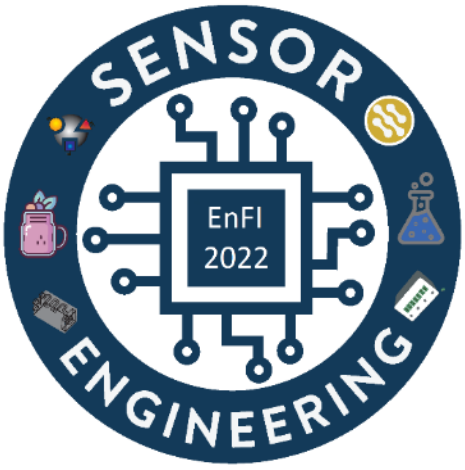

Book of Abstracts

13th International workshop on Engineering of Functional Interfaces

Maastricht, July 5-6. 2022

https://www.maastrichtuniversity.nl/events/engineering-functional-interfaces-2022

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Welcome to EnFI 2022

Dear colleagues and friends,

Welcome and thank you for joining the 13th edition of the international workshop series “Engineering of Functional Interfaces (EnFI) – 2022”. On behalf of the Organizing Committee and the Scientific Advisory Board, it is our pleasure to finally invite you to the Netherlands.

After two years of pandemic-related restrictions and postponing, Maastricht University is proud to organize the first Dutch edition of EnFI and we look forward to meeting you at the lovely castle Vaeshartelt in our hometown Maastricht. We hope you enjoy the international setting of the City, which is a reflection of Maastricht University, the most international university in the Netherlands. The university is considered to be one of the best young universities in the world and is therefore an excellent partner of the EnFI conference series that supports the development of new research talent.

An example of this, lays in the fact that we will once again adhere to the unique format that has characterized and made EnFI special from the very start. International top researchers will introduce four different topical sessions by means of keynote lectures. In these topical sessions, all PhDs and postdocs will have the opportunity to contribute a short three-minute oral presentation. This presentation will serve as an appetizer for a more in-depth poster presentation at the accompanying poster market. Young researchers will also have the opportunity to publish their results in the Topical Section on “Engineering of Functional Interfaces” in the journal *Physica Status Solidi A.* All manuscript will be peer reviewed by international experts and final journal publications are indexed as original articles in Web-of-Science. This ensures that research results presented at EnFI will be broadly visible and accessible.

As Sensor Engineering research department, we will obviously dedicate a session to our field of research, which exemplifies that EnFI places the concept of functional interface engineering in a very broad perspective. Research topics vary from very fundamental studies on understanding the physical or chemical principles of engineered surfaces to more applied research topics focused on developing novel nanoscale technology or integrating these engineered interfaces into high-tech applications. The multidisciplinary nature of these specific research topics has made EnFI into a scientific meeting where chemists, physicists, biomedical scientists, pharmacists, and engineers discuss the latest trends in material science and engineering. This year, we will continue to stimulate these cross-border collaborations through an informal barbecue in the evening of the first day of the conference on Tuesday (July 6).

In this abstract booklet, we will offer you all the practical information you require to attend the conference including: the scientific schedule, an overview of each topical session (sequence and abstract numbers), the abstracts in full detail, and the contact details of the corresponding authors.

We hope that you enjoy the conference!

Hanne Diliën & Kasper Eersels

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Practical information

Oral Presentations

The oral presentations have to be presented by means of a Powerpoint presentation that is **strictly limited to 3 minutes**. We will inforce this time limit as we have a very tight schedule (see time Table in next section).

Double-check the overview of abstracts in each topical section in this booklet. Before the start of each topical session, there are EnFI organizing team members present in the conference hall that will help you to put your presentation on the computer used for presenting. Find out beforehand in which section you have to present and bring your presentation on a Flash drive **10-30 minutes** before the start of the topical section (so before the keynote).

Poster presentation

Poster boards will be ready for you in the poster market (location indicated at the venue) and will be labeled with a session code and poster number (i.e. A12). Please check the schedule of each topical session beforehand and remember your unique code. SE group members will be present to help you.

WIFI

Wi-Fi is available at the location upon depend at the front desk of the hotel.

Scientific Programme

Day 1 - Tuesday July 5, 2022

8.00 – 9.15: Registration

9.15 – 9.30: **Welcome: Prof. Dr. Pamela Habibovic**, Rector Magnificus Maastricht University

Session A: Sensors and Actuators

9.30 – 10.15: **Keynote Lecture: Prof. Dr. Peter Lieberzeit**, Universität Wien, Austria

10.15 – 11.45: Short oral presentations

11.45 – 12.30: Poster market A with coffee

12.30 – 13.30: Lunch Break

Session B: Nanotechnology and Surface Characterization

13.30 – 14.15: **Keynote lecture: Prof. Dr. Patricia Losada-Pérez,** UL de Bruxelles, Belgium

14.15 – 15.45: Short oral presentations

15.45 – 16.30: Poster market B with coffee

Intermezzo: Interreg session on public-private collaborations

16.30 – 17.00: **Tutorial lecture Robotics: Dr. Glenn Mathijssen**, VUB and Alberts NV, Belgium

17.00 – 17.15: Group picture

17.15 – 18.00: **Smoothie vending machine demo:** Alberts NV

17.30 – 18.00: **Meet the Editors** – Interactive Q&A session on how to submit to Elsevier's Sensors and Actuators B: Chemical and Physics in Medicine – **Prof. Dr. Patrick Wagner and Prof. Dr. Peter Lieberzeit**

18.30 – 21.30: Conference Dinner: Barbecue

Day 2: Wednesday July 6, 2022

Session C: Smart Devices and Instrumentation

09.00 – 09.45: **Keynote lecture: Prof. Dr. Hans-Joachim Krause**, FHAachen Jülich, Germany

09.45 – 11.15: Short oral presentations

11.15 – 12.00: Poster market C with coffee

12.00 – 13.00: Lunch

Session D: Surface Chemistry and Electrochemistry

13.00 – 13.45: **Keynote Lecture: Prof. Dr. Frank-Michael Matysik**, Universität Regensburg, Germany

13.45 – 15.15: Short oral presentations

15.15 – 16.00: Poster market D with coffee

16.00 – 16.30: Jury session

16.30 – 17.00: Closing session – Poster awards, closing ceremony and announcement EnFI 2023

Topical Session A: Sensors and Actuators – Schedule

Keynote Lecture 1: Molecularly Imprinted Polymer Thin Films: From Empirical to Systematic Understanding - Prof. Dr. Peter Lieberzeit (Universität Wien, Austria)

Short Oral Presentations

A1 – Felix Thier – The role of analyte alterations in mass-sensitive sensing of living cells: a case study…

A2 – Aidin Nikookhesal – Chemistry-oriented engineering of 2D interfaces based on graphene…

A3 – Manlio Caldara – Thermal Detection of Glucose in Urine Using a Molecularly Imprinted Polymer…

A4 – Jake McClements – Molecularly Imprinted Polymer Nanoparticles Enable Rapid, Reliable…

A5 – Ko-Ichiro Miyamoto – Visualization of pH distribution in a vertical cross section of plant rhizosphere…

A6 – Carl F. Werner – LAPS-based multi measurement cell array sensor

A7 – Tobias Karschluck – Multiplexer platform for automated capacitive field-effect sensor charac…

A8 – Juul Goossens – Development of a Portable Optical Sensor for the Evaluation of MIP Dye…

A9 – Adrian Onken – Franck-Hertz revisited. Gas sensing with the potential of gas identification.

A10 – Fatemeh Ahmadi Tabar – Thermarl detection of PFOA in river water employing a molecularly…

A11 – Daniele Storelli – PEDOT:PSS sensor interface with peptide constructs for detection of an…

A12 – Margaux Frigoli – Indirect Detection of Pseudomonas Aeruginosa Using MIPs

A13 – Dua Özsoylu – Development of a sensor platform for the detection of pathogenic bacteria in…

A14 – Mehran Khorshid – A MIP-based impedimetric biosensor for the medical monitoring of…

A15 – Michelle Brandao Silva de Assis – Development of a miniaturized electrochemical sensor…

A16 – Janek Weispflog – Signal enhancement for voltammetric detection of heavy metal ions

A17 – Hu Peng – Inket-printed 3D microelectrode arrays for amperometric nanoparticle…

A18 – Rocio Arreguin Campos – Imprinted polydimethylsiloxane-Graphene Oxide Composite…

A19 – Rachel Jacques – High-sensitivity LAPS imaging of cardiomyocyte action potentials

A20 – Melanie Welden – Quality control in beer and wine: detection of acetoin and diacetyl…

Poster market with coffee

Molecularly Imprinted Polymer Thin Films: From Empirical to Systematic Understanding

Peter Lieberzeit[1], Mahdieh Bagheri[1,2], Shahin Haghdoust[1,2], Martin Werner[1,2], Birgit Bräuer[1,2], Christine Unger[1], Monika Marjanovic[1]

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Abstract: Surface imprinted polymers have proven a powerful tool in synthesizing recognition materials for nano- to micro-sized particles. For instance, both stamp-imprinted layers and matrices polymerized *in situ* lead to appreciable sensor responses for engineered nanoparticles, but also biospecies. However, limited batch-to-batch reproducibility has led to systematic microscopy studies. They lead both to in-depth understanding of the binding behaviour and to first independent evidence of the imprinting process altering the surface chemistry of polymers.

Keywords: Surface-imprinted polymers, Nanoparticles, Biospecies, Sensing, Raman microscopy, AFM.

Introduction

Surface molecular imprinting has become a standard technique to generate biomimetic recognition for binding micro-organisms and biospecies such as bacteria [1]. Despite many sensor applications reported in the literature, the processes occurring on the surface are still not full understood.

Results and Discussion

Engineered nanoparticles are interesting targets, both as analytes and for better understanding the details of binding. Two imprinting strategies, namely stamp imprinting and in-situ polymerization [2] lead to the desired sensor responses, for metal (Ag, Au) and magnetite nanoparticles (MNPs), respectively. The selectivity patterns of MNPs-PVP sensor (Figure 1) indicate influence of core material, shell, and – of course – nanoparticle diameter.

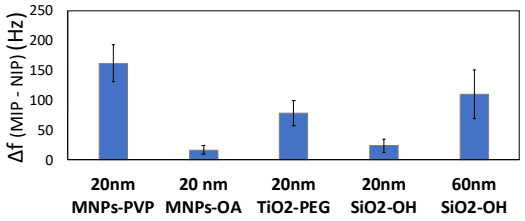

Figure 1: *Summary of selectivity pattern of MNPs-PVP sensor at c=3e[15] n/L of NPs against mentioned competitors.*

For bioanalytes, the picture is less clear: differences between MIP and NIP seem smaller, in the same way as rebinding effects overall. Light microscopy and AFM reveal that the binding affinity of the imprinted thin films strongly depends on the inherent affinity of the respective polymer [3]. Also, rebinding seems difficult for analytes with large aspect ratios, e.g. the tobacco mosaic virus (TMV).

These finding clearly show that it necessary to gain better understanding on MIP properties and the processes going on on the surface. Both peak-force quantitative nanomechanics (PF-QNM) measurements in AFM and Raman microscopy serve that purpose [3]. There combination reveals the following three key findings: (1) Bacteria are completely removed from the surface, i.e. one can rule out surface contamination by residues of the cell wall. (2) It is possible to distinguish different bacteria species on polymer surfaces by Raman microscopy. (3) If the polymer contains functional groups, imprints resulting from different bacteria species lead to different surface properties on the polymer. It is possible to distinguish both of them from the pure polymer surfaces.

Conclusions

It becomes evident that understanding the physicochemical properties of MIP surfaces is key to further optimizing them. Not least, this is important for them to deliver on the promise of providing good-value, robust recognition layers that are inherently suitable to replace natural antibodies.

References

[1] Unger, C.; Lieberzeit, P. A. *React. Funct. Polym* **2021**, doi:10.1021/acsabm.1c01020.

[2] Leibl, N.; Haupt, K.; Gonzato, C.; Duma, L. *Chemosensors* **2021**, doi:10.3390/chemosensors9060123.

[3] Werner, M.; Glück, M. S.; Bräuer, J.; Bismarck, A.; Lieberzeit, P. A. *Soft Matter* **2022**. doi:10.1039/D2SM00137C.

Acknowledgements

Part of the work presented herein has been funded by the Austrian Science Fund (FWF), contract no. I3568-N28.

A1 - The role of analyte alterations in mass-sensitive sensing of living cells: a case study using human thrombocytes

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[1]Department of Physical Chemistry, Faculty of Chemistry, University of Vienna, Währinger Straße 42, 1090 Vienna, Austria

Abstract: In this study, quartz crystal microbalances (QCMs) in combination with thin-film molecularly imprinted polymers (MIPs) provide the sensing setup to investigate the influence of analyte properties in cell-sensing, using human thrombocytes as model analytes. We have shown that analyte alterations due to storage strongly affect binding behaviour to MIP and QCM surfaces and thereby sensor responses.

Keywords: biosensing, analyte alterations, thrombocytes, QCM, MIP.

Introduction

Surface modification of QCM gold electrodes is the key technique in creating selectivity towards the respective analyte. Molecularly imprinted polymers (MIPs) are a prominent example of introducing selectivity to the sensing system. Biological analytes of interest range from proteins to whole cells [1]. The stability and robustness of the synthetic biomimetic materials play a major role in the versatile setting of biosensing [2]. The biological analyte itself, however, is still prone to alterations affecting measurement results: Living cells (i.e. thrombocytes) will change their properties depending on storage time and parameters. This work highlights the effects of analyte adulteration on sensing outcome using blank QCMs and QCMs coated with MIPs.

Results and Discussion

Co-polymers of styrene, 2-hydroxyethyl methacrylate (HEMA) and ethylene glycol dimethacrylate (EGDMA) provide good imprinting quality (Figure 1) while not significantly diminishing biocompatibility. Figure 2 depicts the influence of thrombocyte storage time on blank QCM sensor response signal, allowing conclusions on thrombocyte viability and their binding behaviour.

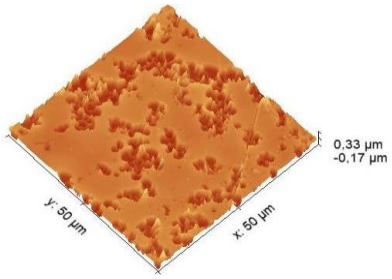

Figure 1: *Thrombocyte-imprinted poly(styrene-co-HEMA-co-EGDMA) layer. Imprint dimensions match resting thrombocyte size and shape.*

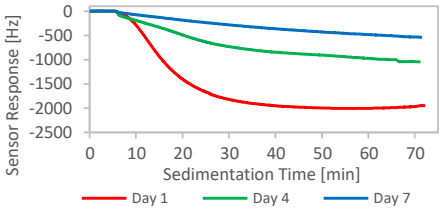

Figure 2: *Influence of thrombocyte storage time on blank QCM sensor response. Measurement results indicate a 4-fold decrease in signal extent upon injection of 10^5cells/µL in PBS after 7 days of storage.*

Results in Figure 2 show that there is a direct link between sensor response and thrombocyte viability, as dead cells lack the ability to aggregate and thereby firmly bind to the QCM surface.

Conclusions

The observed results show that imprints alone will not yet lead to selective rebinding, as analyte alterations play a major role in the respective sensing outcome. This needs to be taken into consideration when designing novel materials for sensing of biospecies. However, selectivity governed by the MIP together with viability measurements may allow the fabrication of a sensing device for observing the status of thrombocyte concentrates.

References

[1] B. Bräuer, C. Unger, M. Werner, P. A. Lieberzeit, *Sensors* **2021**, *21*, 16

[2] Y. Saylan, Ö. Erdem, F. Inci, A. Denizli, *Biomimetics* **2020**, *5*, 20

Acknowledgements

This project is funded by the University of Vienna and supported by the Austrian Red Cross, which we gratefully acknowledge.

A2 - Chemistry-oriented engineering of 2D interfaces based on graphene for electronics and biomedical applications

Aidin Nikookhesal [1], Phillip Nickl [2], Sven Ingebrandt [1], Mohsen Adeli [2,3,4], Vivek Pachauri [1]

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Abstract: Graphene oxide (GO)-based interfaces, despite their disadvantages of lattice defects and low charge-carrier mobilities, are highly interesting for electronics and biomedical applications. In this work, a chemistry-oriented approach is used concomitantly towards improvment of GO interfaces for covalent interactions and its usage as an electrical transducer for biomedical applications. This improvement was achieved by the covalent functionalization of GO thin films with triazine. A one-pot method for reproducible functionalization of GO layers by a nitrene [2+1] in a controlled and gram-accurate cycloaddition reaction under mild conditions is demonstrated.

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

Introduction

Graphene oxide as a transducer is suitable for a wide range of biomedical applications, usually carried out by its conjugation with biomolecules, organic polymers, and other nanomaterials (particles, quantum dots etc.). In the development of GO-based electrochemical biosensors, a persistant issue is the formaton of lattice-defects and their adverse influence on the electrical and electrochemical properties of the device platforms fabricated [1]. Generally, lattice-defects are aggravated further during the chemical modification of the atomically thin graphene layers. Use of the nitrene [2+1] cycloaddition reaction has been shown to be an advantageous route for the conjugating of functional moieties to graphene in bulk [2]. In this work, we explore the use of nitrene [2+1] chemistry for thin film realizations and esuing device platforms with improved material charcateristics for technology applications, especially in nanoeletcronics.

Results and Discussion

First, the Si/SiO_2 wafers were silanized using APTES based on a gas phase silanization technique. Then, a GO stock solution was prepared in NMP. According to the protocol, 2,4,6-Trichloro-1,3,5-triazine (TCT) and sodium azide (NaN_3) were added to GO solution to carry out cycloaddition of triazine groups with GO layers to form GO-Trz conjugates followed with an aqueous and aceton wash to remove the residual salts. For the self-assembly thin film formation, GO-Trz solution was placed in a glass crystallization dish and the Si/SiO_2 wafer immersed in it for 24 hours at 60^0 C.

To ensure that the functionalization of GO with triazine was successful (Figure 1). GO-Trz thin films were characterized using SEM, AFM, and Raman to ensure the homogeneity and thicknesses.

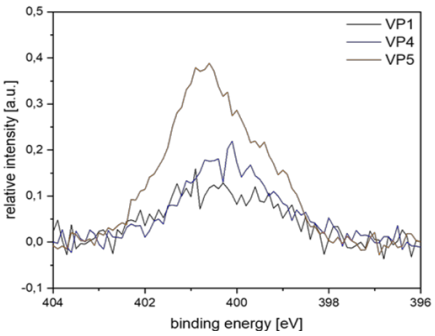

***Figure 1**. High resolution N1s XPS spectra of three differently prepared GO-Trz samples. All binding energies are in the range of nitrogen atoms with sp2 hybridization.*

Conclusions

A chemically mild and straightforward route for the controlled covalent functionalization of GO by *in situ* nitrene cycloaddition was demonstrated with promising outcomes for the realization of GO-Trz films on wafer. It was shown that highly homogeneous graphene-based thin films can be obtained for overall system integration of high quality 2D interfaecs.

References

[1] A. Zhang and C. M. Lieber, *Chem. Rev.*, 116, 1, 215-257, 2016.

[2] A. Setaro et al., *Nat. Commun.*, 8, 1–7, 2017.

