.3 µM was observed.

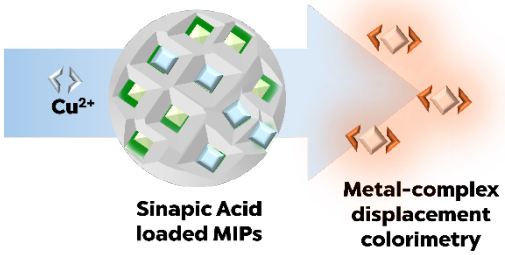

Figure 1: *Schematic of the sensor principle.*

The dose response was assessed using a UV-VIS spectrophotometer as well as a smartphone to highlight its performance. Furthermore, the selectivity of the sensor was investigated against different structural analogues. Outstanding performance was observed as the combination of selective MIP and selective complexation did not generate a substantial response for any interferent. Lastly, the real-life applicability was assessed by quantifying the sinapic content of fruits and herbs, and the results were benchmarked by LC-MS.

Conclusions

A visual sensor that enables rapid and selective detection of sinapic acid without the need for sophisticated instruments has been developed.

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Cellular dynamite: Miconazole-induced bio-mechanical transitions in yeast interfaces monitored by QCM-D

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Abstract: To address the growing challenge of antifungal resistance, this study explores the biophysical and interfacial mechanisms of drug action beyond traditional biochemical assays. Using quartz crystal microbalance with dissipation monitoring (QCM-D), we reveal how miconazole, used as an antifungal model influences the adhesion and mechanical responses of two yeast strains—*Saccharomyces cerevisiae* and *Candida albicans*.

Key words: QCM-D, Miconazole mechanisms, antimicrobial resistance, antifungal drugs, cell biomechanics

Introduction

The increasing prevalence of antimicrobial resistance and declining therapeutic effectiveness highlights the need to understand not just the biochemical, but also the biophysical and interfacial mechanisms of drug action. While traditional assays typically focus on metabolic or genetic endpoints, there remains a critical gap in our ability to unravel how antifungal agents mechanically perturb whole-cells and their adhesion behavior at solid–liquid interfaces. In this context, label-free, time-resolved techniques like QCM-D offer unique access to the biomechanical fingerprint of microbial responses.[1] Therefore, we employed QCM-D to probe the long-term interfacial response of *S. cerevisiae* and *C. albicans* to miconazole. Miconazole is an antifungal drug that disrupts the ergosterol synthesis pathway, compromising membrane structure and fluidity.[2]

Results and Discussion

QCM-D measurements were performed on cells pre-incubated with miconazole (0.01–10%). The resulting frequency (Δf) and dissipation (ΔD) profiles reveal two distinct regimes (Figure 1). In the first, Δf and ΔD increase steadily over time in a concentration-dependent manner, reaching saturation values from approximately −150 Hz at 0.01% to ∼−500 Hz at higher concentrations, consistent with gradual fungal cell adhesion to the sensor surface. The second regime is characterized by a sudden, concentration-dependent shift in Δf and ΔD, with values reaching −973 ± 7.1 Hz, −3971 ± 39.6 Hz, and −5349 ± 33.9 Hz for 1%, 5%, and 10% miconazole, respectively, indicating collapse and buildup of cellular material. At higher drug levels, this is accompanied by sequential disappearance of higher overtones, implying vertical accumulation and complete wave damping at the overtone sensing depth. The number and timing of overtone loss correlated with drug concentration — higher concentrations led to more disappearing overtones at earlier times. These responses are diminished at lower temperatures, higher ionic strengths, and higher cell densities, suggesting environmental modulation and drug partitioning effects. *Candida albicans* exhibits similar trends but with reduced responses, indicating lower biomechanical sensitivity. Co-incubation of *S. cerevisiae* with small amounts of *C. albicans* suppressed drug-induced shifts, suggesting a buffering effect of the latter.

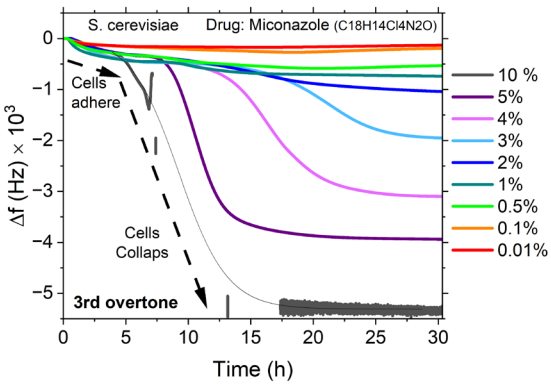

Figure 1: QCM-D monitoring of concentration-dependent miconazole activity on S. cerevisiae.

Conclusion

This study emphasizes the value of QCM-D analysis in disclosing the biomechanical mechanisms of antifungal drugs and drug resistance.

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Acknowledgement

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Double-imprinted nanoMIPs for targeted breast cancer therapy

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Abstract: This research introduces a cost-effective nanomaterial-based approach using innovative double imprinting technology. The resulting nanoparticles selectively target estrogen receptor α (ERα)-expressing breast cancer cells with strong binding, low toxicity, and controlled drug release. Their performance was evaluated using a biomimetic scaffold-assisted 3D breast cancer model that mimics the tumour microenvironment. This strategy offers a promising alternative to traditional antibodies, potentially improving access to advanced cancer treatments for broader patient communities.

Keywords: Chemotherapy; Imprinted nanomaterials; Targeted therapy; Breast cancer; Biomimetics

Introduction

Breast cancer (BC) is the most frequently diagnosed cancer worldwide, with 70% of cases being ERα positive.[1] ERα, a key driver of tumor progression, is found not only in the nucleus but also on the membrane, where it mediates rapid signalling.[2] Current ER-targeting therapies, such as tamoxifen and antibody-drug conjugates (e.g., Enhertu) face limitations including toxicity, high cost, and immune intolerance.[3] To overcome these challenges, we developed cost-effective, double-imprinted molecularly imprinted polymer nanoparticles (nanoMIPs) targeting ERα. These nanoMIPs enable selective, nuclear delivery of doxorubicin and show high cytotoxicity in ERα-positive BC models, including 3D scaffolds.

Results and Discussion

The synthesized DOX-loaded nanoMIPs had a spherical morphology with a typical size ranging from 140-170 nm. These materials rival the affinity of commercial antibodies, with a KD (binding affinity) of 10 nM for ERα receptor as determined by SPR measurements. Moreover, these nanoMIPs specifically bound and elicited cytotoxicity (~80%) to ERα positive cancer cells compared to ERα negative cell lines (~15%) via nuclear delivery of DOX. This suggested that these smart nanocarrier systems can minimize off-target side effects while improving on drug efficacy. Furthermore, it was observed that FLU-DOX-nanoMIPs not only penetrated effectively to 3D scaffolds of ERα positive BC cell line but also elicited cytotoxicity, as witnessed by live-dead staining.

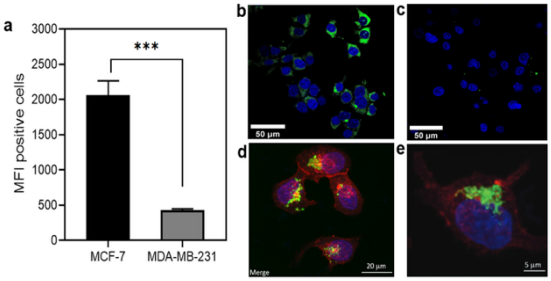

Figure 1: *Specific binding and internalization of nanoMIPs (syn-Abs) in ER+ MCF-7 cells shown via flow cytometry and confocal imaging, highlighting membrane-to-nucleus drug delivery.*

Conclusions

Double-imprinted nanoMIPs enable targeted delivery of doxorubicin to ER-positive breast cancer cells, offering a cost-effective and scalable alternative to antibody-based therapies.