Acknowledgements

We acknowledge Hans Hermann Voss-Stiftung and Exploratory Research Space project Pep2D from RWTH Aachen University for their generous support.

A3 - Thermal Detection of Glucose in Urine Using a Molecularly Imprinted Polymer as a Recognition Element

Manlio Caldara[1], Joseph W. Lowdon[1], Thomas J. Cleij[1], Hanne Diliën[1], Kasper Eersels[1], Bart van Grinsven[1]

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[1]Sensor Engineering Department, Faculty of Science and Engineering, Maastricht University, 6200 MD Maastricht, The Netherlands

Abstract: Molecularly imprinted polymers (MIPs) able to detect glucose in a specific manner could offer an alternative to a field dominated by enzyme-based devices. In this work, a dummy imprinted polymer is prepared toward the sensing of glucose. In essence, the MIP particles were integrated into an adhesive layer by micro-contact deposition. The layer is then evaluated with the so-called heat-transfer method, allowing the determination of the specificity, sensitivity and selectivity of the receptor layer. Finally, a potential application of the sensor in terms of non-invasive glucose monitoring was demonstrated by exposing the receptor layer to increasing glucose concentrations in human urine samples.

Keywords: molecularly imprinted polymers, glucose sensing, heat-transfer method, non-invasive glucose monitoring, non-enzymatic glucose sensor.

Introduction

Currently, commercial devices for glucose sensing are mostly enzymatic-based sensors, which have low enzymatic stability. An emerging technology that offers promise to overcome this issue is the use of molecularly imprinted polymers (MIPs) in sensory arrays. MIPs are synthetic polymer-based materials capable of selectively binding a target. Since electrochemical reactions are absent in a MIP based sensory platform, it is therefore a logical step to pair the synthetic receptor with a more compatible readout technology, like the so-called "heat transfer method" (HTM). In essence, the method is capable of measuring the thermal resistance across a liquid-solid phase boundary[1], with MIPs being the receptor layer in between the two.

Results and Discussion

The best rebinding efficiency was obtained with an acrylamide-based MIP using glucuronic acid as dummy template.

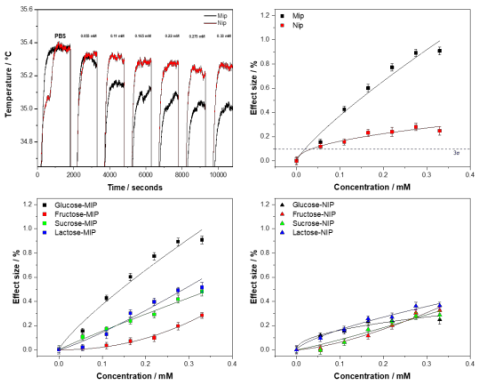

Figure 1: HTM rebinding and selectivity analysis in PBS solutions.

The MIP particles were integrated into a thermally active layer which was used for the determination of sensitivity and selectivity in PBS solutions using the HTM method (**Figure 1**). Finally, the thermal response of the prepared layer was analysed after infusions with increasing glucose concentrations in human urine samples (**Figure 2**).

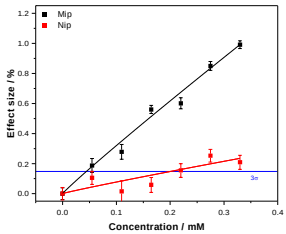

Figure 2: HTM analysis in human urine samples.

Conclusions

The combination of a low-cost detection platform with a straightforward, easily scalable production process, leading to a disposable glucose sensor that is competitive to state-of-the-art sensor platforms, makes these findings very interesting in terms of commercial applications and follow-up research to further optimize the sensor and integrate it into a handheld or wearable device. The results demonstrate that the sensor might offer a non-invasive, low-cost alternative to traditional devices.

References

[1] Van Grinsven, B.; Eersels, K. et al. *ACS Applied Materials and Interfaces* **2014**, *6* (16), 13309–13318. https://doi.org/10.1021/am503667s.

Acknowledgements

This work was supported by the European Regional Development Fund through the Saber Print project, funded by the Interreg VA Deutschland-Nederland program, grant number 144277.

A4 - Molecularly Imprinted Polymer Nanoparticles Enable Rapid, Reliable, and Robust Thermal Detection of Emerging Pathogens

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[2] Physics Department, Université Libré de Bruxelles, Boulevard du Triomphe CP223, 1050 Brussels, Belgium.
[3] MIP Diagnostics Ltd., Colworth Park, Sharnbrook, MK44 1LQ, Bedford, UK.

Abstract: Molecularly imprinted polymer nanoparticles are developed to act as synthetic antibodies for the detection of COVID-19. The synthetic receptors are far more robust than antibodies, resulting in longer shelf-life and possible measurements in diagnostically challenging environments (*e.g.*, salvia, wastewater). Thermal measurements demonstrate that the sensor's detection limit was 6000-times lower than commercial lateral flow tests and the sensor could accurately detect COVID-19 in clinical patient samples.

Keywords: biosensors, COVID-19, diagnostic testing, molecularly imprinted polymer nanoparticles (nanoMIPs).

Introduction

Rapid antigen tests are commonly used for COVID-19 population screening. However, they lack sensitivity and have antibody receptors, which can only function in narrow temperature/pH ranges due to their low robustness.[1] Consequently, molecularly imprinted polymer nanoparticles (nanoMIPs) were synthesized as a robust alternative to traditional biomaterial receptors.

Results and Discussion

The nanoMIP production process was fast (2 h), scalable, and only used a tiny SARS-CoV-2 fragment (~10 amino acids). The developed nanoMIPs rivalled the affinity of SARS-CoV-2 antibodies under standard testing conditions and surpassed them at elevated temperatures or in acidic media. Therefore, nanoMIP sensors possess clear advantages over antibody-based assays as they can function in a range of challenging media and have the potential for longer shelf-life.

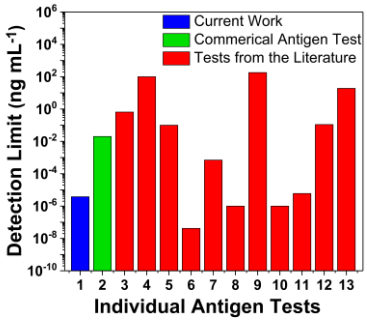

Figure 1: *Comparing detection limit values for our nanoMIP sensor to a commercial rapid antigen test and recent antigen tests from the literature.*

A thermal assay is developed that uses nanoMIPs electrografted onto screen-printed electrodes to quantify SARS-CoV-2 antigens. Heat-transfer based measurements demonstrated superior detection limits compared to commercial rapid antigen tests and most antigen tests from the literature for several variants of the spike protein (***Figure 1***). A prototype thermal assay is also developed which can rapidly (~15 mins) validate clinical patient samples with excellent sensitivity and specificity (***Figure 2***).

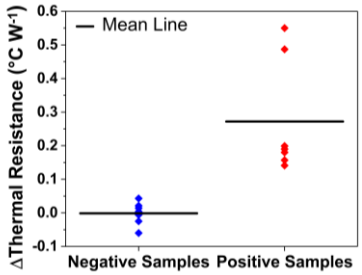

Figure 2: *NanoMIP sensor's response to samples from COVID-positive and negative patients.*

Conclusions

The straightforward epitope imprinting method and high robustness of nanoMIPs produces a SARS-CoV-2 sensor with significant commercial potential for population screening, as well as possible measurements in diagnostically challenging environments. NanoMIP technology can also be applied to almost any target of interest including bacteria, toxins, biomarkers, and other emerging pathogens.

References

[1] Iacobucci, G. *BMJ* **2021**, doi:10.1136/bmj.n1483

Acknowledgements

The authors acknowledge funding and support from Newcastle University, the Rosetrees Trust, the Wellcome Trust, and the Fonds de la Recherche Scientifique.

A5 - Visualization of pH distribution in a vertical cross section of plant rhizosphere by a chemical imaging sensor

Ko-ichiro Miyamoto[1*], Daisuke Sato[1], Carl Frederik Werner[2] and Tatsuo Yoshinobu[1,3]

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[3]Department of Biomedical Engineering, Tohoku University, Sendai, Japan

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Abstract: A chemical imaging sensor is a semiconductor-based chemical sensor which can visualize pH distribution label-free. In this study, a modified chemical imaging system was proposed to observe the pH distribution in a vertical cross section of plant rhizosphere. Lowering of the local pH in the course of the growth of a plant root was observed by comparing the optical images and the pH images.

Keywords: chemical imaging sensor, plant root, rhizosphere, metabolic activity.

Introduction

The monitoring of plant health is a key to 'smart agriculture'. However, the measurement of the metabolic activity of a root under the soil can be a challenge. We previously reported on visualization of pH change around a root horizontally growing in a thin agarose plate [1] using a chemical imaging sensor [2]. In this study, we implemented a modified measurement system to observe the metabolic activity of a root growing in the vertical direction.

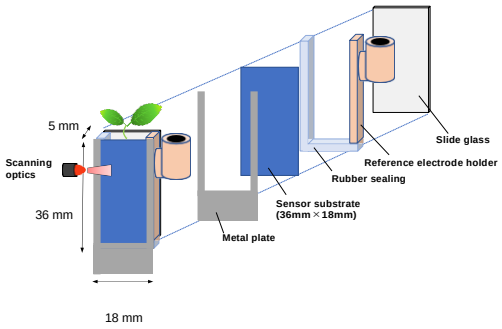

Figure 1: *The modified chemical imaging sensor system for visualization of the rhizosphere pH.*

Experiment

Figure 1 shows a schematic view of the measurement system in this study. The differences from the conventional setup of a chemical imaging sensor system are as follows: (1) The sensor substrate and scanning optics are vertically emplaced. (2) A cultivation cell filled with transparent agar gel with a thickness of 5 mm was mounted on the sensor surface. (3) A camera module was installed to observe the root optically. A radish seed was seeded on the agar gel, and both optical and pH images were collected every one hour.

Results and Discussion

Figure 2 shows the growth of the radish root and photocurrent distribution. The lowering of the photo-current indicates the lowering of the pH value. Figiure 2b shows therefore that the pH in the rhizosphere decreased during the growth of the root, as a result of the metabolic activity of the radish.

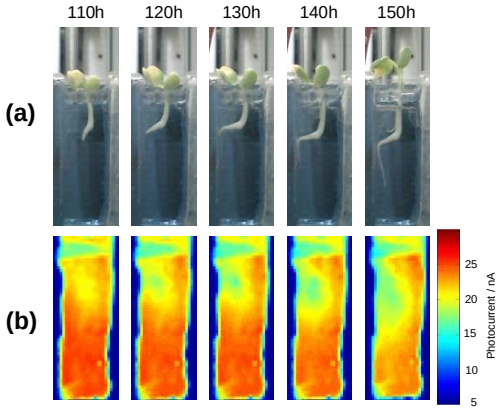

Figure 2: *(a) Optical images of the growth of the root. (b) Rhizosphere pH distribution obtained by the modified chemical imaging sensor.*

Conclusions

In this study, we proposed a modified measurement system to observe both the shape of the root and the rhizosphere pH value. The local pH value was lowered accompanying the growth of the root. The measurement system can be a powerful tool to monitor the metabolic activity of the plant root.

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A6 - LAPS-based multi measurement cell array sensor

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Abstract: A light-addressable potentiometric sensor (LAPS) is a semiconductor-based (bio)chemical imaging sensor. It can observe analyte concentrations in aqueous solutions in a spatially and temporally resolved manner. In this study, a real-time LAPS setup with 8x8 measurement spots is combined with a microfluidic structure in order to realize a multi analyte sensor with 16 measurement cells. The system is optimized to only use one common reference electrode but avoid cross-talk between the measurement cells.

Keywords: Light-addressable potentiometric sensor, LAPS, multi analyte, real-time, biosensor

Introduction

A LAPS is a semiconductor-based potentiometric sensor [1]. Its main advantage is its addressability, which enables chemical imaging and thus spatially and time-resolved observation of analyte concentrations in aqueous solutions. The lateral resolution of LAPS is realized by one or more light sources, while the LAPS chip is laterally unstructured. This makes LAPS an ideal candidate for the combination with microfluidics [2]. In this study, 16 individual measurement cells are integrated on a recently developed 8x8 real-time LAPS set-up which allows 30 fps with a delay under 100 µs. Having individual measurement cells on one LAPS chip requires a strategy of placing the reference electrode in order to allow a good signal-to-noise ratio, to have a wide measurement range in each measurement cell, to avoid electrochemical reactions between the cells and to avoid crosstalk. For the demonstrated multi analyte system, we placed a common reference electrode in the downstream and individual wire electrodes in each measurement cell.

Results and Discussion

The individual measurement cells are made of PDMS molded from a 3d printed mold. They have a volume of about 15 µl, a separate inlet and outlet and a wire electrode. Each measurement cell consists of 4 LAPS measurement spots. LAPS as potentiometric sensor, requires a reference electrode, that is placed in the common downstream of the measurement cells. However, the high electrical resistance introduced by the relatively small and long tubes between LAPS chip and reference electrode is insufficient for the LAPS photocurrent and lead to crosstalk [3]. Therefore, wire electrodes to collect the ac photocurrent are integrated inside each measurement cell. To avoid electrochemical reactions inside and between the measurement cells, they are capacitively coupled to the measurement circuit.

Figure 1 shows the normalized photocurrent of two measurement cells, one always filled with pH7 and one changed from pH 7 to pH4 and back to pH 7.

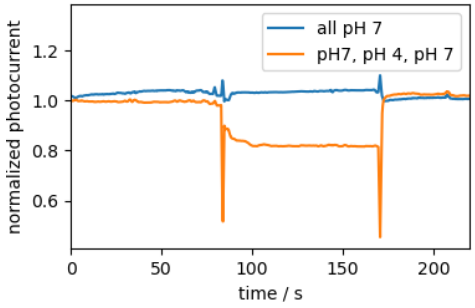

Figure 1: *Normalized photocurrent of two different measurement cells measured simultaneously. One cell was only filled with pH 7 (blue), while the pH solution of the other cell (orange) was changed (pH 7, pH 4, pH 7).*

Conclusions

A real-time LAPS with an 8x8 LED array was combined with a PDMS microfulidic with 4x4 individual measurement cells. A single reference electrode was used in the downstream of the microfluidic outlet. To improve crosstalk and the signal-to-noise ratio, all measurement cells contain a wire electrode connected to bypass capacitors.

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Acknowledgements

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A7 - Multiplexer platform for automated capacitive field-effect sensor characterization

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Abstract: A multiplexer platform for an automated characterization of capacitive field-effect sensors by means of the capacitive-voltage ($C-V$) and the constant-capacitance (ConCap) mode is presented. Therewith, 16 sensors can be operated simultaneously. The sensors are mounted in a multi-cell arrangement and electrically connected to the impedance analyzer Zahner IM6ex by the base station. A Python script for the automated characterization of the sensors executes the user-defined measurement protocol.

Keywords: capacitive field-effect sensors, multiplexer, pH sensing, automation, Python, multi-cell.

Introduction

The capacitive electrolyte-insulator-semiconductor field-effect sensor (EISCAP) is a well-studied platform as chemical sensor for pH sensing [1] and as biosensor, by addition of receptor layers consisting of e.g., enzymes or antibodies [2]. Typically, the electrochemical characterization of EISCAPs is performed manually with only one individual sensor mounted in a single measurement cell. A multiplexed set-up would offer a higher throughput and reduced assay time while ensuring comparable testing conditions for all mounted sensors. Figure 1 shows our developed multiplexer platform, which can be directly connected to the R-MUX card of a Zahner IM6ex device via a D-Sub cable.

Results and Discussion

We improved our prototype multiplexer platform [3] by adjusting the multi-cell design to be more user-friendly and by addition of a base station. A new "quasi-parallel" constant-capacitance (ConCap) mode was added to our Python script, which relies on the GitHub repository from the manufacturer [4] for communication between Python (V. 3.9.7) and the ThalesUSB software (V. 5.8). The quasi-parallel ConCap mode allows to measure all 16 channels with a minimal time delay between each sensor.

The set-up was validated by the pH characterization of 16 Al/p-Si/SiO_2/Ta_2O_5 EISCAPs with the common measurement modes [3] in the quasi-parallel ConCap configuration. No difference in the typical sensor characteristics between sensors mounted in the single- or the multi-cell arrangement was found. Additionally, the quasi-parallel ConCap mode was tested by immobilizing nanoparticles and detecting them by their intrinsic molecular charge.

Figure 1: *The multi-cell is mounted in a base station and fixed by the cover, which is used to press the rear-side contact of the sensors onto the spring-loaded contact pins.*

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Acknowledgements

Part of this work was funded by the Deutsche Forschungsgemeinschaft (DFG: German Research Foundation)– 445454801. The authors thank H. Iken and B. Schneider for technical support.

A8 - Development of a Portable Optical Sensor for the Evaluation of MIP Dye-Displacement Assays in the Context of Food Screening

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Abstract: This research aims to develop a portable optical biosensor for the quality assessment in food products. A flow cell, with the integration of Molecular Imprinted Polymer (MIP) technology, provides a colour displacement assay in the presence of the target molecule. A passive flow cell design based on capillary forces ensures the handling of the fluids. A built-in mini spectrometer analyses the colour intensity which relates to the presence of the target analyte. Depending on the MIP-manufacturing on different analytes, the sensor is versatile in the detection of different targets; the focus will be laid on food safety and traceability.

Keywords: MIP-based Biosensor, Portable, Optical, Food Screening

Introduction

Traceability and food screening are fundamental parts to ensure the quality, safety, and authenticity of the food we consume. However, the standard analytical methods are associated with some general challenges: high-cost, method portability, need for skilled personnel, can involve complex procedures, and may involve lengthy measurement steps. Therefore, within recent years, there has been an increase in the development of methods utilising handheld and portable devices. (*1*, *2*)

In this work, an optical biosensing device is developed using a Molecularly Imprinted Polymer (MIP)-based dye displacement assay. This assay comprises of dye-filled MIPs, which in presence of the target analyte, based on competitive MIP-binding, releases the dye into the solution. As a result, the colour-reaction indicates the presence of the target analyte. (*3*)

This research aims to develop a portable, easy-to-use, and fast sensing device for the on-site detection in liquid samples. Depending on the MIP-manufacturing on different analytes, the sensor is versatile in the detection of different targets.

Results and Discussion

In this study, a fluidic flow cell (Figure 1) was developed to easily perform the dye-displacement assay. A standardized MIP-containing filter can be set up, ensuring a generalized measuring setup. Liquid samples can be inserted via the inlet, which are automatically and passively flown towards the sample-colour measuring area. Capillary forces and wetting of paper are the main driver for the fluid flow.

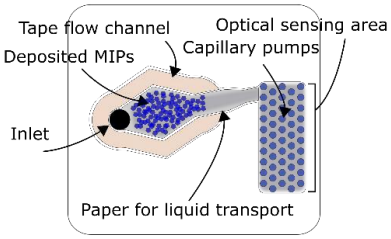

Figure 1: *Flow cell in which the liquid sample can be inserted to perform the dye-displacement assay.*

The flow cell can entirely be inserted into the newly developed optical measuring device. The sensing device comprises of a printed circuit board which regulates the built-in spectrophotometer (BO-HAMA-C12880-V2) and a LED. The device can be connected to a computer for data analysis.

Conclusions

This research demonstrates the use of an integrated MIP-based dye-displacement assay into a fluidic flow cell for the detection of a target analyte. The displaced dye is detected via an optical sensor, which is part of a portable measuring device.

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Acknowledgements

This work is supported and funded by Food Screening, which is carried out with a contribution from the European programme Interreg Euregio Maas-Rhine.

A9 - Franck-Hertz revisited. Gas sensing with the potential of gas identification

Adrian Onken [1], Achim W. Hassel[2], Simon Thies[1], Min-Hai Ngyuen[1], Robert Köhler[3], Kasimir M. Phillip[1], Julia Körner[4], Wolfgang Viöl[3], Theodor Doll[1]

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Abstract: Micro gas sensors detect the presence of substances, but cannot identify them. A novel approach of probing referenceable ionization energies may resolve this problem. It extends the photoionization principle towards tunable energies via replacement of photons by accelerated photo electrons. A voltage variation at the accelerator provides electrons of tunable energies which can be used for substance detection. The current limitations and challenges are discussed.

Keywords: Ionization energy, photoemissive materials, nano vacuum electronics, gas detection

Introduction

Sensors for detecting gases are widely used in our modern societies, whether integrated in complex control systems as the core of measuring devices or stand-alone signal transmitters. For signal generation, sensors use a variety of physical and physiochemical effects, often derived quantities, which therefore require precisely specified environmental conditions. In addition to mass spectrometry, a sensor principle that uses the ionization potentials of substances as a fundamental physical property for substance detection would be of interest. Such a hypothetical photoionization detector (PID) with tunable wavelength has been realized with 2-photon excitation in the Laser Ion Mobility Spectrometer. However, the setup is not transportable. We therefore present a miniaturizable concept using photoelectrons in air.

Results and Discussion

Photoelectrons were successfully generated using an emitter chip. 60% of electrons had an energy sharpness of 1eV over reaction and flight lengths of several millimetres. Measurements showed that the natural air components and hardly interact with the electrons of varying energies. However, when VOC admixtures are added, fluctuations occur in the measurement signal, which are probably due to the ionisation processes of the molecules of the added gas. The ionisation energies of such admixtures have not yet been fully described. Further research is required.

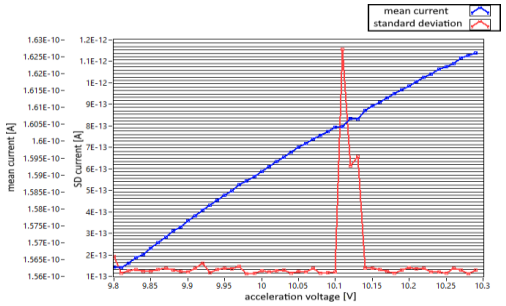

Figure 1: *Ionization current over time with acceleration voltage variation: At about 10.1 a distinct peak occurs in the standard deviation, which coincides with the ionisation energy of the added isopropanol (10.15eV 0.08)* [1]

Conclusions

There are about 3000 potentially interesting substances whose ionization energies lie in the range of 5 - 15 eV. Within the range of the resolution accuracy 43 substances can theoretically be considered as possible candidates for ionization energy identification per resolution unit. This fact needs further consideration and possibly the use of prior knowledge from an AI-referenced cloud.

References

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Acknowledgements

This research was funded by the state of Bavaria (Germany) through “Bayern Innovativ” contract no.2020-5430-DB-07.

A10 - Thermal detection of PFOA in river water employing a molecularly imprinted poly acrylamide as a receptor layer

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Abstract: Sensors based on molecularly imprinted polymers (MIPs) are emerging as cheap and fast alternatives to mass spectrometry method for detection of perfluorooctanoic acid (PFOA). In this study, we optimized a MIP bulk polymerization protocol for the selective rebinding of PFOA. These particles were then employed as the receptor layer for thermal analysis with heat transfer method (HTM). The results show that it is possible to create a PFOA MIP in a low-cost straightforward manner, which can be integrated into an equally cheap thermal readout method, to create a sensor for routine screening of aqueous solutions for the presence of PFOA.

Keywords: poly-fluoroalkyl substances, molecularly imprinted polymer, heat transfer method, perfluorooctanoic acid.

Introduction

PFOA is a member of the poly-fluoroalkyl substances (PFAS) and has been extensively used for decades in various products. These substances have the ability to bio-accumulate and are potentially carcinogenic and neurotoxic. Therefore, a sensing tool that could enable highly-sensitive, rapid, and cost-effective method for monitoring PFOA directly in the field, would be highly desirable [1]. Molecular imprinting is a well- established synthesis technique that can produce synthetic receptors [2]. MIPs could be combined with several transducer principles such as HTM to detect various molecules [3]. In this work, we demonstrate the use of HTM in a low-cost, MIP- based sensor for the detection of PFOA in aqueous solutions.

Results and Discussion

PFOA MIPs were created by bulk polymerization. The synthesis procedure was first optimized by carefully tweaking the ratio of template, monomer, and crosslinker in the pre-polymerization mixture. A non-imprinted polymer (NIP) was prepared in the exact same manner, but in the absence of the template molecule. These MIPs and NIPs were immobilized on an aluminum chip for thermal detection experiments. The time-dependent temperature profile of MIP and NIP to increasing PFOA concentrations in PBS is shown in Figure 1. The data clearly demonstrate that increasing the amount of PFOA for MIP will cause the temperature registered in the flow cell to decrease. Therefore, MIP is able to detect PFOA in regulatory relevant concentration regimes in controlled substances. In addition, a very first proof-of-application was also provided. To this extent, river water samples were collected, gently filtered and spiked with different concentrations of PFOA. The results of these experiments show that the sensor is capable of detecting PFOA within the regulatory limits in simulated environmental settings.

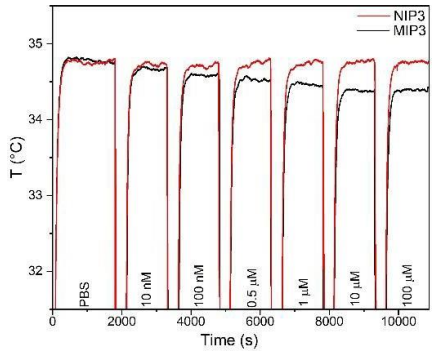

Figure 1: *Temperature response for both MIP and NIP after infusions with different concentrations of PFOA (10 nM−100 µM) in PBS.*

Conclusions

In this research, an optimized synthetic approach for making PFOA MIPs through free radical bulk polymerization was presented. The most specific MIP was chosen for thermal detection of PFOA, illustrating that it is possible to detect the target in low concentrations. The sensor is able to detect PFOA in real world samples which provides proof that MIP-based thermal sensing has the potential of offering a low-cost, fast sensor technology that allows to measure environmental samples for PFAS presence in real time.

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A11 - PEDOT:PSS sensor interface with peptide constructs for detection of an urokinase-type plasminogen activator as cancer biomarker

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Abstract: Cancer biomarkers play a crucial role in assessing different stages of tumor progression and subsequent treatment procedures. Urokinase-type plasminogen activator (uPA) has been identified as one of the potential biomarkers for cancer diagnosis due to its high relevance in tumor metastasis. Here, novel anchor peptides (AP) and cyclic peptide receptors (CPR) on PEDOT:PSS conductive polymers were utilized to detect uPA via surface plasmon resonance (SPR) and Organic Electrochemical Transistor (OECT) transduction methods.

Keywords: Cancer diagnosis, Urokinase-type plasminogen activator, Anchor peptides, Cyclic peptides, SPR, OECT.

Introduction

Proteolytic degradation of the extracellular matrix is one of the crucial steps for metastasis. Though several protease systems are implicated, it has been identified that the uPA and its receptors play a central role [1]. It has also been found that the uPA levels are upregulated in several types of cancer and that they are involved in tumorigenesis. In general, methodologies like enzyme-linked immunosorbent assay (ELISA) and immunohistochemistry are used to quantify uPA at the protein level and RT-PCR at the mRNA level [2]. However, the sophistication of the aforementioned technologies demands new sensor schemes. This study explores two different transduction mechanisms, surface plasmon resonance (SPR) and organic electrochemical transistor (OECT), to detect uPA. In both cases, self-assembled novel anchor peptides conjugated with uPA-specific receptors (cyclic peptide moieties) [3] on PEDOT:PSS conductive polymers are utilized to detect varying concentrations of uPA in buffer. Here we present our new results obtained on the design of this new scheme for biosensor realization where interactions of AP and AP-CPR constructs to PEDOT:PSS films and uPA biomarkers are studied using SPR and OECT platforms.

Results and Discussion

In both cases, the binding of bioreceptor-modified anchor peptides (BAP) to the sensor substrates coated with PEDOT:PSS are shown (**Figure. 1**). The SPR measurement shows an angle shift of about 1° upon binding of 30 µM BAP (flow rate: 100 µL/min). The angle shift is attributed to the effective refractive index change on the polymer film due to the binding of BAP. Similarly, the OECT measurement showed a measurable signal in the transfer characteristics of devices upon surface modification with BAP (1 µM, 30 µL). The change in transfer characteristics is attributed to the difference in charge density due to the adhesion of BAP to the PEDOT:PSS, within the vicinity of the electrical double layer at the solid-liquid interface.

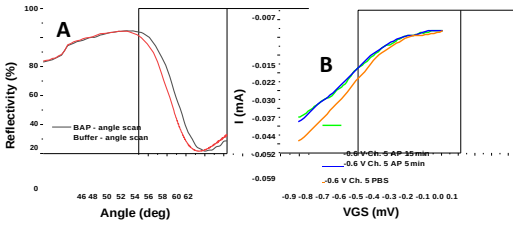

Figure 1: *Measurement results performed using (A) SPR and (B) OECT showing the binding of BAP to PEDOT:PSS film at the sensor platform.*

Conclusions

The AP-CPR strategy enables direct biologization of nanoscale transducers as opposed to multi-step chemical or physical modification strategies. This new strategy to circumvent harsh surface modification procedures for realization of biofunctional layers is expected to result in advanced biosensor designs, to be demonstrated here with an example of uPA bioassay.

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Acknowledgements

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A12- Indirect Detection of Pseudomonas Aeruginosa using Molecularly Imprinted Polymers

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Abstract: *Pseudomonas Aeruginosa* is an opportunistic ubiquitous bacterium commonly found in soil and water, capable of causing serious infections. This study exploits pyocyanin, the most produced toxin of *P. Aeruginosa*, to develop Molecularly Imprinted Polymers (MIPs) for the indirect detection of the bacterium in the environment. This method offers a cheap and easily scalable technology that overcomes the drawbacks associated with classical laborious sensing techniques based on the identification of the whole microorganism.

Keywords: imprinted polymers, *Pseudomonas Aeruginosa*, food safety.

Introduction

In 2017, multidrug-resistant *P. Aeruginosa* caused an estimated 32,600 infections among hospitalized patients and 2,700 deaths in the USA [1-2]. Because of its infectious properties, it is important to have a versatile and low-cost technology to detect the bacterium. In order to do this, we decided to exploit one of the main toxins secreted by *P. Aeruginosa*, namely pyocyanin, in order to synthesise MAA-based polymers [3]. These MIPs can be immobilized onto aluminium chips and subsequently used to detect the bacteria by thermal means. Thus, correlating the concentration of pyocyanin introduced to the senor to a change in the transmitted temperature [4].

Results and Discussion

In order to find an optimum MIP for binding pyocyanin an investigation in the monomeric and cross linker composition and ratios was undertaken. The performance of each MIP was assessed by conducting rebinding experiments, where known masses of MIPs were incubated with increasing concentrations of aqueous pyocyanin (0.025-0.5 mM).

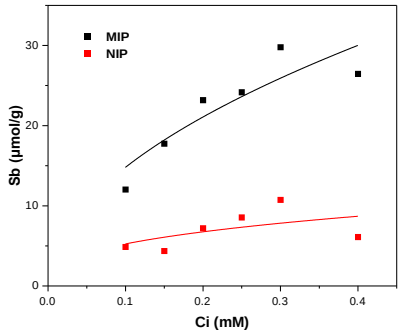

Figure 1. *Binding isotherm for MIP/NIP after incubation with increasing concentrations of pyocyanin.*

After incubation, the MIPs were filtered and the remaining pyocyanin (C_f) in solution was determined used UV-visible spectroscopy. From this value, the amount of pyocyanin bound to the MIPs (S_b) was calculated and the corresponding MIP binding isotherm plotted (Figure 1). From the data collected it was clear that the MIP shown performed the best demonstrating an imprint factor of 3.68 (C_f = 0.2 mM) and an overall binding capacity of 29.77 µmol/g .

Following this analysis, MIP particles were immobilized onto aluminium chips to perform thermal analysis across the solid-liquid interface. The receptor layer was then exposed to increasing concentrations of pyocyanin and the thermal response monitored to construct a dose response [5].

Conclusions

The results of this study demonstrate that the indirect detection of *P. Aeruginosa* using MIP-based sensors offers a cheap and easily scalable technology that overcomes the drawbacks associated with classical laborious sensing techniques based on the identification of the whole microorganism.

Acknowledgments

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A13 - Development of a sensor platform for the detection of pathogenic bacteria in aquaculture systems

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Abstract: In this work, a sensing platform based on surface imprinted polymers (SIPs) and a capacitive biosensor with interdigitated electrodes (IDEs) is introduced. The developed flow cell was found to be effective for directing and keeping the analyte solution in parallel channels containing the electrodes. This setup can be used to detect pathogenic microorganisms in the future in marine and freshwater aquaculture systems.

Keywords: imprinted polymer, pathogenic microorganism, capacitive biosensor, interdigitated electrode.

Introduction

Food and water contamination by pathogenic microorganisms is one of the major concerns in public health as well as in the food industry. Therefore, rapid and accurate detection of these contaminations is crucial to maintain high standards of food quality and environmental safety. Currently, several approaches are used to detect and monitor the microbial contaminations; however, in addition to the demand for fast, low-cost, highly sensitive, and selective sensor systems, having the ability to be autonomous, and on-site in real-time monitoring is one of the desired goals for future applications [1,2]. To achieve these goals, herein we introduce an electrochemical sensor system using a capacitive biosensor based on an interdigitated electrode (IDE) together with surface imprinted polymers (SIPs) as recognition elements.

Results and Discussion

As a measurement set-up, a prototype of a flow-through cell was designed in computer-aided design (CAD) software. For the channels of the flow-through cell, a mold was printed using a 3D printer and it was used for developing the polydimethyl-siloxane (PDMS) layer that defines the fluidic channels on the IDE electrodes. In addition, the housing materials were also printed in the 3D printer to hold the PDMS in the correct place according to the inlets/outlets of the channels and electrical connections. For electrical connections, spring-loaded pogo pins were used. An overview of the set-up is depicted in Figure 1.

Conclusions

In this work, we introduce a sensor setup, which can be used to detect pathogenic microorganisms in a differential way thanks to the provided double-fluidic channels offering a possibility of parallel measurement.

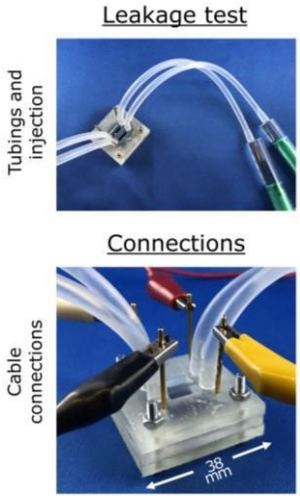

Figure 1: *Overview of the flow-through cell for the designed capacitive biosensor based on an interdigitated electrode (IDE) and surface imprinted polymers (SIPs).*

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A14 - A MIP-based impedimetric biosensor for the medical monitoring of lung-disease patients

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Abstract: This work reports on fabrication of a molecularly imprinted polymer (MIP)-based impedimetric biosensor to monitor biomarkers that are related to chronic obstructive pulmonary disease (COPD) and cystic fibrosis (CF). The purpose is to identify how far airborne pollutants cause a worsening of the symptoms, in which case the biomarker concentrations serve as indicators. Therefore, 3-nitrotyrosine (3-NT) was selected as the model biomarker and we show that the corresponding MIPs is highly sensitive to the target.

Keywords: COPD, CF, 3-nitrotyrosine, MIPs, impedance spectroscopy

Introduction

The measure of the environmental influences of an individual from conception to death and how those exposures relate to health and disease is well defined by the "exposome" concept. Chronic respiratory diseases induced by air pollution is considered the leading cause of about 7 million environment-related deaths per year. Therefore, the diagnosis of chronic obstructive pulmonary disease (COPD) and cystic fibrosis (CF) as chronic resp- iratory diseases are of particular interest in human exposome research [1]. Literature studies show that the level of 3-nitrotyrosine (3-NT), which is an oxidative stress metabolite produced during nitra- tion of tyrosine, is significantly elevated in the exhaled breath condensate (EBC) of COPD and CF patients [2, 3]. In this research, 3-NT was selected as a model biomarker for COPD and CF to synthe- size a specific molecularly imprinted polymer (MIP) layer using the electropolymerization techni- que. Furthermore, the MIP was used as the biorecognition layer to develop an impedimetric-based biosensor for COPD and CF patients.

Results and Discussion

In this work, we developed an EBC-collection unit, which collects ca. 2 ml EBC during 5 min breath-ing. Also, we used home-designed gold (Au)- coated multi-electrode glass sensors. Each sensor chip includes 4 circular sensing spots (two electro- des per spot with equal surface area). The sensors were cleaned with isopropanol and acetone in a sonicating bath and dried with nitrogen (N_2) gas. MIP electropolymerization was performed in a mixture of pyrrole, dopamine (as monomers), and 3-NT (as template) diluted in KCl solution. However, the template was omitted in the non- imprinted polymer (NIP) mixture. Afterwards, each working electrode was coated with either MIP or NIP via chronoamperometry for 15 – 20 cycles using a potentiostat. A polished titanium (Ti) wire and an Ag/AgCl electrode were used as counter and reference electrodes, respectively. The extraction of the template was done by immersing the polymer coated sensor in H_2SO_4, NaOH, and deionized water on a shaker at room temperature. To test the sensitivity of the MIP versus the NIP, a calibration impedimetric measurement was performed using different concentrations of 3-NT (100 pM up to 1 µM) in 1 □ PBS for 1 hr per concentration at 19 ℃ (Figure 1). Furthermore, the layer characteristics were studied by Atomic Force Microscopy (AFM).

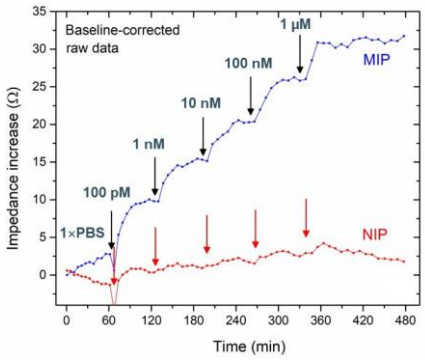

Figure 1: Baseline-corrected results showing a highly sensitive MIP for 3-NT compared with NIP.

Conclusions

The results demonstrate that the electropolymerized MIP is sensitive to 3-NT concentrations in the range of 100 pM – 1 µM. This analytically useful range covers the full concentration range that can be expected in healthy and in lung-disease patients. Furthermore, the first measurements on 3-NT spiked EBC samples have been successful.

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Acknowledgements

Support by the European H2020 project REMEDIA (grant No. 874753) is gratefully acknowledged.