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Towards on-site solid-phase extraction of per- and polyfluoroalkyl substances (PFAS) in soil and wastewater

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Abstract: Per- and polyfluoroalkyl substances (PFAS) are highly stable contaminants which pose a significant threat to the environment due to their ability to accumulate in living organisms. Currently, the detection of PFAS in soil and wastewater is performed by high-performance liquid chromatography and mass spectrometric detection in a laboratory. The aim of the "PFAS-resolve" project is to develop a system for on-site analysis.

Keywords: PFAS, polyfluoroalkyl, solid-phase extraction

Introduction

PFAS are so-called "forever chemicals" as they are virtually non-degradable in nature. They are suspected carcinogens and can be linked to various diseases [1,2]. While PFAS are strictly limited in the European Union, the extent of PFAS contamination in soil and wastewater remains difficult to determine [3,4].

In the Interreg-funded "PFAS-resolve" project, the aim is to develop a system which can prepare wastewater and soil samples followed by an on-site measurement using molecular imprinted polymer (MIP)-based chemical sensors.

To analyze PFAS in soil and wastewater samples, purification and concentration are required before a measurement can take place. Solid-phase extraction (SPE) is a well-established method to separate the analyte of interest from impurities in complex samples preparation before PFAS detection.

Results and Discussion

In Figure 1, the main steps of solid-phase extraction are shown. Here, we aim to demonstrate a prototype for the on-site solid-phase extraction of PFAS as a first building block for on-site analysis of PFAS, which allows the later integration with a sensor platform. The completed platform should allow sample preparation combined with a specifically designed measurement and control electronics.

As a first step towards the on-site extraction of PFAS from soil samples, we are comparing the performance of different commercial solutions for SPE.

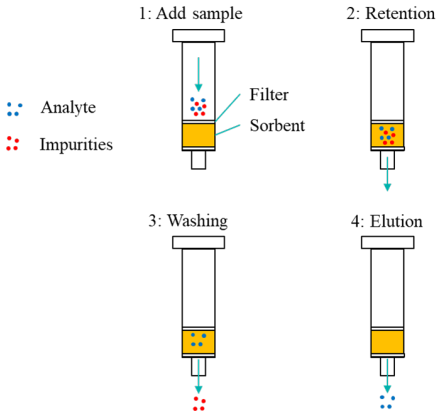

Figure 1: *The four main steps of the solid-phase extraction procedure.*

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Acknowledgements

Electrochemical Biosensors and Biodevices for Medical Diagnosis and Water Monitoring

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Abstract: There is a great need for low-cost intelligent biochips capable of massive parallel detection to be used in portable instrumentation. Electrochemical methods are inherently low-cost, miniaturisable and easily integrated into multiplexed systems for the parallel screening of panels of biomarkers. Of particular interest are biologically sensitive field-effect transistors (BioFETs) and impedance-based sensors. We will exemplify the use of synthetic bioreceptor molecules, as alternatives to antibodies, in impedance and BioFET sensors for the detection of a range of biomarkers in medical diagnosis and for water/wastewater monitoring. We will also exemplify the use of integration processes to create fully functional Lab-on-Chip biodevices.

Keywords: biosensors; impedance sensors; BioFETs; point-of-care testing

Introduction

There is a great need for low-cost biosensor chips capable of massive parallel detection to be used in portable instrumentation. Biosensors have a number of very important applications in everyday life including diagnostics for disease detection and monitoring, viral and bacterial identification, detection of contaminants in the environment, detection of biowarfare agents, etc. To have a wide use in applications, biosensors need to provide a combination of high selectivity and sensitivity, speed, low cost and portability. Further advantages are provided by sensor devices capable of simultaneous detection of multiple molecules such as for medical diagnostics, screening tests in drug development and analyses of toxic substances.

Electrochemical methods are inherently low-cost, miniaturisable and easily integrated into multiplexed systems for the parallel screening of panels of biomarkers. Of particular interest are biologically sensitive field-effect transistors (BioFETs) and impedance-based sensors. Improved selectivity and robustness can be provided by using synthetic molecules such as DNA aptamers, peptide aptamers and molecularly imprinted polymers as alternatives to antibodies, as well as oligonucleotide-based approaches in impedance and BioFET sensors for the detection of a range of biomarkers in medical diagnosis and for water/wastewater monitoring.

Examples of biosensors and lab-on-chip devices

We have developed a range of biosensors based on electrochemical impedance or BioFETs for a wide range of applications related to point-of-care or point-of-use medical or environmental monitoring.

BioFETs using extended gate structures can be used for a range of applications, depending on the type of gate material and bioreceptor used. Using dielectric materials one obtains local variations in pH due to e.g. an enzymatic reaction [1] or a phosphorylation process [2]. One can also keep the metal gate of the transistor and use the FET to measure variations in open circuit potential / threshold voltage that occur upon biomolecular binding events that lead to variations in charge or dielectric properties in the biolayer region [1,3,4].

Electrochemical impedance biosensing can be performed either in a Faradaic mode (i.e. with redox molecules in solution) – examples include detection protein cancer biomarkers [5], T cells for HIV management systems [6] or drugs in wastewater [7] – or in a non-Faradaic mode (without the addition of redox mediators) which enable real-time monitoring of biomolecules – examples include protein biomarkers in serum [8] or bacteria in tap water [9].

Such biosensors can be integrated with microfluidics and electronic addressing for on-chip sample preparation, sensing and data transmission in fully functional Lab-on-Chip biodevices for point-of-care applications.

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Towards a multi-sensor array system for online monitoring of drinking water quality

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Abstract: A continuous supply of clean drinking water is essential for a healthy population. Drinking water in Germany is obtained by about 70% from ground- and spring-water, and critical physical, biological and chemical parameters are regularly monitored offline in certified laboratories. In order to detect changes in the water quality and potentially harmful contaminations, a remote online system for continuous multi-parameter analysis is needed, which is the subject of the presented work.

Keywords: Ion-selective electrode (ISE); water quality; continuous monitoring; ground water

Introduction

In 2022, an average of 126 liters of drinking water was consumed per person in Germany. Of this, about 4% is used directly for food preparation and drinking [1]. 70% of drinking water is obtained from ground- and spring water sources, which are often located within water protection areas, serving as a first protection barrier. In Germany, the "Trinkwasserverordnung" [2] defines the regulatory limits for various water parameters, including physical (e.g., pH, conductivity (σ), temperature (T)), (micro-)biological (e.g., maximum amount of colony forming units (CFU) of various bacteria), and chemical (e.g., pesticides and ions) parameters. According to the report of Germany's central environmental authority [3], the allowed limits of coliform bacteria, turbidity, CFU, as well as for specific ions are regularly exceeded in their controls. In the ongoing OnTrAn ("Vernetztes Online Trinkwassersensorsystem zur kontinuierlichen Überwachung der Qualität durch intelligente Analyseverfahren") project, an automated multi-sensor array system, consisting of a biological sensor, ion-selective electrodes (ISEs) and sensors for physical parameters will be developed to allow online analysis of the current status of drinking water as an early warning system for detecting abnormalities.

Results and Discussion

The results of a literature search of available ISEs, laboratory-based test measurements of selected ISEs, and physical parameters are discussed. In addition, a first demonstrator of a flow-through setup to detect multiple ions in the same liquid will be presented, see schematic in Fig. 1.

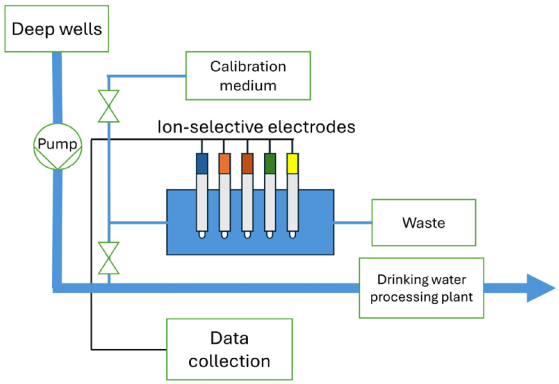

Figure 1: *Schematic of multi-sensor array in a bypass of the drinking water pumping system before reaching the water processing plant.*

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Acknowledgments

The authors thank the Central Innovation Program (project number:16KN0996445) for small and medium-sized enterprises (SMEs) funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and also the project partners, INCOstartec GmbH, LANTECH Informationstechnik GmbH, Fraunhofer IGB, and Stadtwerke Klingenberg.