A15 - Development of a miniaturized electrochemical sensor for on-site nitrate monitoring

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Abstract: Here we present the results of a potentiometric nitrate sensor, which has the potential to be used for *in-situ* nitrate determination. The results show the reproducibility and long-term stability of the sensor. The sensor will be able to monitor nitrogen fertilization processes on agricultural land as well as surface and ground water.

Keywords: nitrate sensor, all-solid state, potentiometric measurements, *in-situ* determination.

Introduction

Agriculture and its increasing intensification play a key role in our society. Nitrogen converted to nitrate can pass from soil to groundwater through leaching processes. Excessive nitrate contamination of ground and surface water has harmful effects on the environment and human health. Therefore, monitoring nitrate levels in soil and surface water are fundamental in agriculture [1]. Nitrate selective sensors are already available on the market. However, these sensor systems are not suitable for on-site in field and often require a qualified professional for sample preparation steps [2]. The aim of this work is to overcome these difficulties by developing a miniaturized, screen-printed sensor in an all-solid-state configuration for potentiometric determination of nitrate in aqueous samples and for *in-situ* use in soil. The composition of the electrode structures is being optimized to achieve stability and reproducibility for long-term measurements, even with influence of different physico-chemical interferences.

Results and Discussion

The developed sensor electrode is based on graphite paste, modified by polypyrrole layer as a conducting polymer and with an ion selective membrane. This sensor was investigated at different steps of the measurement procedure during different time intervals. Figure 1 shows the result of the conditioning step of the sensor in nitrate standard solution. This measurement was repeated several times with the same sensor, and the sensor was dried between the measurements. Figure 2 shows the calibration curve of graphite sensor at different times. Electrochemical characterization of the sensor in aqueous samples exhibits stable and reproducible potential values in the nitrate concentration range from 10^{-4} mol/L to 1 mol/L with an average sensitivity of > 50 mV/decade.

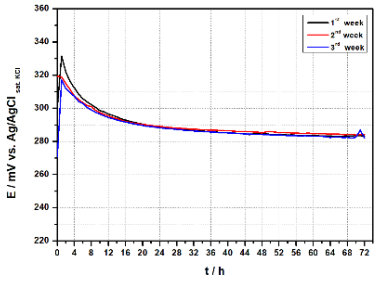

Figure 1: *Potentiometric response behaviour of the conditioning steps repeated over weeks.*

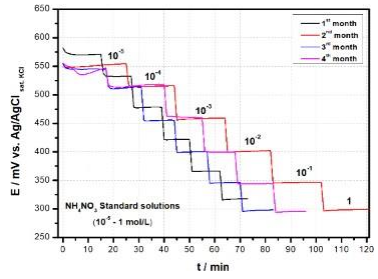

Figure 2: *Calibration step curves for the same sensor analysed over several months.*

Conclusions

The graphite-based nitrate sensor showed, under preliminary conditions, important characteristics for the performance of these sensors in the environment. Furthermore, the storage conditions between the measurements hardly affected the lifetime and the performance of this sensor during the investigations.

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A16 - Signal enhancement for voltammetric detection of heavy metal ions

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Abstract: Special all-solid-state electrodes have been developed and applied for the selective detection of Cd(II), Pb(II), As(III) and As(V) in aqueous samples. Screen-printed electrodes (SPEs) represent an elegant opportunity for the sensitive and reliable determination of heavy metal ions by stripping voltammetry. In this presentation, novel SPEs are described, which consist of a three-electrode system. In order to achieve very low detection limits, special signal enhancements were made in the form of co-depositions.

Keywords: Cd(II), Pb(II), As(III) and As(V) detection, screen-printed electrodes, stripping voltammetry

Introduction

As a result of mining, the water quality in former East Germany has been significantly affected for several decades. Heavy metal ions such as Pb(II), Cd(II) or an increased arsenic content of former tin ore mines occur geogenically in the southern mountainous regions of Saxony in highly elevated levels of the ground and surface water bodies.

Results and Discussion

The optimized measurement parameters allow the monitoring of mining-relevant ion concentrations down to the drinking water limits with a short deposition time. They are applied to anodic stripping voltammetry to achieve the necessary high measuring sensitivity [1]. In addition to the influence of interfering metal ions, special modifications were made for the specific detection of targeted heavy metal ions and for signal enhancement. For example, the lower limit of detection for Pb(II) can be decreased by bismuth-modified graphite electrodes or by the addition of Bi(III) into the electrolyte [2] (Fig. 1).

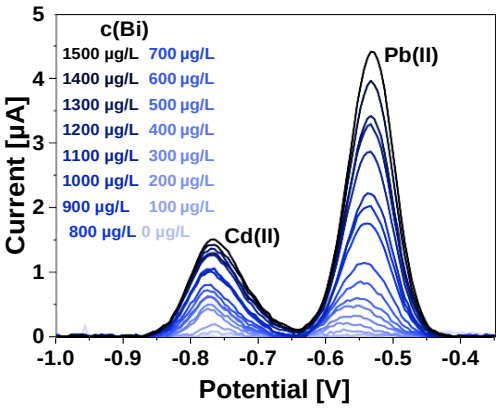

Figure 1: *Simultaneous determination of Pb(II) and Cd(II) by anodic stripping voltammetry with the addition of Bi(III) into the electrolyte.*

The well-separated peaks for Cd(II) ($c_{Cd(II)}$ = 5 µg/L) and Pb(II) ($c_{Pb(II)}$ = 1 µg/L) can be increased by the addition of Bi(III). Another example in real-world applications is the significant interference of Cu(II) for the detection of As(III). This can be used for a signal enhancement, too. For this, the Cu film is typically generated by electrodepositing or co-depositing of Cu(II) with As(III) onto a gold working electrode.

Conclusions

The results show that the legally required detection limits cannot be achieved by implementation of only a pure deposition step. To achieve higher sensitivities, co-depositions were used for the investigations. Both, for the individual analysis and for simultaneous measurements of Cd(II) and Pb(II), the addition of Bi(III) has a positive effect.

The use of a portable electroanalytical potentiostat not only enables heavy metal ion detection under laboratory conditions, but also on-site explorations. These sensors represent an effective way for the monitoring of Cd(II), Pb(II), As(III) and As(V) in mining and surface waters.

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Acknowledgements

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A17 - Inkjet-printed 3D microelectrode arrays for amperometric nanoparticle detection

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Abstract: A fast process for the fabrication of 3D microelectrode arrays with insulated pillar structures was developed by combining ink-jet printing with laser-patterning. Printed 3D structures are insulated using parylene C and electrode tips are exposed via laser ablation in a vertical alignment. As a proof of principle, we employ the fabricated 3D microelectrode arrays for the electrochemical detection of stochastic impacts of silver nanoparticles.

Keywords: inkjet-printing, laser-patterning, 3D microelectrode arrays, nanoparticle detection.

Introduction

Silver nanoparticles (AgNPs) are extensively used in diverse products. As a result, tons of AgNPs are released into aquatic ecosystems every year. However, a fast and reliable on-site detection method for AgNPs is still missing. Chip-based single-impact electrochemistry can provide means to measure nanoparticles cost-effectively and reliably. In this approach, nanoparticles are detected in solution by sensing their stochastic collisions on appropriately-polarized microelectrodes [1]. Nevertheless, a planar electrode array design still restricts the particle detection to the chip surface and does not allow detection in 3D environments. The present work addresses this challenge and introduces arrays of 3D electrodes as detection sites that directly access the bulk solution.

Results and Discussion

Our approach combines inkjet-printing and laser-patterning technology to generate 3D ring electrode arrays for low-noise amperometric recordings. A schematic of the fabrication process is shown in Fig. 1. In a first step, pillar structures were directly inkjet-printed onto a substrate (Fig. 1a). An adhesion layer of titanium followed by the main conductive layer of platinum was subsequently deposited onto the sample using a sputtering process to coat the entire surface of the sample including the printed 3D pillar structures with metal. As a next step, laser patterning was used to define the feedlines and electrodes. A layer of parylene C was deposited via a CVD process to passivate the sample. To expose a defined ring electrode only at the tip of the pillar we used a laser ablation process (Fig. 1b). Fig. 1c and Fig. 1d show close-up images of individual 3D electrodes and their tips.

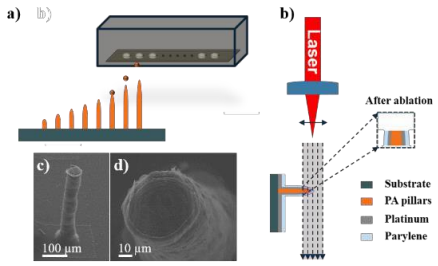

Figure 1: *(a) Schematic of the inkjet-printing for the 3D electrode arrays. (b) Schematic for the laser ablation process. (c-d) SEM images of an individual tip after straight cut.*

Conclusions

We presented a simple process for the fabrication of 3D MEAs by ink-jet printing in combination with laser-patterning. The 3D MEAs allow the detection of silver nanoparticles in aqueous solutions. We believe that this concept can be applied for electrochemical detection within various 3D environments.

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Acknowledgements

We greatly appreciate the financial support from China Scholarship Council (CSC) and funding from the German Research Foundation (DFG; grant number WO 1510/7-1).

A18 - Imprinted Polydimethylsiloxane-Graphene Oxide Composite Receptor for the Biomimetic Thermal Sensing of *Escherichia coli*

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Abstract: This work presents an imprinted polymer-based thermal biomimetic sensor for the detection of *Escherichia coli*. A novel and facile bacteria imprinting protocol for polydimethylsiloxane (PDMS) films is investigated and these receptor layers are functionalized with graphene oxide (GO) in order to improve the overall sensitivity of the sensor. The limit of detection attained for the sensor employing PDMS-GO imprints was 80 ±10 CFU/mL. The device has been benchmarked with a commercial impedance analyser, tested for selectivity and employed to monitor *E. coli* contamination in spiked fruit juice.

Keywords: Biomimetic sensing, imprinted polymers, food safety, cell imprinting, graphene oxide.

Introduction

The incorporation of imprinted polymers (IP) into sensing devices has enabled the detection of a wide range of analytes going from molecules to whole cells. Biomimetic platforms for bacteria possess the potential of being a low-cost and on-site testing monitoring tool for food safety, where the accurate detection of pathogens is crucial for preventing disease.

This study presents an IP-based thermal sensor for the detection of *E. coli*. The design of the synthetic receptor involves a novel and facile imprinting protocol for PDMS films and their functionalization with GO in order to improve the overall sensitivity of the device (Fig. 1).

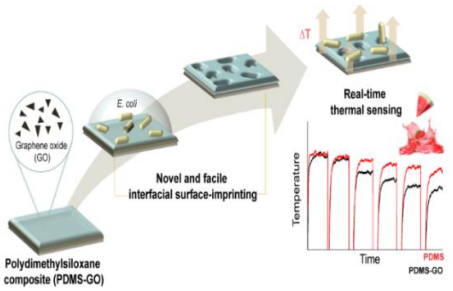

Figure 1: *Schematic representation of the approach presented in this work for PDMS-GO receptors.*

Results and Discussion

PDMS was successfully imprinted *via* interfacial imprinting by directly sedimenting *Eschericha coli* onto the polymer, attaining an imprint density of 21.7 ± 4.8%, an enhanced coverage in comparison to traditional microcontact imprinting.

The receptors were functionalized with GO and the heat-transfer method was employed as transducing platform in order to monitor the temperature changes at the solid-liquid interface upon the recognition of *E. coli* by the PDMS. Dose-response curves allowed the calculation of the limit of detection (LoD) of the sensor (670 ± 140 CFU/mL when employing neat PDMS and 80 ± 10 CFU/mL for PDMS-GO composites). Moreover, the synthetic receptors proved to be suitable for impedimetric sensing, exhibiting a LoD of 30 ±4 CFU/mL.

The sensor was tested for selectivity against an additional *E. coli* strain, *C. sakazakii* and *S. aureus*. The device exhibited a response which was roughly twice towards the targeted bacteria in comparison to the analogue species.

As proof of concept application, the sensor was employed for *E. coli* quantification in fruit juice. The results were in alignment with the performance in buffer, and the sensitivity would fall within the European Commission Regulation EC 1441/2007 on microbiological criteria for this type of foodstuffs.

Conclusions

The use of PDMS as commercial resin and the proposed imprinting protocol for bacteria-IP add to the scalability in the preparation of synthetic receptors. The functionalization of the layers with GO was investigated for the first time for the enhancement of the thermal transducer, attaining a competitive sensitivity in comparison to other IP-based sensors. The improvements made on the device could enable end-users to determine the concentration of bacteria in liquid food samples [1].

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Acknowledgements

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A19 - High-sensitivity LAPS imaging of cardiomyocyte action potentials

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Abstract: Accurate monitoring of cardiomyocyte action potentials (APs) is essential to understand disease propagation and for therapeutic trials. Light-addressable potentiometric sensors (LAPS) have been used in this pursuit with limited success due to low membrane potential sensitivity. Here we propose a novel method to improve the contact between the cell and sensor, enhancing sensitivity. The method was validated through direct comparison with measurements in standard culture and by investigating responses to drugs with known electrophysiological effects.

Keywords: photoelectrochemical imaging, LAPS, cardiomyocyte, action potentials.

Introduction

Sudden cardiac death is responsible for over 100,000 deaths in the UK, and the study of cardiomyocyte (CM) action potentials is essential for both disease development studies and therapeutic trials [1]. Manual patch clamp assays provide 'gold standard' measurements in this pursuit, but can only measure a single cell at a time [2]. LAPS have previously been employed to measure APs of living cells, however have suffered from poor sensitivity, as focal adhesions of cells in standard culture lead to a small electrolyte filled gap between the cell membrane and sensor surface - effectively screening the membrane charges [3]. LAPS sensors based on silicon-on-sapphire substrates with carboxylate-terminated self-assembled organic monolayers as ultrathin insulators [4] were used in this work.

Results and Discussion

Initially the sensitivity of the sensor was established in standard 2D culture of CMs by monitoring the photocurrent at a fixed position under a cell, which showed small amplitude APs (figure 1a, (top)). A custom force probe was used to place a cardiomyocyte organoid under pressure, thereby eliminating the gap between cells and sensor. The resulting photocurrent signal and the corresponding LAPS image of cardiomyocyte cells are shown in figure 1a (bottom) and b, respectively. The average amplitude of APs for cells with increased contact force was over 4.6 times that of the 2D cell culture.

The method was then further validated by studying the effects of the drugs Verapamil and Phenylepherine with known electrophysiological effects. The expected changes in beating profiles, frequency and amplitude of the APs were recorded successfully using this method.

In several cases multiple cells were recorded simultaneously allowing for phase differences between adjoining cells to be quantified.

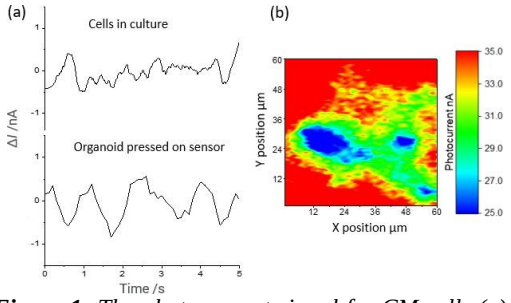

Figure 1: *The photocurrent signal for CM cells (a) in standard culture and with an organoid under pressure (b) the LAPS image of CMs in the organoid*

Conclusions

Action potentials of individual cardiomyocytes were successfully monitored with LAPS by pressing organoids onto the sensor surface. A clear improvement in sensitivity was established compared to standard cell culture. The technique is able to monitor several cells simultaneously and can have a large impact in the analysis of the role of APs by monitoring the interactions of adjoining cells. Further experiments of fast cellular responses using LAPS will now be possible after mitigation of the screening effect.

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A20 - Quality control in beer and wine: Detection of acetoin and diacetyl by means of a TMV-assisted capacitive field-effect biosensor

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Abstract: A field-effect based acetoin/diacetyl biosensor using *tobacco mosaic virus* nanotubes as scaffolds for high-density immobilization of the enzyme acetoin reductase is presented. The sensor is characterized regarding its acetoin and diacetyl sensitivity in buffer solution and beer samples. Furthermore, the sensor's sensitivity towards acetoin and diacetyl can be adjusted by the pH value of the measurement solution.

Keywords: *Tobacco mosaic virus*, acetoin, diacetyl, acetoin reductase, field-effect sensor, alcoholic beverages.

Introduction

Acetoin and diacetyl are natural by-products during the fermentation process of beer and wine. Their buttery-like aroma has a major impact on the beer flavor and wine bouquet [1]. The concentration depends on the fermentation progress, whereby their detection during fermentation can enable a constant quality control and avoid unnecessary maturation time. We recently introduced a field-effect biosensor immobilized with the enzyme acetoin reductase (AR) from *Alkalihalobacillus clausii*, DSM 8716^T by crosslinking for acetoin detection [1]. The sensor was also applied for acetoin measurements in real samples [2].In this work, a novel immobilization method for AR is presented: *Tobacco mosaic virus* (TMV) particles are utilized as nanoscaffolds for the dense immobilization of AR on capacitive electrolyte-insulator-semiconductor (EIS) sensors. The developed biosensor is characterized regarding its acetoin sensitivity and long-term stability. Furthermore, the detection of diacetyl is realized with this novel biosensor for the first time. The successive detection of acetoin/diacetyl was realized by tuning the sensor's sensitivity via adjustment of the pH value of the measurement solution.

Results and Discussion

For the biosensor fabrication, biotinylated TMV particles were immobilized on the gate surface of the Al/p-Si/SiO_2/Ta_2O_5 sensor structure (figure 1). For high-density immobilization of AR on the TMV particles, the enzyme was conjugated with streptavidin for biotin-streptavidin-affinity binding. For electrochemical sensor characterization, capacitance-voltage and constant-capacitance methods were used.

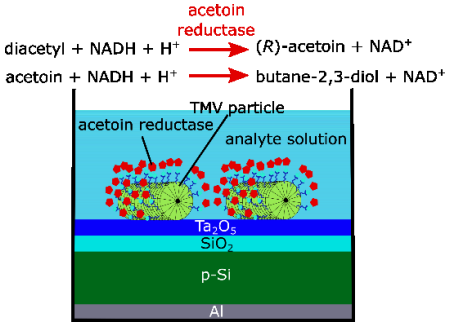

Figure 1: *Enzymatic reactions catalyzed by the AR and schematic structure of the EIS sensor immobilized with acetoin reductase-functionalized TMV particles.*

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Acknowledgements

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Topical Session B: Nanotechnology and Surface Characterization – Schedule

Keynote Lecture 2: Adsorption of lipid membranes at solid-liquid interfaces: acoustic and thermal sensing - Prof. Dr. Patricia Losada-Pérez (Université Libre de Bruxelles, Belgium)

Short Oral Presentations

B1 – Benno Schneider – Combined light-addressable sensor-actuator platform to study pH gradients…

B2 – Bo Zhou – Photoelectrochemical detection of Ca(II) ions using hematite nanorods

B3 – Gil van Wissen – Detection of riboflavin in food samples using Molecularly Imprinted Polymers

B4 – Farnoosh Vahidpour – Miniaturized enzyme-based interdigitated electro set-up for H_2O_2…

B5 – Farnoosh Vahidpour – Multi-sensing to tailor sterilization conditions in aseptic food industry

B6 – Gabriela Figueroa Miranda – Delineating charge and capacitance transduction in system-integrated…

B7 – Chunling Li – Effect of ZnO nanoparticles to the electrical characteristics of PEDOT:…

B8 – Andrea Kauth – Optimizing electrical pulse parameters for electrofection on microelectrode arrays

B9 – Stefan Leisten – G-Quadruplex modified nanoparticles as optically active BioNano-interfaces…

B10 – Huijie Jiang – Revisiting Fresnel's law with 2D MOFs for rapid detection of phthalates…

B11 – Dibyendu Khan – Novel fabrication technique for skin-friendly electrodes on a stretchable…

B12 – Jan Sündermann – Establishment of a foreign body reaction model

B13 – Shaukat Ali Lone – The role of Nb addition on the crystallographic, electrochemical and….