Development of a catheter-based sensor for the *in situ* detection of histamine in IBS diagnosis

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Abstract: The irritable bowel syndrome (IBS) affects a significant portion of the global population, yet its diagnosis remains challenging due to the absence of reliable molecular markers. In this study, we aim to directly sense histamine concentrations in the duodenum using a catheter-based, minimally invasive biosensor. We build on recent work using molecularly imprinted polymers (MIPs), coated on gold electrodes, for selective histamine detection by impedance spectroscopy in complex biological fluids.

Keywords: biosensors; histamine detection; catheter sensors; bowel disorders; molecularly imprinted polymers

Introduction

Functional bowel disorders, including IBS, represent complex gastrointestinal conditions characterized by gut-brain axis dysfunction, immune activation, and altered mucosal responses [1]. Histamine, released by activated mast cells, plays a key role in symptom generation in a subset of patients. Current diagnostic procedures are invasive and limited. We propose a minimally invasive approach using catheter-based impedance sensors functionalized with molecularly imprinted polymers (MIPs) for detecting histamine concentrations directly at the site of symptom generation [2].

Results and Discussion

The sensor uses electropolymerized polypyrrole molecularly imprinted polymers (MIPs) coated on gold microwire electrodes to achieve selective histamine detection under simulated intestinal fluid conditions (FaSSIF). The binding mechanisms between histamine and the MIP, involving π–π interactions and hydrogen bonding, are illustrated in **Figure 1a**. Impedance spectroscopy and equivalent-circuit modelling revealed that histamine binding to the MIP-modified electrodes primarily increases the resistive component of the electrode-liquid interface. Using different histamine concentrations in 1 × PBS as a model environment, the sensor demonstrated a detection limit down to 10 nM, covering the physiological and patho-physiological range (up to >1 µM) relevant for IBS diagnosis.

Measurements were carried out inside a dummy body setup at a controlled temperature of 37 °C to simulate human conditions. Differential sensing with non-imprinted polymers (NIPs) corrected for nonspecific adsorption and matrix effects. The catheter tip design, shown in **Figure 1b**, incorporates a fluid collection chamber with a filter, enabling real-time sampling while maintaining sensor stability across different pH and digestive environments.

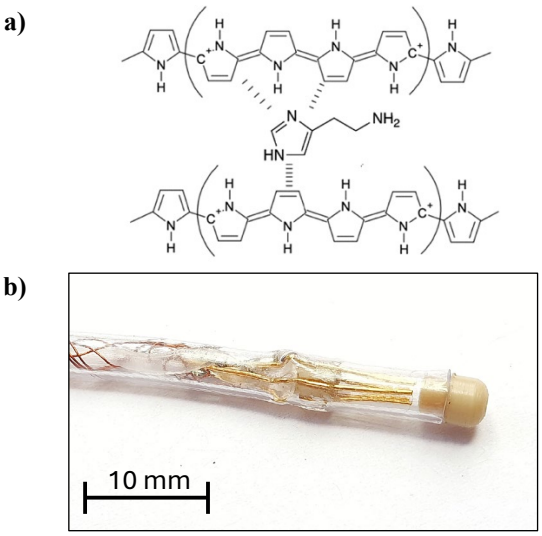

Figure 1: a) *Binding mechanism between histamine and the poly pyrrole-based MIP through π–π interactions and hydrogen bonding.* ***b)*** *Photograph of the catheter tip featuring six gold electrodes and a measurement chamber designed to aspirate intestinal fluid. A filter inside the tip prevents the entry of larger intestinal particles into the reservoir.*

Conclusions

The catheter-based MIP sensor enables selective histamine detection under physiological conditions, supporting its potential for minimally invasive IBS diagnostics and real-time monitoring in future in vivo applications.

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Acknowledgements

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Sodium-sensitive capacitive field-effect sensor

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Abstract:
Capacitive field-effect Electrolyte-Membrane-Insulator-Semiconductor (EMIS) sensors have been utilized for the detection of the Na^+-ion concentration in solutions. To establish the sensitivity to sodium ions of the realized sensor, polyvinyl chloride (PVC) membranes containing sodium ionophore X have been immobilized via drop-coating on top of field-effect sensors with two different insulators – silicon nitride (Si_3N_4) and tantalum pentoxide (Ta_2O_5). The functionalized sensors have been systematically characterized by impedance spectroscopy, capacitance-voltage- (C-V), and constant-capacitance (ConCap) methods in terms of sensitivity, measurement range, cross-sensitivity, and drift behavior in different concentrations of sodium solutions.

Keywords: sodium sensor; capacitive field-effect sensor; PVC membrane; sodium ionophore X

Introduction

The detection of sodium is very important in clinical analytics, biochemistry, and environmental studies. The present work is continued from recently published results with a calcium-sensitive field-effect polymeric-membrane-based EMIS sensor to estimate the risk of urinary stone formation in human kidneys [1].
Polymeric membranes with sodium ionophore X were immobilized under different conditions on top of field-effect capacitors with different transducer materials, and the sensor performance as well as the adhesion and long-term stability of the membrane was studied.

Results and Discussion

Two different types of 10 x 10 mm² EMIS sensors were prepared: (1) a 200 µm n-doped Si substrate with a ~50 nm thick SiO_2 and ~50 nm thick Si_3N_4 layer as gate insulator and pH-sensitive transducer layer, and (2) a 500 µm p-doped Si substrate with a ~30 nm thick SiO_2 and ~60 nm thick Ta_2O_5 layer as gate insulator and pH-sensitive transducer layer, respectively. Both types of sensors had a ~300 nm thick Al layer as rear-side contact. The polymeric membrane cocktail with different components including sodium ionophore X was prepared and drop-coated on the sensor surface with and without silanization using hexamethyldisilazane.
The polymeric membranes were physically characterized by digital 3D-videomicroscopy and scanning electron microscopy in terms of adhesion, homogeneity, etc. For electrochemical studies, impedance spectroscopy, capacitance-voltage- (C-V) and constant-capacitance (ConCap) measurements have been performed in different concentrations of sodium solutions prepared with 1 M Tris buffer, adjusted to pH 8.
Figure 1 shows four representative calibration plots with average sensitivities of 57.4 mV/pNa, 58.5 mV/pNa, 58.9 mV/pNa and 56.2 mV/pNa for the 1st, 2nd, 3rd and 4th measurement cycle, respectively.

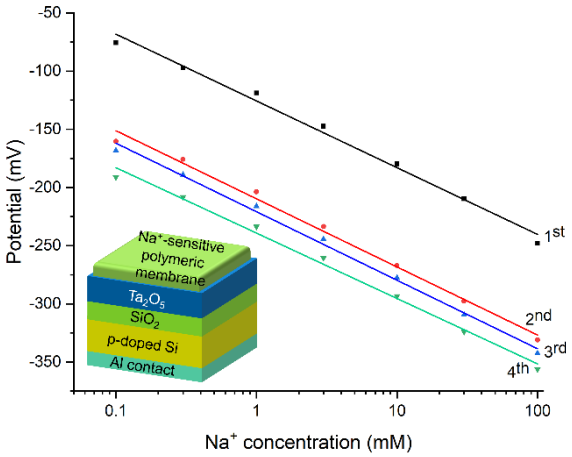

Figure 1: *Exemplary calibration plots of the EMIS sensor for four measurements within a period of 10 weeks, and sketch of the sensor arrangement (inlet).*

The same structures of EMIS sensors were also operated as light-addressable potentiometric sensor (LAPS) and the results were compared with those of the capacitance measurements.

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Electrochemical detection of PFAS employing gold electrodes imprinted with polypyrrole

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Abstract: Conventional methods for detecting polyfluoroalkyl substances (PFAS) are laboratory-based, expensive, and time-intensive. Electrochemical sensors present a promising alternative, enabling potential on-site PFAS detection. In this study, gold electrodes coated with molecularly imprinted polymers (MIP) are used to identify perfluorooctanoic acid (PFOA). The sensor's effectiveness was assessed through electrochemical impedance spectroscopy (EIS), revealing its capability to detect PFOA in concentrations ranging from 0.1 nM to 10 µM, with a detection limit of 0.1 nM.

Keywords: polyfluoroalkyl substances; electrochemical impedance spectroscopy; molecularly imprinted polymers; on-site detection

Introduction

PFAS are a group of substances extensively used in the manufacturing of various consumer products. Over time, their accumulation in the environment has raised concerns, as studies have shown they are toxic and potentially cancer-causing [1]. This underscores the urgent need for a sensitive, fast, and affordable method to monitor PFAS levels [2,3]. Electrochemical sensors have emerged as a promising solution, employing changes in electrochemical signals to detect PFAS. To improve selectivity, electropolymerized MIP can be used to functionalize sensor surfaces. This research illustrates that integrating PFOA electropolymerized MIPs with EIS can yield a low-cost, durable sensor suitable for real-world sample analysis.

Results and Discussion

In this study, chronoamperometry was used to electropolymerize pyrrole onto the surface of gold electrodes. MIP and non-imprinted polymers (NIP) were synthesized on different regions of the same electrode and their impedance values were recorded by conducting EIS measurements. Subsequently, impedance increase values for both MIP and NIP were calculated (Figure 1). The results reveal a clear trend of increasing impedance with rising concentrations of PFOA. The practical limit of detection for the MIP sensor was 0.1 nM. In contrast, the NIP sensor exhibited lower impedance increases, confirming that the target binding in the NIP is non-specific within the polymer matrix.

Additionally, the sensor's practical performance was evaluated using EIS measurements in river water and egg yolk samples. This developed sensor shows promise for large-scale production aimed at on-site PFOA detection.

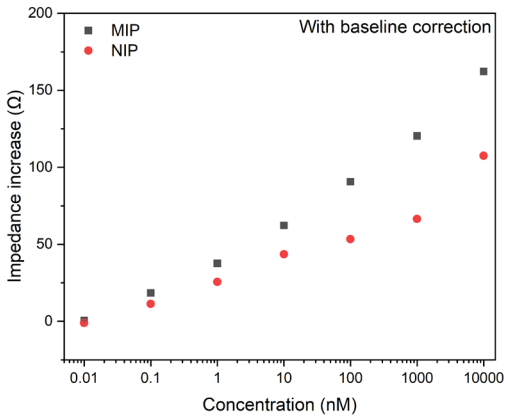

Figure 1: *Impedance increase for MIP and NIP at different concentrations of PFOA.*

Conclusions

This study introduces an electrochemical sensor designed for detecting PFOA in real-world samples, highlighting its potential as a cost-effective tool for rapid on-site PFAS screening.

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KU Leuven and Maastricht University through the Global PhD Partnership funded the work presented in this article.

Cross-sensitivity of pH-sensitive HfO_2 extended-gate field-effect transistors to interfering Na^+ ions

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Abstract: This work investigates the impact of interfering Na^+ ions on the pH-sensing properties of extended-gate field-effect transistors with HfO_2 as pH-sensitive material. Experiments were performed according to the fixed interference method (recommended by IUPAC) under constant activity of the interfering ion (Na^+) and varying activity of the primary ion (H^+). From the experimental data, selectivity coefficients of HfO_2 were evaluated.

Keywords: extended-gate ISFET, floating-gate, HfO_2, Na^+ cross-sensitivity, fixed interference method

Introduction

Ion-sensitive field-effect transistors (ISFETs) are widely used for pH measurements in various applications. However, their performance can be negatively affected by cross-sensitivity behavior towards interfering ions. This occurs when the ISFET responds to ions other than the primary ion (in this case, H^+ ions) and affects the accuracy of the pH measurement. The most commonly used approach to measure selectivity coefficients is the fixed interference method (FIM), which was recommended by IUPAC (International Union of Pure and Applied Chemistry) [1]. By FIM, the ISFET response signal is measured in solutions of constant activity of the interfering ion(s) and varying activity of the primary ion. In this work, cross-sensitivity of HfO_2 extended-gate field-effect transistors (EGFET) to the interfering ion sodium (Na^+) has been studied using the FIM. HfO_2 is considered as one of the best pH-sensitive materials for ISFETs [2, 3], however, its cross-sensitivity to interfering ions has rarely been investigated.

Results and Discussion

EGFET chips characterized in this work were developed by Texas Instruments GmbH, Freising, Germany. Each chip contains three HfO_2-gate EGFETs with adjustable floating-node charge, enabling individual calibration. The HfO_2 layers were prepared by atomic layer deposition. To determine cross-sensitivity of EGFETs towards Na^+ ions, four chips were tested in parallel under constant Na^+ concentration (1 M) and varying pH value according to FIM (see Figure 1). The pH of buffers was additionally controlled by means of a pH glass electrode. Based on measurement results, the selectivity coefficient of HfO_2 EGFETs has been evaluated. Details of experiments and obtained results will be presented at the conference.

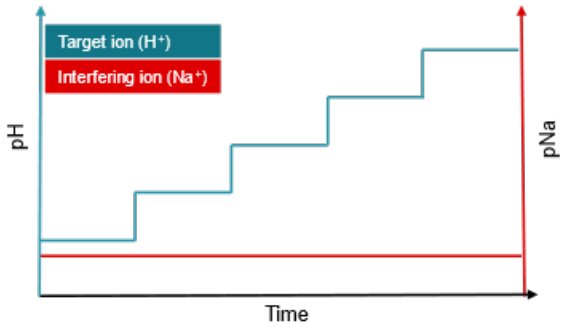

Figure 1: *Schematic of measurement procedure.*

Acknowledgements

The authors would like to thank P. Bühlmann for valuable discussion.

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One-Step Polyaniline-Platinum Nanoparticles Grafting on Porous Gold for self-powered glucose monitoring

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Abstract: Bioelectronics, which integrates biological systems with electronic devices, holds significant promise for advancing medical diagnostics and therapies. However, most devices currently depend on conventional batteries that are difficult to miniaturise without compromising capacity. Glucose fuel cells (GFCs) offer a sustainable and biocompatible alternative for powering medical devices. Here, we present a non-enzymatic GFC fabricated on a printed circuit board using a rapid one-step electrodeposition process, forming a polyaniline (PANI)-platinum nanoparticle composite on highly porous gold (hPG). The resulting device exhibited high sensitivity, long-term stability, and sufficient power output to enable practical bioelectronic applications.

Keywords: glucose fuel cells, highly porous gold, platinum nanoparticles, polyaniline, electrocatalyst, bioelectronics.

Introduction

GFCs are increasingly explored as power sources for implantable and wearable medical devices due to their biocompatibility and use of physiologically available glucose. Non-enzymatic systems, in particular, offer superior long-term stability compared to enzyme-based designs. Porous gold has emerged as a promising electrode support due to its large surface area and high conductivity. Combining this with conductive polymers and catalytic nanoparticles may provide enhanced performance and durability [1, 2].