B14 – L. Bar – Interactions of hydrophilic quantum dots with defect-free and defect containing…

B15 – Tobias Karschuck – Modeling and experiments of field-effect capacitors decorated with AuNPs.

B16 – Dominik Knapic – Singal enhancement for voltammetric detection of heavy metal ions

B17 – Animesh Pratap Singh– Towards integration of microfluidic key gates for future hardware security

B18 – Christian Olmos van Velden – Compact PCB-based, liquids microheater with modular design…

B19 – Renato Rogosic – Electropolymerisation of surface imprinted polypyrrole for the rapid detection…

B20– Faranak Eivazi – Towards a dual-modality field-effect/magnetic immunosensor chip

B21– Sebastian Freko – Development, Fabrication and Characterization of a Transformable and…

Poster market with coffee

Adsorption of lipid membranes at solid-liquid interfaces: acoustic and thermal sensing

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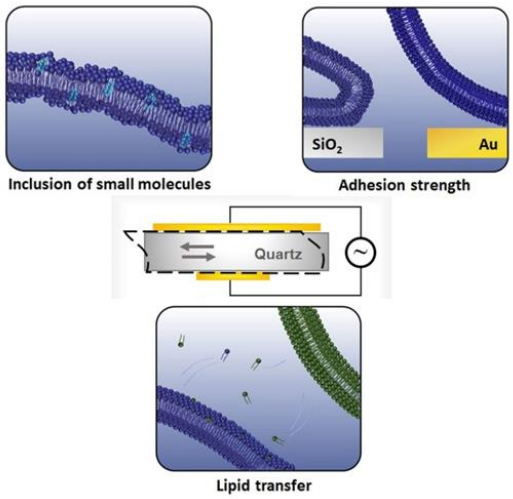
Biointerfaces encompass natural interfaces between biomolecules, their assemblies and organic or inorganic surfaces they interact with. Their study is motivated by the need to monitor and understand biomolecular adsorption at interfaces to develop materials for biosensors, diagnostics, and therapeutics. Artificial lipid membranes are useful model systems for many processes taking place at the cell membrane. When supported into solid materials, they have the potential to generate biosensing platforms of enhanced sensitivity. Moreover, lipid-coated nanostructured materials can be used for controlled drug delivery purposes giving the high drug loading capacity of the nanostructured system, whose release could be modulated by the supported lipid bilayer. In this talk, we address different strategies to planar lipid layers onto solid surfaces, namely vesicle fusion, surface functionalization by self-assembled monolayers, solvent exchange and lipid interactions with fusing agents [1-3].

Surface-sensitive techniques based on robust physical principles provide useful tools for studying lipid. Quartz crystal microbalance with dissipation (QCM-D) is a label free, acoustic-based surface-sensitive technique which is widely used in bio-interfacial science of solid-supported lipid membranes. Its sensitivity to mass and energy dissipation changes at the solid-lipid layer-liquid interface allows monitoring in real time the formation of different membrane geometries onto solid and soft surfaces. The usefulness of QCM-D will be exemplified in the particular case of lipid membrane vesicle adsorption. Examples of how the interplay among elastic and adhesive contributions define the formation of adsorbed vesicle layers or supported lipid bilayers will be shown. Apart from the kinetics of film formation, QCM-D is steadily growing as a versatile technique to detect and characterize the phase behavior of solid-supported lipid membranes [4]. Examples of how phase transitions in supported lipid membranes detected by QCM-D can be used as descriptors for monitoring specific lipid-membrane related mechanisms such as vesicle adsorption, changes in lipid organization upon addition of inclusions, and lipid transfer kinetics by monomer diffusion will be provided [5-7].



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B1 - Combined light-addressable sensor-actuator platform to study pH gradients inside microfluidic channels

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Abstract: A light-addressable sensor-actuator platform, that combines a light-addressable electrode and a potentiometric sensor arranged at the top and bottom of a microfluidic channel, is presented. To demonstrate the system's applicability, the enzyme activity of penicillinase can be controlled within the fluidic channel by actively adjusting different pH values. The enzyme is immobilized utilizing *Tobacco mosaic virus* particles as scaffolds.

Keywords: light-addressable electrode, light-addressable potentiometric sensor, *Tobacco mosaic virus*, penicillinase.

Introduction

Sensors, liquid-handling devices, or actuators are usually integrated into a microfluidic system to perform a chemical or biological analysis on a single chip. These so-called lab-on-a-chip devices used in the past rigid sensor and actuator structures such as electrodes. On the contrary, a light-addressable electrode (LAE) and potentiometric sensor (LAPS) are based on semiconducting materials, which can adjust their "active area" spatially resolved during runtime. In combination, photoelectrochemical reactions (e.g., pH changes) can be triggered and monitored using the LAE **[1]** and LAPS **[2]**, respectively. In this work, the joint implementation of both technologies into a common microfluidic system will be presented and applied to control the pH-dependent activity of the enzyme penicillinase.

Results and Discussion

To fabricate the combined microfluidic system, enzyme-loaded *Tobacco mosaic virus* (TMV) particles are deposited on the Al/n-Si/SiO_2/Si_3N_4-LAPS structure. On top, a laser-cutted double-sided microfluidic tape defines the microfluidic channel geometry, while the channel is closed with a glass/SnO_2:F/TiO_2-LAE structure (figure 1). The streptavidin-conjugated penicillinase is bound to the biotinylated TMV by biotin-streptavidin affinity binding.

First, the penicillin sensitivity of the LAPS is characterized and the change in the catalytic conversion of penicillin to penicilloic acid and H^+ ions under varying pH buffers is evaluated. Moreover, the pH is adjusted under flow conditions utilizing the LAE, and the resulting enzyme response is monitored using LAPS.

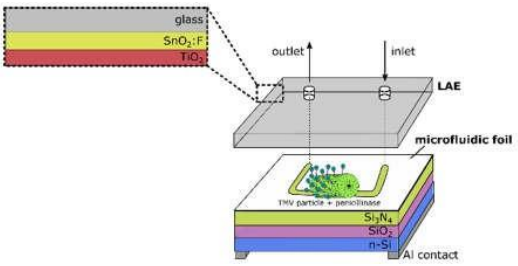

Figure 1: *Schematic structure of the combined LAPS-LAE setup with functionalized TMV particles.*

Conclusions

This work describes a microfluidic platform enabling time- and spatially resolved pH measurements and manipulations. The successful application to control the enzyme activity shows the potential to further study biological systems without the need for predefined electrode structures.

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Acknowledgments

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B2 - Photoelectrochemical detection of Ca(II) ions using hematite nanorods

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Abstract: A photoelectrochemical sensor using α-Fe_2O_3 (hematite) nanorods as the sensor substrate is proposed for detecting calcium ions (Ca^{2+}). The fabrication of sensors was started with a hydrothermal process to prepare the hematite nanorod substrates followed by modification of the sensor surface with a Ca^{2+} selective layer. The sensors showed an amperometric response in the concentration range of 1 µM to 10 mM.

Keywords: Photoelectrochemical sensor, calcium ions sensing, hematite nanorods

Introduction

Photoelectrochemical sensing is a label-free, non-contact electrochemical method to detect analytes at the photoelectrode/electrolyte interface with high sensitivity. Developing calcium ion (Ca^{2+}) sensors is important as Ca^{2+} is crucial for cell signalling which affects every aspect of cellular life. Light-addressable potentiometric sensors (LAPS) have been used to detect Ca^{2+} by measuring the horizontal shift of the current-voltage (*I-V*) curves [1]. Photoelectrochemical imaging system (PEIS) based on semiconductor/electrolyte structure has been proposed to image cellular process with high spatiotemporal resolution [2]. Herein, PEIS using hematite nanorods coated with polyvinyl chloride (PVC) containing a calcium ionophore as sensor chip was examined to measure Ca^{2+} concentration in aqueous solutions.

Results and Discussion

To explore the Ca^{2+} sensing performance, *I-V* curves were measured in a series of concentrations of calcium chloride ($CaCl_2$) solutions at a light modulation frequency of 1 kHz. As shown in Figure 1a, the photocurrent increased with the Ca^{2+} concentration from 1 µM to 10 mM (the photocurrent differences became more significant at higher applied voltage). A calibration curve was obtained by plotting the photocurrent values at 1.2 V as a function of the logarithm of the Ca^{2+} concentration (Figure 1b).

The sensor response is purely amperometric compared to previous potentiometric sensors that used PVC sensitive membrane such as field effect transistor (FET) [3] and LAPS [1]. This photocurrent response is attributed to the ultrathin PVC layer enabling the light-activated faradaic electrochemistry at the interface. The binding of Ca^{2+} increased the concentration of hydroxide ions that diffused to the sensor surface thus promoting the oxidation reaction.

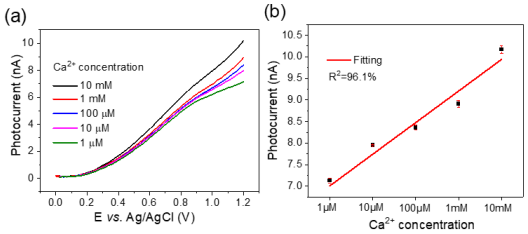

Figure. 1: *(a) I-V curves of the hematite nanorods-based photoelectrochemical sensor measured at different Ca^{2+} concentration (b) corresponding calibration curve with linear fitting.*

Conclusions

Hematite nanorods coated with PVC containing a calcium ionophore have been used as sensor chips for photoelectrochemical detection of Ca^{2+} in a concentration range from 1 µM to 10 mM. This strategy allows the amperometric detection of ions compared to traditional potentiometric ion sensors.

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Acknowledgements

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B3 - Detection of Riboflavin in Food Samples Using Molecularly Imprinted Polymers

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Abstract: With a society that has an increased focus on reducing meat, animal by-product intake, riboflavin (vitamin B2) deficiency is becoming a greater issue. Finding food sources with higher B2 levels is therefore imperative. The rapid analysis of food samples for riboflavin is however problematic, as conventionally it requires analytical techniques that are time consuming, costly, and are laboratory bound. Molecularly Imprinted Polymers (MIPs) could however provide a solution, proving to be robust, selective, low-cost and most importantly portable. This research therefore seeks to develop a MIP for the detection of riboflavin and highlight its implementation into a sensor.

Keywords: riboflavin sensing, molecularly imprinted polymer, food screening

Introduction

Riboflavin, also called vitamin B2, is an essential nutrient in our diet, participating in many crucial metabolic processes. The main dietary sources for riboflavin are dairy products, meat and dark-green vegetables like spinach. However, in societies where the intake of riboflavin is low due to low meat and dairy consumption, its deficiency is endemic resulting in symptoms like migraine or anemia. Currently, riboflavin contents of food are measured by high performance liquid chromatography, which is time- and labour-consuming [1]. An alternative that could allow for direct on-site measuring are MIPs, which are highly cross-linked synthetic polymeric materials, able to selectively bind specific targets [2]. Thus, in this work, we demonstrate the synthesis of MIPs capable of selectively binding riboflavin from food samples.

Results and Discussion

To ensure the stability and improve the solubility of riboflavin, the molecule was initially modified by acetylation before attempting the development of a MIP and any ensuing studies. Once this was achieved, various MIP compositions were investigated by changing the functional monomer used in the synthesis of the bulk polymerized MIPs. The monomers used were methacrylic acid (**1**), vinylbenzyltrimethyl ammonium chloride (VBTMA) (**2**), acrylamide (**3**) and 2,6-bis(acrylamide)pyridine (**4**).

Of the monomers tested VBTMA (**2**) was found to be the best at binding riboflavin. The ratios of these components were then scrutinized, analysing how this affected the affinity of the polymer towards the target by simple binding experiments (Figure 1).

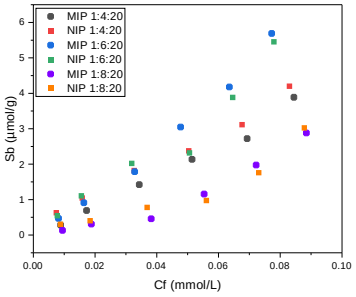

Figure 1: *Binding isotherms for (**2**)-MIPs with different template:monomer ratios after incubation with increasing concentrations of riboflavin .*

It is observed that the 1:6:20 ratio provided the best specific binding towards riboflavin, while also providing the highest binding capacity of the materials tested. These MIPs were then carried forwards towards the development of a sensor that could tangibly quantify the presence of riboflavin.

Conclusions

The results demonstrate that MIPs can be imprinted with riboflavin, and these MIPs have the potential to be integrated into sensory platforms for the subsequent analysis of riboflavin in complex samples.

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Acknowledgements

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B4 - Miniaturized enzyme-based interdigitated electrode set-up for H_2O_2 vapour/aerosol detection during sterilization in medical industry

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Abstract: The sterilization of medical tools in medical isolators is typically performed using hydrogen peroxide (H_2O_2) vapour/aerosol concentrations <1000 ppm under ambient conditions. Ideally, onsite/inline monitoring of the H_2O_2 concentration at different positions inside the medical isolator is highly advantageous to define the sterilization efficiency. Here, we present a novel enzyme-based biosensor for H_2O_2 detection, which enables – due to its flat sensor surface and miniaturized size – a future 2D- or 3D mapping of the medical sterilization chamber.

Keywords: sterilization, hydrogen peroxide vapour/aerosol, enzymatic membrane, capacitive signal

Introduction

Hydrogen peroxide (H_2O_2) is widely used as a sterilization agent in aseptic industry [1]. By far, researches have studied online monitoring of aseptic food packaging, which applies concentrations of gaseous H_2O_2 up to 8% v/v at elevated temperatures (up to 240 °C) [2]. Yet, in medical industry, lower concentrations of H_2O_2 vapour/aerosol are applied and monitored usually by bulky and expensive detectors. Here, we introduce a cost-efficient and miniaturized enzyme-based interdigitated electrode (IDE) set-up, which detects H_2O_2 vapour/aerosol up to 1000 ppm. The enzyme horseradish peroxidase (HRP) is coated on the (active) IDE to react toward H_2O_2. A second (passive) IDE remains uncoated. The arrangement of the two IDEs forms a differential set-up for the capacitive detection of the H_2O_2 vapour/aerosol.

Results and Discussion

Figure 1 schematically presents the differential set-up of the IDEs, including the active (with HRP membrane, left) and passive IDE (right). The surface morphology of the IDEs is characterized by optical microscopy, scanning electron microscopy (SEM) and profilometry. Capacitance measurements are employed for the detection of the H_2O_2 vapour/aerosol by the novel IDE set-up: the HRP membrane (on the surface of the active IDE) reacts to H_2O_2 and this enzymatic reaction affects the impedance and consequently, the capacitance of the IDE structure, following formula (1):

$$C = \frac{-\sin(\varphi)}{2\pi f Z} \qquad (1)$$

Here, Z represents the impedance, φ is the phase angle between the impedance and the capacitance, and f the frequency. The capacitance measurements confirmed the detection of H_2O_2 vapour/aerosol concentrations up to 1000 ppm.

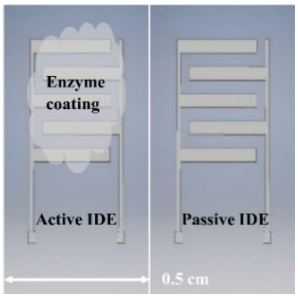

Figure 1: *Schematic of the IDE differential set-up; the passive IDE (right) and the active IDE (left, coated by the HRP enzymatic membrane).*

Conclusions

A differential set-up of enzyme-based IDEs has been developed for H_2O_2 detection. Due its flat shape and miniaturized size, the biosensor set-up can be used for future 2D- or 3D mapping of medical isolators.

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B5 - Multi-sensing to tailor sterilization conditions in aseptic food industry

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Abstract: This research introduces a multi-sensing platform for the simultaneous evaluation of several process parameters, which play critical roles in food package sterilization processes. To validate the sensor results, microbiological tests (count-reduction tests) were performed, using highly resistant spores of *B. atrophaeus* DSM 675. Correlating the process parameters and the microbiological testing results, the most effective conditions can be defined for achieving the highest killing-rate of the spores to guarantee an optimal aseptic packaging.

Keywords: multi-sensing platform, sterilization process parameters, gaseous hydrogen peroxide, spore kill-rate

Introduction

Gaseous hydrogen peroxide (H_2O_2) has become a preferred sterilant for food package sterilization. To improve the sterility monitoring, efforts have been made to develop miniaturized sensors for online detection [1]. Here, however, various sterilization parameters have to be taken into account, which include: H_2O_2 gas concentration, temperature, flow direction, relative humidity, etc. We have developed a single platform, which can assess these sterilization parameters simultaneously. In parallel, count-reduction tests are performed to validate the spore killing rate.

Results and Discussion

For developing the multi-sensing platform (see figure 1), a flexible calorimetric gas sensor is applied for detection of the H_2O_2 gas concentration and temperature [1]. A humidity sensor is used for recording the relative humidity in the sterilization chamber. In parallel, an array of Pt-100 temperature elements detects the gas flow direction. In that regime, two gas flow rates of 8 and 12 m^3/h are applied. Several H_2O_2 concentrations were considered: 0, 2.2, 4.1, 5.7, 7.1 and 7.7% v/v. Initial gas temperatures of 210, 240 and 270 °C were utilized. For the reference microbiological experiments (count-reduction tests), the same operating cycles are applied, where the spores were sterilized by gaseous H_2O_2 under the exposure times of 0.2, 0.4 and 0.6 s. The assessed parameters are correlated to tailor the optimal sterilization conditions.

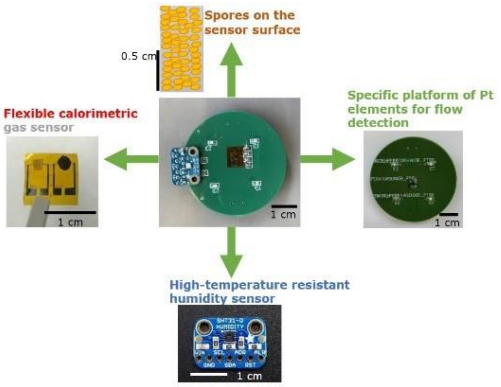

Figure 1: *Various process parameters in aseptic food processing, which are evaluated simultaneously by the multi-sensing platform; adapted from [2].*

Conclusions

This combination of different sensors as multi-sensor platform enables a more specific evaluation and prediction of how the input parameters must be adjusted during the sterilization process. Costly and time-consuming microbiological tests might be reduced in future applications.