Results and Discussion

A nanocomposite electrode was fabricated by the simultaneous electropolymerisation of polyaniline and in-situ formation of platinum nanoparticles onto highly porous gold via chronopotentiometry, completed in under one hour. Structural characterisation confirmed the preservation of the porous morphology and uniform nanoparticle distribution. The GFC achieved a maximum power density of 61.74 ± 1.25 μW cm^{-2} at a current density of 220.55 ± 2.64 μA cm^{-2} with an open-circuit potential of 614 ± 20.04 mV under 6 mM glucose at 37°C. When evaluated in synthetic interstitial fluid (SIF), the sensor exhibited a sensitivity of 190.6 ± 21.0 μA mM^{-1} cm^{-2} within the detection range of 2–7 mM. Long-term stability testing revealed minimal performance loss over three months.

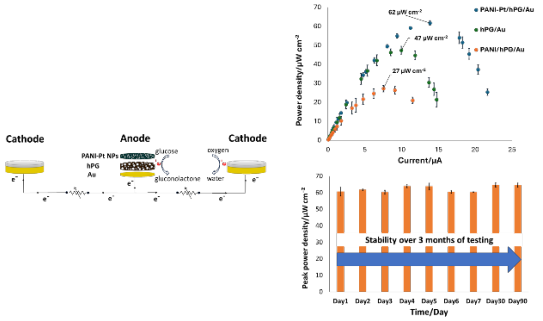

Figure 1: *Schematic representation of GFC configuration, highlighting the electrode architecture, energy output, and long-term operational stability.*

Conclusions

This work demonstrates a simple, rapid method for fabricating high-performance, stable GFCs using a PANI-Pt/hPG electrode. The results show strong potential for self-powered glucose monitoring and other bioelectronic applications where reliability and durability are essential.

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Biofunctionalization of aluminium surfaces with *Mycobacterium leprae* epitopes for serological detection of leprosy

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Abstract: Current serological tests for leprosy lack sufficient sensitivity and specificity. Using bioinformatics tools, we designed synthetic peptides and a multiepitope protein to detect anti-*Mycobacterium leprae* antibodies. We biofunctionalized aluminium chips with APTES to coat them with the new protein and tested them with real samples using the Heat Transfer Method (HTM). Preliminary results showed successful differentiation between exposed and non-exposed individuals. This standardization marks an important step toward developing a more sensitive biosensor for serological detection of *M. leprae* infection.

Keywords: Biofunctionalization; Leprosy; Serological Tests; Immunosensor; Heat Transfer Method.

Introduction

Leprosy remains a significant global health issue, particularly in endemic regions such as Brazil and India[1]. The World Health Organization (WHO) emphasizes the need for improved diagnostic tests to detect *Mycobacterium leprae* infection in both symptomatic and asymptomatic individuals[2]. At the moment, the diagnosis of leprosy relies primarily on symptoms and clinical manifestations[3]. Biosensors could represent an alternative to traditional diagnosis, offering the advantages of being low cost and portable for being used in situ. This study aimed to biofunctionalize aluminium chips for use in biosensing screening tests for *M. leprae* exposure.

Results and Discussion

For surface hydroxylation we used 20% Base Piranha. Subsequently, we completed the biofunctionalization with APTES and glutaraldehyde, as confirmed by FTIR analysis. EDX results showed a reduction in aluminium surface concentration from around 97% to 51%, with the remaining 49% corresponding to elements in the chemical layer, such as carbon, oxygen, and silane. An ELISA-like immunoassay performed on the biofunctionalized chips revealed a distinction among blank, non-infected, and infected sera. HTM analysis showed a temperature difference of 0.2 °C between leprosy contact and non-infected sera (Figure 1) after five injections. This is relevant since contacts are at increased risk of developing leprosy and may contribute to transmission[3]. Early detection with high sensitivity can support surveillance programs and prevent disease progression[2]. The effect size was 2.5 times greater in infected sera compared to both non-infected and tuberculosis samples, indicating no cross-reactivity with other important *Mycobacterium* specie. To our knowledge, no HTM-based biosensor with a similar architecture has been reported for leprosy detection.

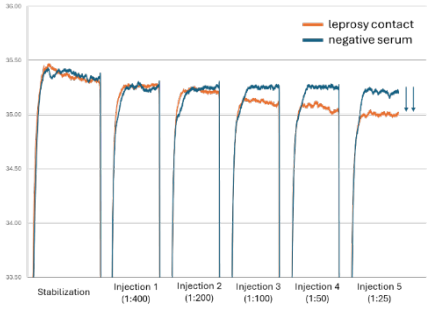

Figure 1: *Representative temperature response of the biofunctionalized aluminium chip after five injections of diluted serum samples (in 0.5% BSA).*

Conclusions

We successfully biofunctionalized aluminium surfaces for use in HTM-based biosensing devices and calibrated the system using sera from individuals with different health conditions. This represents an important step toward developing a more sensitive immunosensor for early-stage leprosy detection.

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Modular measurement platform for multi-ISFET characterization

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Abstract: A highly flexible, modular measurement platform for multi-ISFET (ion-sensitive field effect transistor) characterization was developed and fabricated. The modular layout provides great freedom in experimental design regarding the number of sensors used and a manual or fully automated operation. A maximum of 24 devices (72 ISFETs in total) can be simultaneously installed and characterized, allowing high measurement throughput and multi-parameter assays. During initial functional tests, the leakage currents of the ISFETs were measured and pH characterizations were carried out in both manual and automatic mode.

Keywords: ISFET; pH sensing; multiplexed measurement setup; portable platform; microfluidics

Introduction

Ion-sensitive field-effect transistors (ISFETs) are robust, versatile sensors that can be produced in the micrometer range and whose research has continued with unbroken interest since their invention [1, 2, 3]. Recently, a floating-node ISFET was developed by Texas Instruments GmbH, Freising, Germany [2]. We present a highly flexible, modular measurement platform for characterizing packages with these ISFETs (see Figure 1). The aim of our development was to create a convenient, high-throughput system to expedite the further development of ISFETs and investigate functionalization strategies on them.

Design of the platform

The main part of the new measurement platform is a base station, which houses the electronics and a socket board for up to 24 packages (3 ISFETs each, 72 in total) from Texas Instruments. The sockets are arranged in the 4 × 6 grid of a standard 24-well plate, creating compatibility with external devices such as pipetting robots. Rows of four packages are clamped into the base station by modules with different functionalities. A single module is mounted using just two thumb screws, allowing quick swapping of packages with only minimal interruption to measurement operation. There are currently two basic module types: (i) a well module for manual handling that allows single package manipulation, and (ii) a fluidic module intended for larger scale, automated characterizations. The base station can be equipped with any combination of the module types. The portable platform has dimensions of only 12.7 cm × 10.1 cm × 3.9 cm (excluding reference electrodes and external fluidic system). The functionality of the new platform was successfully demonstrated by leakage current and pH characterizations of ISFETs in manual mode with well modules or automatic mode with fluidic modules.

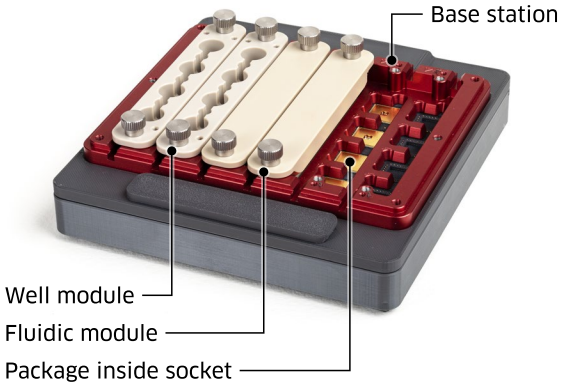

Figure 1: *Modular measurement platform. Overall dimensions are 12.7 cm × 10.1 cm × 3.9 cm.*

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Surface modification of carbon electrodes for nitrite detection

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Abstract: After complex surgeries such as skin-flap transplantations, monitoring the postoperative healing progress is a personnel- and time-consuming task. A reliable method to analyze the healing process is the determination of the nitric oxide concentration, which initiates the different healing stages. The direct detection of nitric oxide is a challenging task due to its short lifetime (<5 s), but it forms the stable oxidation products nitrite and nitrate. Here, we studied three different carbon electrode surface modifications to form an enzyme-free, nitrite-responsive surface, based on the chemicals of the Griess-test.

Keywords: nitrite detection, Griess test, carbon electrode, wound healing

Introduction

Accurate knowledge of the current status of the wound healing process after complex surgeries, such as skin flap transplantation, is of great importance [1]. Nitric oxide serves as a central messenger molecule during the wound healing process [2]. However, due to its short lifetime (<5 s), the direct determination remains challenging. Instead, its stable oxidation products nitrite and nitrate can be analyzed [3]. A classic method for nitrite detection is the spectroscopic Griess test [4]. In this work, we explored the formation of a nitrite-responsive surface on a carbon electrode based on the Griess test components.

Results and Discussion

The individual components of the Griess test, sulfanilamide (SFD), naphtylethylenediamine (NED), and p-phenylenediamine (pPD), were electrochemically deposited on a carbon surface utilizing cyclic voltammetry. The modified carbon electrode was characterized by contact angle and amperometric measurements. Here, a working potential of 0.85 V vs. Ag/AgCl reference electrode was applied and nitrite concentrations ranging from 0.05 µM up to 10 mM were tested. Next to the detection of nitrite, we also studied the detection of nitronium ion (NO_2^+) and the different surface modifications towards cross-sensitive chemicals, like sulphates, phosphates, nitrite and ammonium. The deposition of SFD and NED on a carbon electrode was proven by contact angle measurements. Here, the contact angle clearly changes between a non-treated surface and the treated ones, as demonstrated in Figure 1.

Conclusion

The amperometric studies reveal that depending on the surface modification a nitrite detection between 0.5 µM and 10 mM is possible, having sensitivities resulting between 0.25 $nA \cdot mm^{-2} \cdot \mu M^{-1}$ and 1.08 $nA \cdot mm^{-2} \cdot \mu M^{-1}$: The pPD modification showed the lowest sensitivity, whereas the SFD modification demonstrated the highest sensitivity.

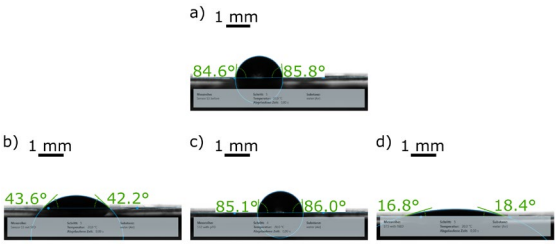

Figure 1: *Contact angle of carbon electrodes in a) a bare state, or modified with b) sulfanilamide, c) p-phenylenediamine, or d) naphtylethylenediamine.*

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3D photoelectrochemical imaging for the investigation of the localized kinetics of photocatalytic water splitting

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Abstract: A 3D photoelectrochemical imaging system (PEIS) for investigating localized kinetics of photocatalytic water splitting in complex porous electrode structures will be presented. Porous ITO coated with hematite via electrodeposition was fabricated and used as the light addressable electrode. Localized deposition of the photocatalyst – Cobalt-phosphate (Co-Pi) was achieved. Photocurrents were excited with a two-photon effect using a focused, modulated 780 nm fs laser to provide depth resolution. The variation of the photocurrents collected in different depths of the photoelectrode demonstrates the potential of 3D photoelectrochemical imaging.

Keywords: light-addressable electrochemistry, 3D photoelectrochemical imaging, porous semiconductor electrode.

Introduction

Electrochemical imaging techniques are powerful tools to investigate charge and catalytic activity of surfaces with high resolution [1]. Complex mesoporous structures are considered for efficient, low-cost photocatalytic solar water splitting. However, current electrochemical imaging technologies have been limited to probing thin films leaving the pore structure effects on gas/liquid exchange rarely examined. Here, we present novel 3D photoelectrochemical imaging technology that is expected to aid the investigation of the localized kinetics of photocatalytic water splitting in the future, using hematite as the photoelectrode which has exhibited excellent performance in both water splitting [2] and photoelectrochemical imaging [3].

Results and Discussion

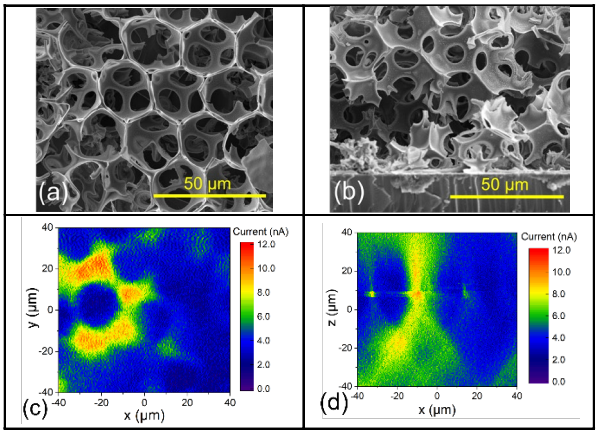

Figure 1: *(a) SEM image of the ITO-hematite photoelectrode (a) top view; (b) cross section; (c) photocurrent image of the XY plane; (d) photocurrent image of the XZ plane.*

An ITO-hematite porous electrode with interconnected pores and a well-connected interface with the substrate (Fig 1a and b) was fabricated successfully. Photocurrent images of the porous structure were taken on both the XY plane and the XZ plane (Fig. 1c and d). The photocurrent was significantly larger when the laser was focused on the pore wall rather than the cavities of the structure, both in the XY scan (Fig. 1c) and an XZ area scan (Fig 1d). The image reveals discernible features showing the shape and size of the observed pores.

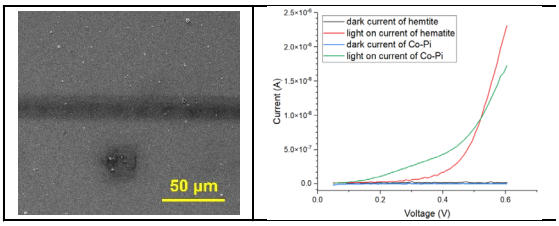

Figure 2: *(a) SEM image of Co-Pi on hematite; (b) Photocurrent test on pure hematite and on Co-Pi coated hematite film.*

Fig 2a shows a localized photo-electrodeposited Co-Pi pattern on Hematite film. The photocurrent test in Fig 2b shows higher photocurrent on Co-Pi film indicating more charge carriers reaching the reaction sites, which boosts the overall efficiency of water oxidation.

Conclusions

A porous ITO-hematite scaffold was fabricated successfully as a photoelectrode for photocatalytic water splitting. Our photoelectrochemical imaging system is able to capture 3D images of pores, thereby demonstrating the significant potential of this technique for studying the localized kinetics of photocatalytic water splitting in the future.

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Photoelectrochemical sensing of potassium ions using polyurethane-coated hematite nanorods

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Abstract: A photoelectrochemical sensor using α-Fe_2O_3 (hematite) nanorods as the sensor substrate coupled with a polyurethane (PU) thin film is proposed for detecting potassium ions (K^+). The fabrication of sensors was started with a hydrothermal process to prepare the hematite nanorod substrates followed by modification of the sensor surface with PU ionophore-based film. The sensors showed an amperometric response in the K^+ concentration range of 1 µM to 10 mM.

Keywords: Photoelectrochemical sensor, potassium ions sensing, hematite nanorods, polyurethane

Introduction

Photoelectrochemical sensing integrates photoexcitation with electrochemical detection, enabling analyte measurement at the electrode/electrolyte interface through light-triggered electrical signals. Developing sensors that can detect potassium ions (K^+) is vital, as K^+ plays a key role in cardiac and neuromuscular functions essential to cellular health and functionality. Light-addressable potentiometric sensors (LAPS) have been employed for K^+ detection using ion-sensitive poly(vinyl chloride) (PVC) films, but these systems often suffer from limited stability and slow response times [1]. Polyurethane (PU) films have demonstrated superior performance in potentiometric ion sensing compared to PVC [2]. In this work, the sensing capability of hematite nanorod substrates coated with PU film (containing a potassium ionophore) was tested in a photoelectrochemical imaging system for K^+ detection.