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Acknowledgements

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B6 - Delineating charge and capacitance transduction in system- integrated graphene-based BioFETs used as aptasensors for malaria detection

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Abstract: Malaria remains a persistent and highly mortal infectious disease lacking efficient point-of-care (PoC) screening solutions. In response, we developed a quantitative electrical biosensor based on two-dimensional biologically sensitive field-effect transistors (2DBioFETs) of reduced graphene oxide as transducers detecting the main malaria biomarker, Plasmodium falciparum lactate dehydrogenase (PfLDH). The 2DBioFETs were biofunctionalized with pyrene-modified 2008s aptamers as specific PfLDH receptors. Aptamer-protein transduction at 2DBioFETs is elucidated based on the delineation of charge and capacitance in an updated analytical model for two-dimensional rGO/biofunctional layer/electrolyte (2DiBLE) interfaces.

Keywords: Malaria detection, *Plasmodium falciparum*, graphene field-effect transistor, aptasensor, aptamer-protein interaction, label-free detection.

Introduction

Nanoscale FETs are promising alternatives for quantitative biomolecular screening at a small footprint. Graphene-based materials as 2D transducers facilitate distinct advantages here, attributed to the highest S/V ratio, excellent electronic properties, and efficient bioconjugation chemistries. This work presents system-integrated reduced graphene oxide (rGO) based 2DBioFETs modified with aptamers as an optimal PoC platform for quantitative screening of malaria while unraveling the signal transduction mechanism across rGO/electrolyte interface beyond the detection of surface charge [1].

Results and Discussion

Intricate effects into the restructuring of surface charges at the biointerface are revealed by the change in the field-effect slopes in addition to the shift in the Dirac point upon the biding of the successive PfLDH concentrations, Fig 1a. Based on the 2DiBLE model, binding of protein onto aptamers (as a biofunctional layer) results in a positive shift in V_{Dirac} due to altered electrostatic potential of rGO (ψ_{rGO}, Fig. 1b, c), as well as a consistent change in the slope of field-effect curves due to change of capacitance at the rGO/BFL interface.

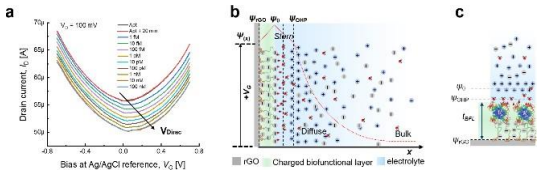

Fig. 1: *Charge and capacitance transduction at aptamer-modified 2DBioFETs for detection of malaria biomarker PfLDH.*

Conclusions

Electrical transduction mechanism at rGOBioFET aptasensors was elucidated beyond changes in surface charge with PfLDH detection down to 0.78 fM in human serum

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G. F.-M. gratefully acknowledges the financial support by CONACYT-DAAD stipend (448904).

B7 - Effect of ZnO nanoparticles to the electrical characteristics of PEDOT:PSS-based organic electrochemical transistors

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Abstract: The incorporation of zink oxide (ZnO) nanoparticles into conducting polymer Poly(3,4-ethylenedioxythiophene):poly(styrene sulfonic acid) (PEDOT:PSS) is known to modulate the electrical characteristics. Different concentrations of ZnO nanoparticles with an average size of 100 nm were dispersed in a PEDOT:PSS solution. The dispersions were investigated using SEM and analysed using a particle analysis software. The electrical conductivity of ZnO-PEDOT:PSS thin films was investigated using the van der Pauw method. Micro-sized organic electrochemical transistors (OECTs) were realized and the effect of the ZnO nanoparticles to the OECT characteristics was studied in different buffer solutions.

Keywords: PEDOT:PSS, ZnO NPs, hybrid materials, OECTs.

Introduction

Incorporating n-type inorganic semiconductor nanoparticles (NPs) into conjugated polymers is of current interest in semiconductor devices. This approach can take advantages of the beneficial properties of both materials: solution processing of polymer semiconductors and high electron mobility of inorganic semiconductors [1]. However, most of the studies are focusing on the field of optoelectronics and solar energy. In this work, we investigated the effect of ZnO nanoparticles to the electrical characteristic of PEDOT:PSS OECTs in order to tailor them for biochemical sensor applications. To the best of our knowledge, the performance of such hybrid materials (PEDOT:PSS-ZnO NPs) in the field of biosensing applications was not reported before.

Results and Discussion

In order to study the dispersion, ZnO-NPs with an average diameter of 100 nm were dispersed in ethanol using ultrasonication. Increasing the sonication time and decreasing the concentration of NPs led to more homogenous dispersions. ZnO-NPs were then mixed with the PEDOT:PSS solution using ultrasound sonication for 5 hours. Afterwards, the ZnO-NPs were homogenously dispersed in the PEDOT:PSS matrices (Figure 1 a). The measurement of electrical conductivity for the PEDOT:PSS-ZnO NPs film showed that with increasing ZnO NPs concentration, the electrical conductivity of the films increased for the case of mixing with pure PEDOT:PSS. In contrast to this, the electrical conductivity of the films decreased when mixing more ZnO NPs with PEDOT:PSS (PEDOT:PSS, 5% ethylene glycol, 1% 3-Glycidyloxypropyl triethoxysilane). To investigate the effect of the ZnO-NPs to the characteristics of OECTs, interdigitated electrode (IDE) arrays were used. The mixture was spin coated on the IDEs with subsequent lift-off and annealing steps [2]. Finally, the chips were encapsulated (Figure 1). OECTs were characterized with three different concentrations of NaCl buffer (1 mM, 10 mM, 100 mM). Results showed that the ZnO-NPs strongly affect the threshold voltage and the on-off ratio of the OECTs.

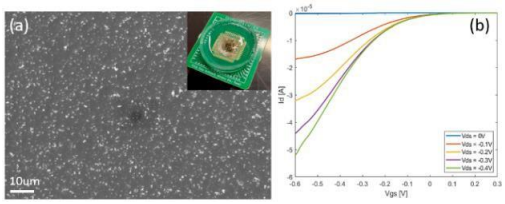

***Figure 1**: (a) SEM image of PEDOT:PSS-ZnO-NPs and an encapsulated, 16-channel OECT chip, (b) transfer characteristics of PEDOT:PSS/ZnO NPs OECTs measured in 10 mM NaCl buffer.*

Conclusions

The effect of ZnO NPs to the electrical properties of PEDOT:PSS was investigated with respect to NPs concentration. ZnO NPs strongly affected the electrical conductivity depending on the composition of the PEDOT:PSS solution. ZnO NPs also affected the threshold voltage and the on/off ratio of fabricated OECTs. Further investigations will be done to understand the role of NPs as well as to tailor the effect towards biosensors applications.

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We are grateful to Jochen Heiss for the help in chip fabrication and Linda Wetzel for the editing. C.L. gratefully appreciates the financial support from the China Scholarship Council.

B8 - Optimizing electrical pulse parameters for electrofection on microelectrode arrays

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Abstract: Electrofection can be used to genetically modify cells or tissue. Hereby, short electric pulses are applied to the target cells or tissue to permeabilize the cellular membrane for specific substances. Implementing efficient and safe electrofection pulse protocols on microelectrode arrays (MEAs) could lay the foundation for multifunctional retinal prostheses that combine cell stimulation with local *in vivo* genetic modifications.

Keywords: electroporation, transfection, microelectrode arrays, electrochemical impedance spectroscopy

Introduction

Viral-based transfection counts as the gold standard in gene therapy. Transfection via electroporation, also called electrofection, is an immune-friendly alternative. Here, short electrical pulses are applied to the cells, which lead to temporary permeabilization of the cellular membrane. This permeabilization enables the cell to take up substances diluted in the surrounding buffer, for example, plasmid DNA encoding therapeutic genes. The applied electric pulses directly affect transfection efficiency as well as cell survival [1]. To optimize the electrofection pulse protocol, electrochemical impedance spectroscopy (EIS) can be used [2].

In our research-training group RTG2610, we investigate whether MEA-based electrofection could be integrated into future retinal implants to protect the photoreceptor layer from further degeneration and therefore increase the stimulation efficiency.

Results and Discussion

First electrofection experiments with HEK293 cells on iridium oxide (IrOx) MEAs, which were fabricated on wafer-scale with standard cleanroom processes, revealed a successful transfection with the pMAX GFP vector (from Cell Line NucleofectorTM Kit V, Lonza). Electrofection was achieved by single biphasic, rectangular pulses between +2V and -2V, each phase lasting 0.5ms.

Although we have already seen successfully transfected cells (Fig. 1), we now utilize EIS to further optimize the pulse protocol. The gathered impedance spectra are fitted to different electrical equivalent circuits (EEC) to describe, on one hand, the electrode-electrolyte interface [3] and, on the other hand, the influence of the attached cells as precisely as possible. With these EECs, we not only want to optimize the electrofection pulse protocol, but also adapt this protocol to different materials (Au, ITO, TiN) and electrode shapes (round and square).

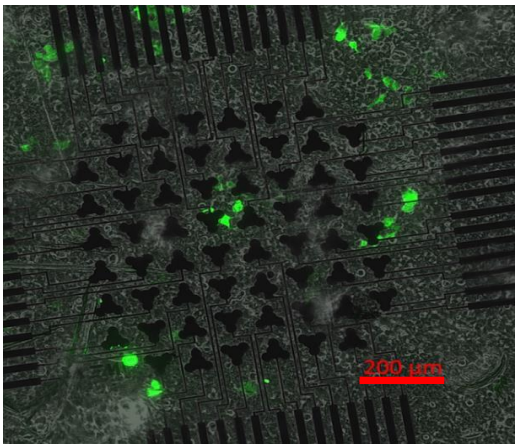

Figure 1: *Fluorescence microscopy image of transfected HEK293 cells on IrOx electrodes.*

Conclusions

With our experimental setup, we are able to optimize the electrical pulse parameters and the experimental protocols for electrofection of adherent HEK293 cells. In the future, we aim to use this method to optimize pulse protocols for in vivo gene delivery for the therapy of pathological neuronal networks.

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This work was supported by the Deutsche Forschungsgemeinschaft (DFG), grant number 424556709/GRK2610. The authors would like to thank Marcel Tintelott for his advices during EIS experiments.

B9 - G-Quadruplex modified nanoparticles as optically active BioNano- interfaces for studying ligand binding

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Abstract: Guanine-rich DNA quadruplex (G4) sequences derived from a human gene (C-Myc) were immobilized on gold nanoparticles (AuNPs) in order to allow the screening of ligand binding interactions using surface plasmon resonance (SPR) technique. It is shown that two hypothesized G4-ligands bound strongly to G4, whereas the control protein MTAN did not, and that the use of AuNPs as a refractive index contrast agent greatly increase the sensitivity of the SPR assay. Furthermore, reversible folding of quadruplexes on the NPs surface was demonstrated by employing a Förster resonance energy transfer (FRET) mechanism at the SPR interface.

Keywords: Quadruplex, DNA, metal nanoparticles, hybrid nanomaterials, SPR, FRET.

Introduction

G4 are special type of non-canonical secondary structures occurring in single-stranded DNA sequences and abundant in the human genome [1]. Studies indicate that G4 are highly relevant in many biological processes, particularly in the development of cancer and cell aging [1,2]. It is expected to discover cancer medications in the form of suitable ligand proteins able to stabilize such G4 structures, which can potentially down-regulate the over-transcription of genes dysregulated due to cancer.

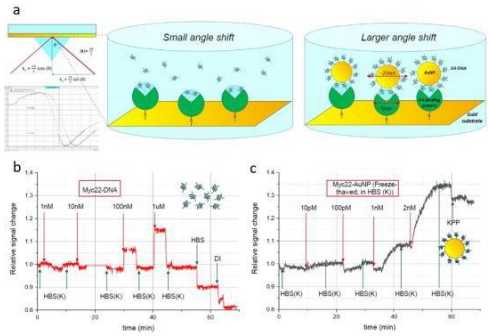

Figure 1: *SPR principle and concept of signal enhancement by the use of AuNPs (a). SPR for Myc22 DNA (b) and Myc22-AuNP conjugates (c).*

Results and Discussion

Three methods for DNA conjugation were investigated and optimized to ensure the presence of folded G4 on AuNPs surface: by increasing the temperature, it was shown that the fluorescence intensity of Cy5, which was attached to one end of the G4 sequence, strongly increases above the characteristic G4 melting temperature. Since this was not observed in a linear control sequence, the temperature increase must have led to the melting of previously folded G4 increasing the distance between the dye and the AuNP (acting as a quencher).

Binding of these Au-NP/G4 conjugates to proteins was then detected and characterized by SPR (Fig. 1,a), a highly sensitive optical technique that is used to study the binding of an analyte to a ligand via refractive index changes at the interface. Even at high concentrations of *1 uM* of DNA, no refractive index change was observed (Fig. 1,b). Upon injection of G4-AuNP conjugates, however, a detectable signal, even for concentrations as low as *10 pM* could be obtained (Fig. 1,c).

Conclusions

Our results confirm the findings of Rauser *et al*. who identified 5TTW and EED as possible ligands of the sequence Myc22 via proteomic screening [3]. Beyond mere ligand studies, G4-modified NPs are a promising, novel material system with many technological applications that will be investigated in the future. Additional SPR studies are being carried out in order to obtain the binding constants for the interaction of G4 and the respective ligands.

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Acknowledgements

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B10 - Revisiting Fresnel's law with 2D metal-organic frameworks for rapid detection of phthalates in the environment

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Abstract: A novel optical approach based on Fresnel's law was developed to analyse the thickness and roughness of metal-organic framework (MOF) thin films and it was utilized to detect phthalates in water. The Fe(BDC-NH_2) or Fe-MOF thin films showed an optimal sensor performance for facilitating a rapid, high sensitivity, low limit-of-detection (LoD) and broad dynamic range for Bis(2-ethylhexyl) phthalate (DEHP) detection with high selectivity. The underlying mechanism was studied as the change of refractive index of MOF after adsorption of phthalates resulting in a contrast variation on selected Si/SiO_2 growth substrates.

Keywords: metal-organic frameworks, thin film, optical detection, phthalates, environmental monitoring.

Introduction

MOFs as porous crystalline solids constructed by metal nodes and organic ligands (or struts) are upcoming materials with great potential for sensor applications including chemical and biomolecule sensing due to their high specific surface area, abundant active sites, tailorable lattice structures and surface functional groups [1]. Phthalates also called phthalate acid esters, common additives in plastics as plasticizers, have been classified as endocrine disrupting chemicals, posing potential threat to human health [2]. In this work we showcase the use of Fe-based MOFs as optical transducers for rapid detection of phthalates and construction of a novel point-of care (PoC) device platform for monitoring of target molecules based on Fresnel's law [3].

Results and Discussion

First, Fe-MOF thin films were deposited in a Layer-by-Layer (LbL) liquid-phase epitaxial growth on Si/SiO_2 wafers and patterned using a lithography process. Applying spectroscopic contrast measurement according to Fresnel's law, the thickness of the MOF thin films showed a linear correlation with the optical contrast (C) (**eq. 1**). For the application in phthalate detection, the response (R) was calculated according to **eq. 2**.

$$C_{MOF} = \frac{I_{substrate} - I_{MOF}}{I_{substrate}} \quad (1)$$

$$R = \frac{C_{MOF} - C_{phthalate@MOF}}{C_{MOF}} \quad (2)$$

Where I_{SiO_2} and I_{MOF} stand for the intensity of the light reflected from the substrate and MOF thin film, respectively.

Next, Fe-MOF thin films on Si/SiO_2 substrates were utilized as sensor chips to detect phthalates in water with concentration ranges from 1 ppb to 10, 20 or 80 ppm depending on the type of phthalate. As shown in **Fig. 1**, in short time (15 min) Fe-MOF exhibit varying response towards phthalate molecules namely DEBP, DiBP and DBP, clearly showing maximal interaction with DEBP exhibiting very low LoDs (1 ppb), high selectivity and in general a broad sensor dynamic range.

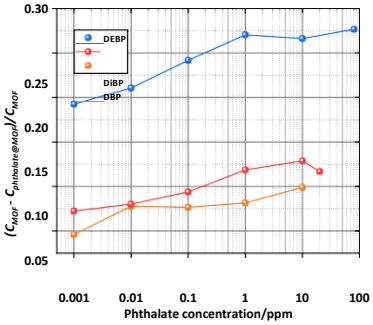

***Figure 1**. Rapid optical detection of phthalate using LbL FPE grown MOF thin films. DBP: Dibutyl phthalate, DiBP: Diisobutyl phthalate.*

Conclusions

The underlying mechanism for phthalates detection may originate from pi-pi interactions and hydrogen bonding between phthalate molecules and BDC-NH_2 ligands with significant changes in optical parameters, which needs to be further investigated using spectroscopy techniques.

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Acknowledgements

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B11 - Novel fabrication technique for skin-friendly electrodes on a stretchable substrate for wearable patches

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Abstract: A stretchable and skin-friendly electrode for wearable patches in personalized healthcare and point-of-care (PoC) applications forms a critical element for seamless integration and better adaptation of these devices in clinical workspace. In this work, we illustrate a novel fabrication technique for such electrodes on a stretchable substrate with a highly reproducible micro- and nanofabrication process to realize a systems-in-a-foil (SiF) this is able to capture cardiac signals from a human with high fidelity.

Keywords: Styrene-ethylene-butylene-styrene, wearable patch, point-of-care, electrocardiogram.

Introduction

Wearable patches that seamlessly adhere to the human skin are highly desirable for point-of-care (PoC) applications and personalized healthcare for rapid, accurate and onsite detection of biopotential signals from a human subject [1]. A stretchable and flexible electrode forms the core element for these patches, not only for faithful acquisition of the biopotential signals, but also for wearable comfort during long-term usage. Numerous variants of such electrodes were demonstrated [2]. Although, these methods have good merits, they lack the ability to be consistently reproduced and up-scaled for better adaptation in commercial applications. Further, styrene-ethylene-butylene-styrene (SEBS), a biocompatible polymer, has also gained significant interest in recent years and is frequently used as stretchable substrate for polymer transistors [3]. In this work, we used this novel stretchable material and established a micro- and nanofabrication process, which can be used as inputs for wearable SiFs for nonintrusive measurements of critical cardiac signals such as electrocardiograms (ECG).

Results and Discussion

After the electrode layer was assembled with the wearable patch (from [1]), it was applied on a human subject to demonstrate its proper functionality and continuous working. A hydrogel was applied on the active electrode areas of the ECG electrodes before applying the patch to the skin to further improve the signal quality. From the recorded signals it can be seen, that with the help of the stretchable electrodes the patch can faithfully capture the distinct peaks and features of the ECG signal (figure 1).

Conclusions

We realized a fully functional medical wearable on a stretchable material and demonstrated its functionality. In future, we will use different classification techniques (like artificial neural networks) for evaluation and arrhythmia detection utilizing this SiF.