Results and Discussion

To evaluate the K^+ sensing performance, current–voltage (*I-V*) measurements were conducted in potassium chloride solutions of varying concentrations under light modulation at 1 kHz. As shown in Figure 1a, the photocurrent increased progressively with the K^+ concentration in the range of 1 µM to 10 mM. A calibration curve was constructed by plotting the photocurrent values at 1.2 V against the logarithm of the K^+ concentration (Figure 1b), demonstrating a clear ion-dependent response.

The sensor exhibits a clear amperometric response across a range of K^+ concentrations. This photocurrent response is attributed to the PU thin film, which facilitates light-activated faradaic electrochemistry at the electrode/electrolyte interface. The selective binding of K^+ ions increases the local hydroxide ion concentration near the sensor surface, thereby enhancing the oxidation reaction and contributing to the observed current response.

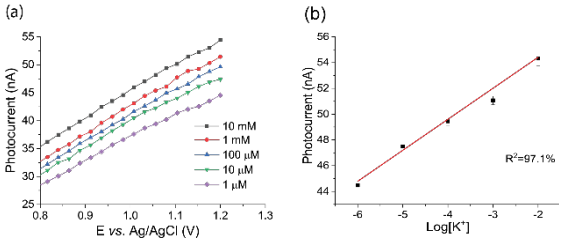

Figure. 1: *(a) I-V curves of the hematite nanorods-based photoelectrochemical sensor measured at different K^+ concentration (b) corresponding calibration curve with linear fitting.*

Conclusions

Hematite nanorods coated with a PU film containing a potassium ionophore were developed for photoelectrochemical sensing of K^+ over a range of 1 µM to 10 mM. The PU coating improves stability compared to PVC-based membranes, enabling reliable ion detection. This approach offers a promising platform for robust ion-selective biosensing and high-resolution ion imaging.

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Acknowledgements

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Magnetic microparticle-based enzymatic detection of C-reactive protein with capacitive field-effect sensors

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Abstract: A new method for the detection of C-reactive protein (CRP) based on antibody-functionalized magnetic microparticles (MP) in a field-effect sensor-based, on-chip enzyme-linked immunosorbent assay is demonstrated.

Keywords: on-chip ELISA, microparticles, C-reactive protein, field-effect sensors, ABTS, HRP

Introduction

We developed a field-effect sensor-based, on-chip enzyme-linked immunosorbent assay for the inflammation biomarker C-reactive protein (CRP). Streptavidin-coated magnetic microparticles (MPs) were functionalized with biotinylated antibodies against CRP. After CRP binding to the particles, a second antibody with bound horseradish peroxidase (HRP) was coupled. After magnetic purification of the particle solution, it was injected over the sensors. MPs were held in place on the sensor surface by a ring-shaped neodymium magnet during the measurement. The oxidation of 2,2′-azino-bis(3-ethyl-benzothiazoline-6-sulphonic acid) (ABTS) by HRP consumes protons. This induced pH change close to the sensor surface can be detected by the field-effect sensors [1]. In this work, we used a portable platform for the multiplexed characterization of 16 capacitive field-effect sensor [2,3]. The MPs can be easily washed away after the measurement when the magnet is removed to reuse the sensor.

Results and Discussion

Four differently treated MP samples were compared during the measurement: MPs without CRP, and MPs treated with CRP solutions of 0.1 mg/L, 1 mg/L and 10 mg/L concentrations, respectively. 50 µL of the functionalized MP samples were injected directly over each sensor chip into the bulk solution. MPs are visibly pulled to the sensor surface by the ring magnets. The enzymatic reaction (which depends on the CRP concentration) increases the pH value, which was examined by collecting capacitance-voltage (*C–V*) curves and in constant-capacitance (ConCap) mode measurements before and after MP injection. A signal of about 20 mV was achieved for a concentration of 10 mg/L CRP. Additionally, the oxidized ABTS will gradually turn the solution green, which allows an additional optical verification of the enzymatic activity.

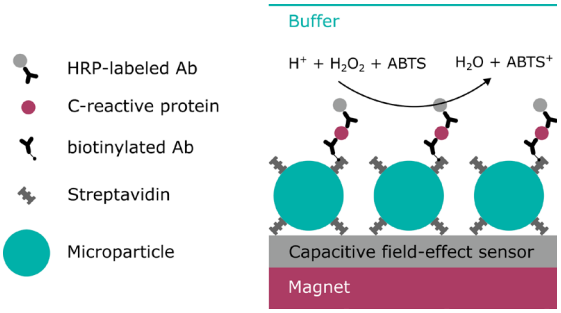

Figure 1: *Microparticle HRP-based CRP sensing with pH-sensitive capacitive field-effect sensors.*

Conclusions

As antibodies against a large variety of biomedically interesting antigens labeled with HRP (and various conjugation kits) are readily available, this is a very promising detection approach for field-effect based immunosensors. The color change reaction enables a future dual detection approach by combining optical and electrochemical determination of protein concentrations.

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A label free electrochemical aptasensor enables ultrasensitive and specific detection of neurofilament light

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Abstract: Plasma neurofilament light (NfL) has been identified as a valuable biomarker of early-stage Alzheimer's disease (AD). Its very low concentration in plasma poses a challenge to its precise detection. In addressing this challenge, we have identified and characterised novel NfL aptamers. These aptamers have been integrated with on-chip gold electrodes to construct aptasensors, resulting in a low K_d value of 1.67±0.47 nM. Furthermore, an ultrasensitive and selective aptasensor was fabricated based on ion-gated organic electrochemical transistors (iOECT), capable of detecting NfL in human serum with as few as thousands of molecules.

Keywords: Alzheimer's disease, neurofilament light, SELEX, aptamer, organic electrochemical transistor

Introduction

NfL is an axonal protein that is released into the plasma following neuronal or axonal injury. The level of NfL in blood begins to change at least 10 years before dementia diagnosis, but in extremely low level, around 0.5 pM only[1]. Aptamers, as a short sequences of RNA or single-stranded DNA are considered as emerging alternatives to naturally derived antibodies [2]. They are generated by SELEX[3]. iOECTs are efficient switches and powerful amplifiers[4]. Modulations on iOECTs happen over the entire volume of the channel, leading to higher performance than FET. Until now, there is no report about OECT being engaged as transducer to sense NfL.

Results and Discussion

Capillary electrophoresis SELEX (CE-SELEX) was utilized to identify aptamer receptors for NfL. We observed that the sequence (Seq-1) having highest enrichment yields a K_d of 78.73 nM. After truncation, the binding affinity of seq-1 (tSeq-1) with a complaint decrease to 181.73 nM. No considerable binding was observed between aptamers and human serum albumin, indicating the high specificity of our aptamer. For the implantation of an electrochemical assay, tSeq-1 was immobilized onto gold microelectrodes. The aptamers retained their target binding capability. The K_d value of (tSeq-1) is improved to 1.67±0.47 nM.

To meet the demands of serum testing, the gate electrode of iOECTs was functionalized with the aptamer. The aptasensor was incubated with NfL in PBS buffer first. The transfer curves were recorded for different NfL concentrations. Then, the aptasensor was evaluated in complex samples by spiking NfL into human serum (Figure 1). Testing in spiked human serum demonstrates the robustness and universality of gate-modified iOECT sensors. The performance of the sensors was very consistent to the PBS results. Just minor deviations were observed with a linear range lasting from 10 aM to 1 pM and a LOD of 9 aM.

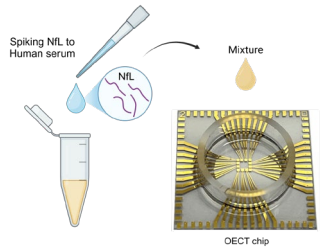

Figure 1: *NfL spiked into diluted human serum and measured by the iOECT array chip.*

Conclusions

We report on the selection of a novel aptamer for NfL, the implementation of different sensors for the detection of this biomarker. With this research, we intend to develop a sensitive and selective aptasensor that facilitates the diagnosis of early-stage AD through minimal invasive blood tests even before cognitive impairment becomes noticeable in individuals' behavior.

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Effect of Parylene Coating on an Ion-Selective Membrane-Modified Light-Addressable Potentiometric Sensor

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Abstract: Light-addressable potentiometric sensors (LAPS) offer spatially resolved analyte sensing. Their label-free operation and compatibility with various sensing membranes make them promising candidates for chemical and biomedical sensing applications. However, selecting an appropriate insulating layer is essential for enhancing device sensitivity, reliability, and biocompatibility. This study proposes using parylene as an alternative insulator to improve the performance of ion-selective membranes. Using a K^+-sensitive membrane, the sensitivity to potassium with the parylene was nearly twice that of the missing passivation layer.

Keywords: light-addressable potentiometric sensor; LAPS; ion-sensing; parylene

Introduction

Light-addressable potentiometric sensors (LAPS) offer spatially resolved analyte sensing based on electrolyte–insulator–semiconductor (EIS) structures [1]. LAPS have attracted significant attention for their ability to visualize ion distributions with high spatial resolution through localized light irradiation. Using ion-selective membranes (ISM), such as PVC membranes with ionophores, enables the selective sensing of ion species [1]. Conventional LAPS use SiO_2 and Si_3N_4 as the insulators and offer good pH sensitivity. However, the high-temperature deposition of SiO_2 limits the range of usable semiconductors. Additionally, the high pH sensitivity requires surface modification to block hydroxyl groups when using ISM. This study proposes using parylene, a room-temperature chemical vapor deposition (CVD)-deposited polymer, as an alternative insulator. Parylene has low defect density, tuneable thickness, high dielectric strength, flexibility, and biocompatibility [2].

Results and Discussion

The used LAPS chips have a layered structure consisting of 200 µm of n-Si, 50 nm of SiO_2, and 50 nm of Si_3N_4. An approximately 40-nm-thick parylene insulating layer (diX-SR) was deposited using a CVD process. The ISM (PVC matrix with valinomycin) was precisely patterned using a printing process (Fig. 1). Ion responsiveness was evaluated by measuring KCl solutions of known concentrations, as shown in Fig. 2. Additionally, ISM performance was measured on unmodified Si_3N_4 and octadecyltrichlorosilane (OTS)-modified Si_3N_4 surfaces. The device with parylene passivation showed the best performance among the tested configurations.

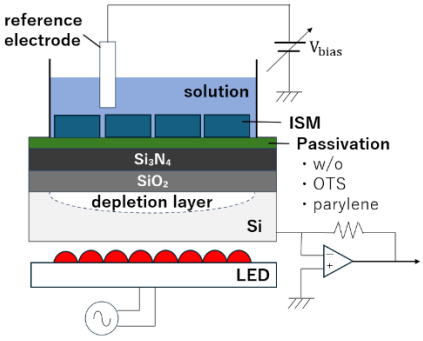

Figure 1: *LAPS device structure with ISM.*

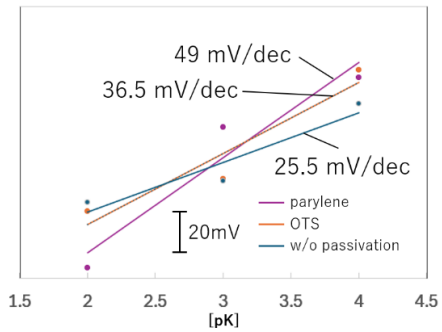

Figure 2: *K^+-sensitivity depending on different passivation types.*

Conclusions

The sensitivity of a potassium-sensitive ISM with different passivation layers (none, OTS, or parylene) was observed. Parylene passivation significantly improved the sensitivity of the ISM on the LAPS. As an organic insulator, parylene shows better adhesion to the PVC membrane, and the missing hydroxyl groups suppress pH cross-sensitivity. The properties of parylene also suggest its use as a promising insulating material for advanced and flexible ion-sensing applications on LAPS.

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Role of impurities on the interfacial stability of iron scales in CO_2 pipelines

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Abstract: We construct a stability diagram to evaluate the interfacial chemistry of iron scales under varied CO_2 stream conditions. Using equilibrium thermodynamics, we examine transitions between key corrosion products: $FeCO_3$, Fe_2O_3, Fe_3O_4, FeOOH, FeS, $FeSO_4$, and $Fe_2(SO_4)_3$. The stability diagrams help identify situations where protective iron compounds can form. In contact with dry CO_2 stream, Fe_3O_4, Fe_2O_3 and $FeCO_3$ can form protective layers. In contrast, under more oxidizing or humid conditions and in the presence of sulfur, the interface favours FeS, $FeSO_4$, $Fe_2(SO_4)_3$, FeOOH.

Keywords: Carbon capture and storage, CO_2 stream, stability diagrams, iron scales

Introduction

Pipeline corrosion is a critical challenge in Carbon Capture and Storage (CCS) hub projects. Corrosion occurs at the dynamic interface between the steel surface and the multicomponent fluid stream, which contains reactive impurities such as H_2S, SO_x, water and oxygen. These species control the reactions at the interface, altering surface chemistry and promoting the formation or degradation of protective layers [1].

Results and Discussion

The equistability boundaries in the stability diagrams (lg[O_2] vs lg[H_2O]) separate regions where different chemical species are stable [2], and crossing a boundary corresponds to a chemical transformation (e.g., corrosion). For example, for the conversion Fe + CO_2 + ½ O_2 ⇄ $FeCO_3$, the coexistence of Fe and $FeCO_3$ is possible when

$$\tfrac{1}{2}\lg O_2 = -\lg K_{Fe/FeCO3} - \lg[CO_2]. \quad (1)$$

This corresponds to a horizontal line in Fig. 1a. The diagrams predict the composition of the top surface of carbon steel when it is exposed to impurities in the CO_2 stream (water, oxygen, sulfur-containing species) as Fig. 1a&b.

Conclusions

Each stability diagram provides predictive knowledge for field engineers overseeing infrastructure exposed to mixed gas conditions. We can predict the chemistry of the reactive stream and the surface of steel in contact with it. Conditions where corrosion occurs are identified, together with the corrosion products.

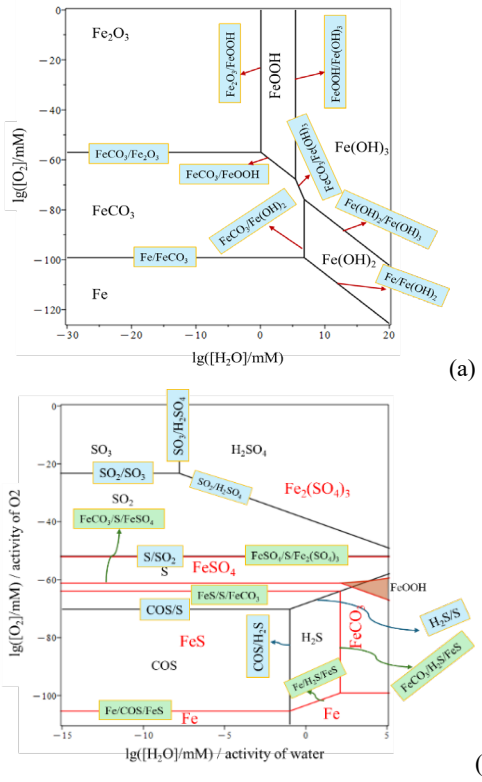

Figure 1: *Stability diagrams: (a) iron scales in the presence of CO_2 and water, and (b) combined diagram for sulfur compounds and iron scales in the presence of sulfur impurities and CO_2+humid. The sulfur impurities are also equilibrated.*

References

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