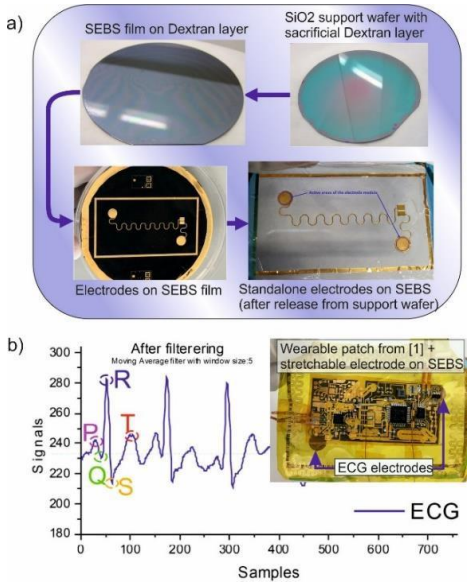

Figure 1: *a) Fabrication process flow for ECG electrodes on a stretchable SEBS substrate; b) Exemplary ECG signals recorded by the SiF (inset).*

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Acknowledgements

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B12 - Establishment of a foreign body reaction model

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Abstract: The foreign body reaction (FBR) is defined as a response of host tissue against (implanted) foreign material. As macrophages play a central role in this immune mediated reaction **[1]**, rat alveolar macrophages were isolated and CINC-1 (IL-8 in humans) release after exposure to medical grade high-density polyethylene (HDPE), non-medical grade ultra-high-molecular-weight polyethylene (UHMWPE) and Latex was measured. Notably, UHMWPE induced time-dependent CINC-1 release in the absence of cytotoxicity (membrane damage). Confocal microscopic analysis unveiled the formation of foreign body giant cells, when cells were plated on UHMWPE, supporting the conclusion that this material can induce an FBR.

Keywords: Macrophages, foreign body reaction, foreign body giant cells, CINC-1, biocompatibility

Introduction

A FBR can lead to serious impairment of implanted sensors and is a major reason for medical device (MD) failure [2]. Since the FBR is currently not part of biocompatibility testing of MDs according to ISO 10993 it was of interest to establish a protocol for prediction of potential FBR induction by a material or device.

Results and Discussion

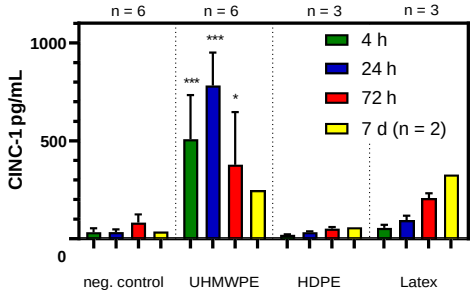

Figure 1: *The release of CINC-1 by rat alveolar macrophages after 4 h, 24 h, 72 h and 7 d in the presence of different materials. Data represent means ± SD of n =3-6 cultures. Significantly different from neg. control: * $p \leq 0.05$, ** $p \leq 0.01$ and *** $p \leq 0.005$.*

As shown in Fig. 1, only UHMWPE mediated significant, time-dependent CINC-1 release from macrophages, however, in the absence of cyto-toxicity, as measured by lactate dehydrogenase activity in the culture supernatants.

In contrast, latex as natural rubber product induced significant membrane damage in the macrophage model, but less and non-significant CINC-1 release. Latex is often used as a positive control in cytotoxicity testing and is proposed by ISO 10993-12 as such.

In line with its use as implant material the medical grade HDPE was shown to mediate neither cytotoxicity nor CINC-1 release.

Notably, the non-medical grade UHMWPE was not cytotoxic and would have passed ISO 10993-5 cytotoxicity testing. Nevertheless, this material exhibited a pro-inflammatory potential with CINC-1 release in rat macrophages, indicative for the induction of an FBR.

This hypothesis was further substantiated by investigating morphology of macrophages cultured for 72 h on UHMWPE. Morphology was determined using immunofluorescence staining of alpha-tubulin and confocal microscopy. It was demonstrated that UHMWPE mediated formation of foreign body giant cells (FBGC), as a result of an ongoing FBR.

Conclusions

To finally proof the induction of a FBR by UHMWPE a broader panel of relevant cyto-/chemokines are still needed. As a perspective, an appropriate protocol for detection of material-dependent induction of FBR might represent a useful add-on for ISO 10993 biocompatibility testing.

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Acknowledgements

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B13 - The role of Nb addition on the crystallographic, electrochemical and nano-indentation of Ti5Zr alloys

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Abstract: TixNb5Zr alloys were prepared via arc melting furnace in an argon rich atmosphere. Six samples with c_{Nb} = 7, 12, 17, 22, 27 and 45 wt.% were heat treated in an evacuated glass ampoule at a temperature of 1000 °C and subsequently water quenched. The Ti-Nb-Zr samples were chemically etched and analysed under optical microscopy. Crystal structure was analysed for each sample by means of x-ray diffraction technique. The samples were electrochemical treated by cyclic voltammetry in conjunction with electrochemical impedance spectroscopy to evaluate oxide formation factor and oxide resistivity. Finally, the evolution of hardness and reduced elastic modulus will be discussed in correlation with Nb content.

Keywords: titanium – niobium alloys; zirconium; hardness; martensite phases; x-ray diffraction; cyclic voltammetry

Introduction

Titanium is one of the most promising biometallic material. Its properties can be significantly changed by alloying and thermomechanical treatment. The β phase Ti has been emphasized strongly to be used in implantation due to its excellent corrosion resistance and mechanical compatibility with human bone [1]. Approximately 27-33 wt.% Nb are required in Ti to completely stabilize β phase at room temperature by means of quenching. However, as Nb is added above this limit the martensitic start temperature falls below room temperature and the observation of non-equilibrium phase ω has been suggested as the major cause of mechanical failures [2]. This work has been undertaken in the light of the recommendation that 5-7 wt.% Zr can discourage the formation of ω phase in Ti-Nb alloys [3].

Results and Discussion

The composition of TiNbZr alloys were checked with the help of energy dispersive spectroscopy and corroborated with the intended targeted composition for all samples. X-ray diffraction (XRD) curves obtained for Ti-xNb-5Zr samples demonstrated that no ω phase was found for any composition of Ti-Nb-Zr alloys however, the martensitic phases α' and α'' were easily distinguished with additional few intense peaks of β phase at higher Nb contents. Optical images of all etched TiNbZr samples revealed extensively rich needle like structures proving martensite formation which altered to smooth surfaces with either no or very less lath shaped martensite. An increment in the oxide formation factor was recorded from a value of 2.2 nm V^{-1} (for Ti7Nb5Zr) to 3.7 nm V^{-1} (for Ti45Nb5Zr). Finally, the oxide resistance obtained exhibited an increase with respect to increasing Nb content in Ti5Zr alloy especially for the anodic oxides grown at potentials less than 3 V vs Ag|AgCl|3 M KCl. The resistivity of all TiNbZr alloys were in the range of 0.2–0.4 MΩ cm^2 for non-anodized alloy.

Hardness values evaluated by nano-indention experiment clearly exhibited a linear decline with the slope and intercept of -0.02384 and 3.172 GPa respectively. No clear trend was found for reduced modulus as shown in the Figure 1b.

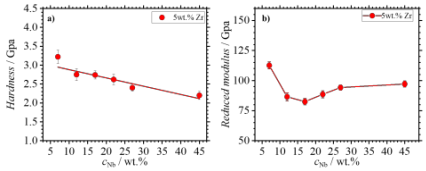

Figure 1: *Hardness (a) and reduced elastic modulus (b) obtained for various Ti-Nb-Zr alloys.*

Conclusions

Depending upon the Nb content (XRD) revealed the presence of various martensitic (α', α'') and β phase. Addition of Nb cause a decline in the hardness of Ti5Zr alloy with an improvement in the oxide resistance in Ringer's solution.

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Acknowledgements

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B14 - Interactions of hydrophilic quantum dots with defect-free and defect containing supported lipid membranes

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Abstract: Quantum dots (QDs) are semiconductor nanoparticles considered as potential nano-theranostic platforms for imaging and sensing. The design and use of QDs requires the understanding of cell-nanoparticle interactions at a microscopic and nanoscale level. Model systems such as supported lipid bilayers (SLBs) are useful, less complex platforms mimicking physico-chemical properties of cell membranes. In this work, we investigated the effect of topographical homogeneity of SLBs in the adsorption of hydrophilic QDs.

Keywords: cell-nanoparticle interactions, supported lipid bilayers, quartz-crystal microbalance, atomic force microscopy.

Introduction

The potential use of nanoparticles as drug delivery, phototherapy and bioimaging agents depends on the understanding and control over nanoparticle-cell interactions [1]. Supported lipid bilayers (SLBs) are convenient artificial membranes models to study the interactions with quantum dots (QDs) *via* surface-sensitive techniques. This subject of intensive research aims at dissecting the role of physico-chemical parameters, i.e., membrane composition, organization, or nanoparticle size. In this work, we used quartz-crystal microbalance and atomic force microscopy to evaluate the influence of defects in SLB such as intact vesicles or bilayer exposed edges, on nanoparticle-lipid membrane interactions.

Results and Discussion

The formation of SLBs was followed in real-time by QCM-D. Homogeneous and inhomogeneous topographies could be obtained by playing with the underlying surface roughness, and checked by AFM. The interactions between hydrophilic, negatively charged CdTe QDs and the lipid layers were studied by the two techniques. In the case of defect-free SLBs, QDs adsorption is driven by electrostatic interactions, leading to no layer disruption. In the case of inhomogeneous layers, QDs target preferentially membrane defects, driven by an interplay of electrostatic and entropic effects, inducing local vesicle rupture and QD insertion at membrane edges [2].

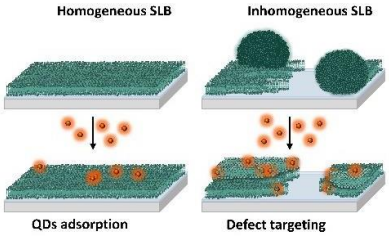

Figure 1: *Simple QDs adsorption onto homogeneous SLB versus defect targeting onto inhomogeneous SLB.*

Conclusions

The information provided can motivate further studies on fundamental mechanisms for defect-mediated QD uptake in more complex biological environments and help towards the design of nanoparticles with specific cytotoxic effects.

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B15 - Modeling and experiments of field-effect capacitors decorated with gold nanoparticles

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Abstract: Nanoparticles are a highly attractive material for the design of field-effect biosensors with increased performance. We present a theoretical model for the behaviour of capacitive electrolyte-insulator-semiconductor sensors (EISCAPs) modified with different coverages of charged gold nanoparticles (AuNPs). The impact of the AuNP coverage on the shift of the capacitance-voltage (C−V) and constant-capacitance signals (ConCap) of the EISCAPs was simulated and studied experimentally. Additionally, the different coverages of AuNPs on the sensor surface were characterized by scanning electron microscopy.

Keywords: capacitive field-effect sensor, gold nanoparticles, capacitive model, nanoparticle coverage.

Introduction

The decoration of biologically sensitive field-effect devices (FEDs) with tuneable nanomaterials, such as AuNPs, oxide nanoparticles, magnetic beads, carbon nanotubes and virus-like particles has opened new horizons for designing biosensors [1].

However, there is a lack of detailed theoretical models for nanoparticle-modified FEDs. Here, we present a capacitive model for capacitive electrolyte-insulator-semiconductor sensors (EISCAPs) decorated with gold nanoparticles (AuNPs), where the capacitance-voltage (C–V) and constant-capacitance signals (ConCap) curves are simulated as a function of the AuNP coverage [2]. Additionally, different coverages of aminooctanethiol-capped AuNPs (AOT-AuNPs) were characterized in the C−V and ConCap mode. The AOT-AuNPs-modified EISCAP surface was physically characterized by scanning electron microscopy to analyze the surface coverage.

Results and Discussion

In Figure 1, the structure and shape of the depletion layer in a p-Si semiconductor is illustrated for an EISCAP modified with ligand-stabilized positively charged AuNPs. In our model, AuNPs are taken into account as tuneable nanometer-sized gates, while the EISCAP consists of AuNP-free and AuNP- covered regions.

The C−V curves were simulated for coverages from n = 0.25 to n = 0.9 and compared to experimentally achieved coverages with AOT-AuNPs from n = 0.12 to n = 0.36. Our theoretical model predicted, that with increasing AuNP-coverage, the amplitude of the gate-voltage shift of the C−V and ConCap curves would also increase. This was confirmed by the experimental results, where a shift of −30 mV was measured for the maximally achieved coverage of AuNPs of n = 0.36. Both, the simulation and experimental results reveal that the AuNP coverage and charge significantly affect the EISCAP signal.

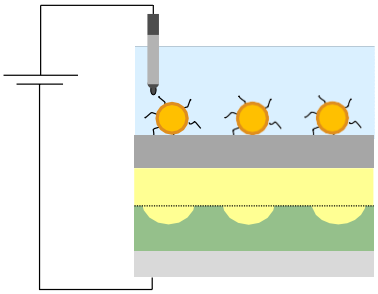

Figure 1: *EISCAP decorated with ligand-stabilized positively charged AuNPs. Adapted from [2].*

Conclusions

The presented capacitive model describes the specific case of EISCAPs modified with AuNPs. It is possible to extend our model to other charged objects, like magnetic nanoparticles, carbon nanotubes or virus-like particles.

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B16 - Surface characterization of fs-laser structured and anodized Ti6Al4V for bone and dental implants

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Abstract: Ti6Al4V dental and bone implants treated with femtosecond laser and subsequent anodization were produced. "Laser-induced periodic surface structures" LIPSS were structured by the femtosecond laser. Subsequently, anodization was done with different electrolytes to investigate its influence on osteoblast growth. The samples were characterized by atomic force microscopy (AFM), scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS). A wettability experiment was completed and finally the bioassessment with osteoblast was undertaken. Produced samples showed both osseorepellent property and increased osseointegration.

Keywords: LIPSS; anodization; osteoblast; implants; Ti6Al4V; osseointegration.

Introduction

Ti6Al4V is a biomaterial used for dental and bone implants. Bone implants such as screws and plates, require explantation after a few months, therefore an osseorepellent surface is needed [1]. On the contrary, for dental implants, a surface with increased osseointegration property is needed. In this work a femtosecond laser [2, 3] treatment combined with anodization was used to produce surfaces suitable both for dental and bone implants.

Results and Discussion

Topography and morphology were characterized by atomic force microscopy (AFM) and scanning electron microscopy (SEM). Femtosecond laser treatment produced micro-cones with superimposed nano-ripples. The average height of cones was found to be 1.95-5.72 µm and the roughness (RMS) 1.32-1.95 µm. Contact angle experiments were done to examine the wettability. It was found that subsequent anodization of the laser treated surface has resulted in increased wettability of the surface which is a desirable feature for implants. To determine the oxide composition the samples were characterized by X-ray photoelectron spectroscopy (XPS). No ion inclusion from the electrolyte was found. Finally, bioassessment with osteoblast was done. Samples anodized with 0.1 M citrate buffer yielded an osseorepellent surface. On the other hand, sample anodized with 0.1 M H_2SO_4 produced a surface with increased growth of the osteoblasts.

Conclusions

Samples anodized with 0.1 M citrate buffer produced an osseorepellent surface suitable for bone implants. On the contrary, samples anodized with 0.1 M H_2SO_4 produced a surface with increased osseintegration property suitable for dental implants.

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B17 - Towards integration of microfluidic key gates for future hardware security

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Abstract: Serious concerns over hardware security are reflected through large-scale hardware attacks in the globalized supply chain of integrated circuits (ICs). In the domain of digital logic-locking schemes several vulnerabilities have emerged in recent years and require attention for future locking strategies. As part of a wider aim at integration of biological information in logic locking of integrated circuits, we propose the implementation of various logic operations by integrating ion-sensitive field-effect transistors (ISFETs) with fluidic-circuits able to process and reversibly convert information from the chemical to the digital domain. In the current prototype, pH value of a fluid act as an indirect 'key' input for logic gate operation. The proposed idea is expected to extend towards implementation of 'biological keys' and be useful in developing paradigm-shifting biological nanoscale logic-locking for future hardware security applications.

Keywords: bioinspired systems, bionanointerfaces, logic locking, ISFETs, microfluidics, hardware security.

Introduction

Logic locking [1] is a powerful technique that can withstand various hardware attacks. In this scheme, several additional gates known as 'key gates' are added in a logic circuit. Unless a correct digital key is provided to these key gates, logic circuit gives a false output and thus functionality of the circuit is hidden. However, several attack models such as Boolean satisfiability (SAT) and machine learning [2] based attacks are found to penetrate through the security provided by logic locking. Here, we propose an idea to go beyond the use of 'digital keys and make use of biochemical or biological information such as pH values and DNAs in the form of 'analog keys' and realize boolean logic operations (NOT and AND, OR). ISFETs are used to read the analog-key and integrated with active microfluidic circuits in unique fashion to perform logic operations [3].

Results and Discussion

To realize the logic gates, we use electrical motor switching valves, actuated by a voltage input. As shown in figure 1, A and B are two voltage inputs to the AND gate (high or low). These valves allow or stop the flow of fluid to the ISFET if input is high or low, respectively. The desired voltage at the output can be set by a constant voltage constant current readout [4] corresponding to a particular pH value. If correct pH fluid flows to the ISFET, the output from readout is 1, else it's 0. Thus, the pH1 and pH2 act like two indirect input bits and desired output of AND gate can be obtained only if the correct pHs are provided. This provides us an opportunity to explore these electrochemical microfluidic logic gates in terms of hardware security applications.

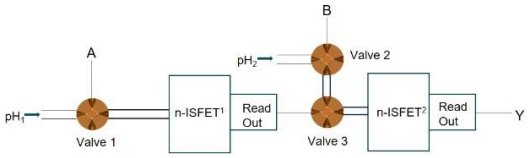

Figure 1: *Realization of two input AND logic gate with ion sensitive field effect transistors, microfluidic valves, electrical read out and two different pHs. A and B are electrical voltage inputs and Y is the output of AND gate.*

Conclusions

A prototype to perform logic operations with ISFETs and active microfluidics is realized as a first step towards the realization of biochemical 'key gates' for future hardware security applications.

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B18 - Compact PCB-based, liquids microheater with modular design for easy integration in educational environments

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Abstract: STEM education in the EU is stagnating, and students are becoming discouraged from pursuing careers in STEM. To reverse this trend, a variety of innovative teaching approaches have been developed. Hands-on education is at the forefront of this movement and the Flui.Go Kit is an example of this. In this work, a microheater was developed using rapid prototyping techniques, capable of safely and reliably increasing the temperatures of solutions to 50ºC, 60ºC, or 70ºC.

Keywords: Microheater, PCB, PID Control, STEM Education, Rapid Prototyping.

Introduction

A 2012 PISA study found that 18% of EU students had low level science skills and that only 28% of students showed an interest in studying STEM [1]. As our society keeps evolving to be more reliant on technology, it will require a workforce capable of understanding these systems. Flui.go, a Maastricht University spin-off, aims to improve STEM education by creating an educational toy that makes complex scientific concepts easy and fun to understand. To expand the capabilities of this toy, a microheater that is reliable and easy to use is needed.

Materials and Methods

Using Rapid Prototyping techniques (PCB/3D Printing/CAD) a microheater was built that needs to rapidly heat liquids to temperatures of 50ºC, 60ºC, or 70ºC.

To achieve this goal, a transistor-controlled circuit was used. The heating element, incorporated onto a printed circuit board (PCB), consists of an exposed copper track (Figure 1). A serpentine pattern was chosen to maximize the amount of direct contact between the heating element and the liquid. To ensure an accurate temperature control system, a PID controller was implemented (Arduino mini pro), the equation for which can be seen below [2].

$$u(t) = K_p e(t) + K_i \int e(t)dt + K_p \frac{de}{dt}$$

A PID controller relies on an accurate and quick feedback system to tell it how it's performing. Two thermistors were used, one at the inlet to measure the temperature of the incoming liquid, and one at the outlet, that relays the exit temperature of the liquid to the PID controller so that it can adjust its current output to the heating element.

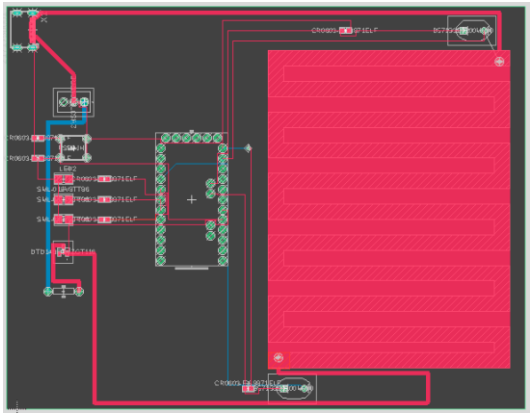

Figure 1: *Printed Circuit Board V1 with integrated heating element.*

Conclusions

The PCB-based microheater, when integrated into the existing Flui.go kit, will enable the expansion of the current pool of experiments in the fields of biology and chemistry. The development of the microheater demonstrates the advantages of rapid prototyping in reducing the time it takes to go from idea to minimum viable product. Furthermore, it opens new possibilities to develop modular add-ons to the kit, ultimately improving the experience that students will have during STEM classes.

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Acknowledgements

The author would like to acknowledge Flui.Go Science for the financial support in this research project.

B19- Electropolymerisation of surface imprinted polypyrrole for the rapid detection of large biological samples

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Abstract: Point of care (PoC) diagnostics acquired importance and recognition in recent times, due to the demonstrated benefits to the general healthcare. Thanks to their advantages in terms of stability and production costs, SIP-based biosensors for the rapid detection of bacteria or other pathological entities, could further boost the diffusion of PoC diagnostic tools. In the present study, a portable and cost efficient device for the synthesis of SIP layers is presented. Two types of templates were used to create the polymer layers which are characterised by SEM imaging. Future outlook of the study would be to characterise the synthesised receptor layer with impedimetric measurements and eventually to integrate such quantitative readout method in the prototyped device.

Keywords: Surface imprinted polymers, E.Coli sensing, Point-of-care.

Introduction

The detection of biological elements is an active area of research that have experienced rapid growth in the past decades. New, more efficient and tailored sensing technologies have been developed. Medical diagnostics is an active and dynamic area of research in sensor engineering, particularly concerning cell-based biosensors [1, 2]. A clear example is given by infectious diseases, which pose a great risk to public health and in which often the medical response is delayed or absent because of a misdiagnosis [3].

Materials and Methods

In this work a flexible printed circuit (FPC) was designed and manufactured through the website PCBway.com. The circuit is made of copper tracks coated with a thin layer of gold, sandwiched between layers of polyimide. Electrochemical deposition process of Pyrrole was performed with an IKA Electrasyn 2.0 machine. A custom made top enclosure was designed and 3D printed in order to allow consistent results between different polymerization runs. The polymerisation solution used consisted of a mixture of 0.1 MNa Phosphate buffer 0.1 M pyrrole monomer and 0.1 M LiClO4. E. Coli cells and MG-63 cells were suspended in the polymerisation solution respectively at a concentration of 10^8 cell/ml and 10^6 cell/ml.

Results

After the deposition process is complete, the electrode changes aspect, transitioning from a bright gold to a black colour. SEM microscopy confirmed the polymer deposition and allowed for the characterization of the superficial morphology of the deposited film. Non-imprinted pyrrole layers showed a characteristic surface morphology, with macro patterns and micro porous texture (Figure 1.A, 1.B), while imprinted layers showed cavities left by the targets.

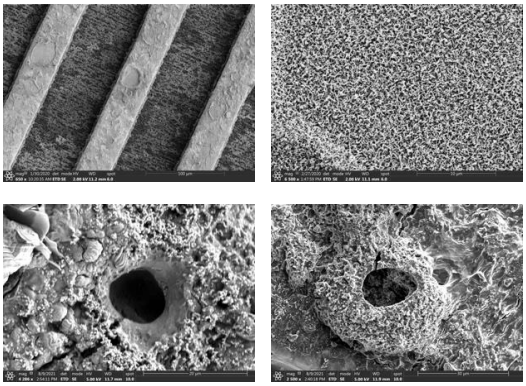

Figure 1. A and B show the characteristic pattern of non-imprinted layers. C and D show the imprints left by the target (MG-63 cells).

Conclusion

Electropolymerised imprinted layers offer numerous advantages in terms of durability and costs when compared to classical biosensor recognition elements. This technology is well suited for point-of-care applications as it can be integrated on a benchtop device. A suitable readout method could be impedimetric analysis. Electrical characterisation of the imprinted layers and their rebinding capacity will follow.

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B20 - Towards a dual-modality field-effect/magnetic immunosensor chip

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Abstract: Electrolyte-insulator-semiconductor (EIS) sensors are a promising platform for direct electrical detection of biomarkers by their intrinsic charge. However, their sensitivity is limited by screening of charges in solution with high ionic strength. Frequency mixing magnetic detection (FMMD) of magnetic nanoparticles (MNP) allows detecting biomarkers in physiological conditions. We aim at combining field-effect and magnetic detection techniques to overcome limitations of both methodologies.

Keywords: capacitive field-effect sensors, electrolyte-insulator-semiconductor (EIS), frequency mixing magnetic detection (FMMD).

Introduction

Electrolyte-insulator-semiconductor (EIS) sensors can detect biomolecules by their intrinsic molecular charge [1]. The sensitivity of EIS sensors is limited by the charge-screening effect and low selectivity in samples with multiple-charged species. One promising strategy to overcome these drawbacks is the coupling of magnetic nanoparticles (MNP) as receptor carriers. An external magnet pulls the MNP with their targets towards the EIS sensor surface.

The frequency magnetic mixing detection technique (FMMD) enables quantification of superparamagnetic nanoparticles and probing of their binding state to biological targets [2]. The MNPs are exposed to a low-frequency field (f_1), which drives the particles into saturation, and a high-frequency field (f_2) to probe the MNP's nonlinear magnetization. The magnetic response of MNPs contains intermodulation products of both excitation frequencies and induces a voltage in the detection coil. The demodulated frequency mixing components (f_1+nf_2) are characteristic of the particles' properties. Brownian relaxation causes phase shifts that yield information about the MNP's hydrodynamic radius.

Results and Discussion

A dual-modality field-effect/magnetic immunosensor chip (FEMIC) can overcome the individual limitations of EIS and FMMD sensing. The dual-modality biomarker detection technique is illustrated in Figure 1.

The principle of the FEMIC technique is to bind the biomarker molecules in the mixture of MNPs in physiological conditions. Antibodies are conjugated on the surface of the MNPs.

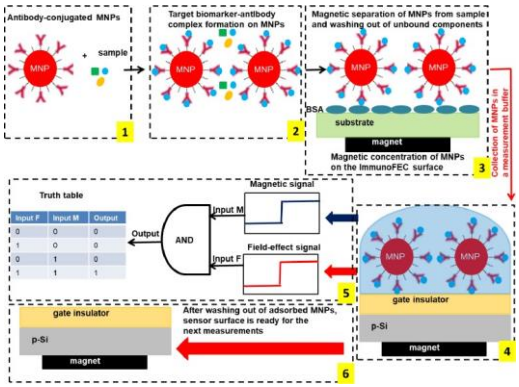

Figure 1: *Concept for a dual-modality field-effect/magnetic immunosensor chip.*

Magnetic separation principle is used to exploit MNPs as carriers that deliver bound biomarkers towards the surface of the EIS chip in a low-ionic strength buffer. The EIS system probes the charge of the adsorbed molecules, whereas the FMMD technique probes the binding between MNPs and biomarkers. This dual-modality technique can improve the overall selectivity and sensitivity.

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Acknowledgements

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B 21 - Development, Fabrication and Characterization of a Transformable and Biocompatible Electrode for Peripheral Nerve Interfacing

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Abstract: Peripheral nerve interfaces (PNIs) provide the opportunity to monitor neuronal activity or treat diseases via bioelectronic intervention. Yet, there are several challenges involved with implanting nerve interfaces such as triggering severe foreign body reactions. Developing PNIs for small nerves is particularly challenging due to microfabrication obstacles, for instance tight bending radii in cuff electrodes, or adequate anchoring to the nerve. In this study, a transformable and biocompatible extraneural PNI made out of parylene-C and platinum-iridium for small nerve interfacing is developed. The fabrication of the small cuff is achieved by a thermoforming process in which a mold is connected to the electrode tip and subsequently rolled into the desired shape.

Keywords: peripheral nerve interface, cuff electrode, parylene-C, thermoforming, locust implantation.

Introduction

The first implemented PNIs were developed in the 1960s and could be used, for example, for diaphragm pacing or treatment of urinary incontinence [1], [2]. Since then, significant advancements in material science and signal processing have led to a variety of implantable PNIs capable of recording and stimulating neural activity with increased selectivity, especially compared to their non-invasive counterparts [3]. Yet, targeting very selective small nerves remains a challenge. Here, we present an easy-to-implement process for fabricating neuronal electrodes that allow interfacing with small nerves from a locust.

Results and Discussion

A fabricated cuff electrode with an inner diameter of 150 µm is shown in Figure 1. Electrochemical characterization of the electrode showed appropriate properties for stimulation as well as for recording.

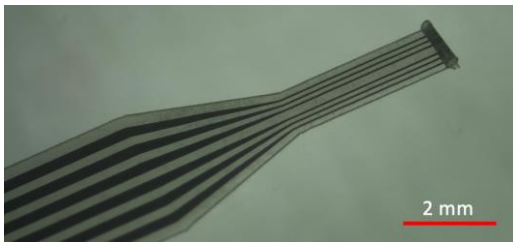

Figure 1: *Fabricated parylene-based platinum-iridium cuff electrode with 6 feedlines.*

Implantation into the locust was fast, simple, and showed an adequate fit around the nerve. In addition, visible leg movement could be triggered by simulating the N5 (Figure 2). Consecutive stimulation using different electrode sites with various amplitudes revealed a certain degree of selectivity, which could be exploited in future applications.

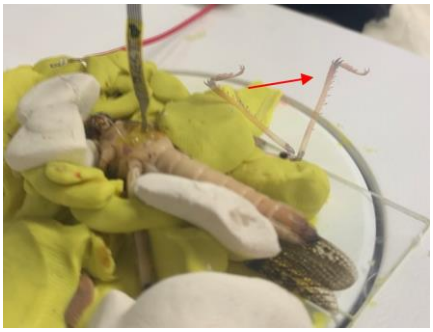

Figure 2: *Overlayed image showing the implantation of a fabricated electrode into the locust (N5). Visible leg movement could be triggered by applying a biphasic pulse. The minimum and maximum extension of the leg is shown.*

Conclusions

We developed a thermoforming process for the fabrication of cuff electrodes, suitable for stimulating small peripheral nerves. Since the diameter of the cuff is only dependent on the diameter of the mold, electrodes can be easily adapted to different nerve sizes for various applications.

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Topical Session C: Smart Devices and Instrumentation – Schedule

Keynote Lecture 3: Magnetic Biosensing and Frequency Mixing Magnetic Detection - Prof. Dr. Hans-Joachim Krause (FHAachen University of Applied Sciences, Campus Jülich, Germany)

Short Oral Presentations

C1 – Ivana Zrinski – Anodic memristors formed on Hf and Ta thin films

C2 – Anika Wulff – Simulation of electrodes interface aging due to interfacial diffusion in AIMDs

C3 – Arnoud Jongeling – Two-photon polymerized microarrays for membrane protein smFRET

C4 – Josef Alexander Bolten – Design of a precise electrophoretic delivery system for simultaneous…

C5 – Danyil Azarkh – Viscoelastic properties of non-Newtonion fluids measure by the magnetic pL…

C6 – Joseph W. Lowdon – Molecularly imprinted polymer based dye displacement assay for the…

C7 – Eashika Ghosh – Concept of multi-layer flexible microelectrode arrays with active electrode…

C8 – Heping Cui – 2D Tellurium-based transistor for biosensor applications

C9 – Lena Hegel – Selective treatment of seizure-like activity in brain slices with capillary ion pumps

C10 – Ramiro Marroquin Garcia – Polyphosphate-based hydrogels for drug delivery applications

C11 – Seppe Bormans – Liquid identification in a microplate format based on thermal and electrical…

C12 – Kevin A. Janus – Curing parameters of a silicone-free carbon electrode screen-printed on a…

C13 – Mohammad Mahdavinasab – Measuring flow rate or mixture ratio by means of thermal…

C14 – J. Royakkers – Early diagnosis of childhood asthma using functionalized diamond substrates

C15– Lukas Hiendlmeier – Towards 4D-printed self-folding cuff electrodes to interface peripheral nerves

C16– Robin Severins – Electrically enhanced microbial hydrogen production at the intersection…

C17 – Jolan Wellens – Towards monitoring implant induced inflammation: hydrogen…

C18 – Andreas Greul – The corrosion of titanium dental implants in the context of a novel…

C19 – Zeynep Izlen Erenoglu – Thin-film porous microelectrode arrays for cell culture applications

C20 – Milad Eyvazi Hesar – Fabrication of coils for wireless, NFC-enabled, stretchable (POSTER ONLY)

C21 – F. Jiang – Platform for high spatial resolution measurements of in-plane (POSTER ONLY)

Poster market with coffee

Magnetic Biosensing and Frequency Mixing Magnetic Detection

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Abstract: Due to its non-invasive nature, magnetometry is a versatile methodology for biosensing. Biomagnetism denotes the purely passive recording of the inherent magnetic field of humans due to electric activity of cells. These extremely small magnetic fields originating from the human heart or brain are recorded with Superconducting Quantum Interference Devices (SQUIDs). Magnetic nanoparticles (MNP) functionalized with antibodies are employed as markers for specific biomolecules. They are selectively detected by means of frequency mixing magnetic detection (FMMD) and yield information on their binding state.

Keywords: Biomagnetism; Magnetic Nanoparticles; Frequency Mixing Magnetic Detection (FMMD); Magnetic Immunoassays

Introduction

An overview of various applications of magnetic field measurements in the field of biosensing is given. Due to the extremely small magnetic field amplitudes generated by electrical action currents inside the human body, recordings of magneto-encephalograms (MEG) and magnetocardiograms (MCG) require ultimately sensitive SQUID sensors and sophisticated suppression of environmental disturbances [1]. For selective detection of biomolecules in magnetic immunoassays, the nonlinear magnetic response of antibody-functionalized MNP is detected by means of Faraday coils and FMMD.

Results and Discussion

FMMD probes the nonlinear magnetization curve of superparamagnets [2]. Upon magnetic excitation at two distinct frequencies f_1 and f_2 incident on the sample, response signals generated at frequencies representing linear combinations $m \cdot f_1 \pm n \cdot f_2$ are detected, see Fig. 1. The appearance of these components is highly specific to the nonlinearity of the magnetization curve of the particles. With this technique, magnetic sandwich immunoassays for detection of Cholera toxin B [2] and *enterococcus faecium* in water, and competitive magnetic assays for penicillin and kanamycin in milk and SARS-CoV-2-specific antibodies in blood [3] have been developed. Coaxial coils provide magnetic excitation fields at two distinct frequencies, e.g. f_1 = 40.5 kHz and f_2 = 63 Hz, incident on the sample. By means of a differential pickup coil, the response signal of the sample inside the coil at frequency $f_1 + 2 \cdot f_2$ is detected. Analysis of the phase of the response gives information on the particles' magnetic relaxation, and thus on their hydrodynamic size and binding state. Variation of excitation amplitudes or static magnetic offset field yields the size distribution of the magnetic cores of the MNP.

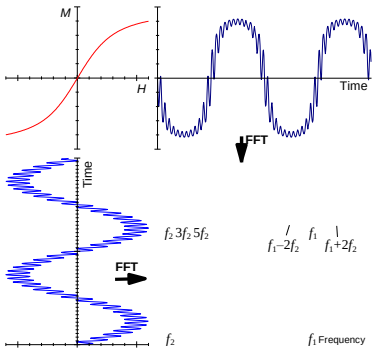

Figure 1: *Upon two-frequency magnetic excitation (light blue), MNP's nonlinear magnetization (red) yields a flattened magnetic response (dark blue) containing harmonics (e.g. $n \cdot f_2$ with odd n) and intermodulation products (e.g. $f_1 \pm n \cdot f_2$ with even n).*

Conclusions

Sensitive magnetometry enables both contact-free measurement of intracorporeal electric currents for human heart and brain diagnostics, and sensitive and selective detection of various biological targets (e.g. proteins, viruses, bacteria, cells, and toxins) via the nonlinear magnetic response of MNP markers.

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Acknowledgements

Support by German BMBF (project no. 13N15253), BMEL (2818710C19), EFRE-NRW (0801299) and DFG (KR3864/8-1) is gratefully acknowledged.

C1 - Anodic memristors formed on Hf and Ta thin films

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Abstract: Nowadays, development of materials for memristive applications is crucial due to the fact that the conventional memory technology has reached processing speed and power consumption limits. In the current study, memristive effects were observed for devices grown on Hf or Ta, used as bottom electrodes. Their respective anodic oxides play the role of the insulating/active layers and Pt were patterned as top electrodes. The performance of Hf and Ta anodic memristors was tremendously improved, while their switching mechanism was explained by conductive filaments formation, successfully imaged by TEM.

Keywords: valve metals, anodic oxides, memristors, conductive filaments

Introduction

Memristors are excellent novel examples in computing systems in which the storage mechanism is based on the resistive switching between high and low resistance states.[1] Such devices are memories in metal-insulator-metal form, frequently based on valve metals and their oxidized forms. The selection of materials plays important roles regarding the performance of device due to the (nano)-conductive filaments formation initiated by ionic drift inside the oxide.[2] Accordingly, anodic fabrication methods are relevant due to the possibility to develop defect-engineered devices.[3–6]

Results and Discussion

Anodic memristors grown on Hf and Ta have shown improved memory and electrical characteristics. The memristive effect was investigated by performing typical *I-U* sweeps. Both Hf and Ta devices switched bipolarly in low voltage range. Additionally, the resistance state ratio was extracted from I-U measurements, which is an important characteristic, describing memory window and power consumption of devices. It was observed that these characteristics varied for memristors grown in different electrolyte solutions. Furthermore, the device lifetime and data retention were longer for memristors anodically formed in phosphate buffer (PB). The switching mechanism of memristors grown on Hf and Ta thin films was explained by conductive filaments (CFs) formation inside of Ta_2O_5 or HfO_2, respectively. The structure of oxides, electrodes and conductive paths were imaged by TEM. Electrolyte species incorporation was confirmed by XPS for both oxides. Finally, optimal electrochemical parameters and solutions were selected for the fabrication of high-performing anodic memristors.[3–5]

Conclusions

The results have confirmed that performance of devices depends on bottom and top electrodes, as well as the oxide nature and its fabrication methods. Understanding these facts, pushes the development of memristor closer to industrial implementation.

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Acknowledgements

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C2 - Simulation of electrodes interface aging due to interfacial diffusion in Active Implantable Medical Devices (AIMDs)

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Abstract: Interfacial diffusion between silicone rubber and metal, like in a cochlear implant, has not yet been described mathematically. This work offers approaches for the description and implementation in a model in COMSOL Multiphysics by using the Stephan equation.

Keywords: moving boundary diffusion, AIMD, interfacial diffusion, lifetime prediction, COMSOL Multiphysics, Stephan Problem

Introduction

Leakage is one of the most common failure mechanism of e.g. cochlear implants (CI). This is due to permeation of fluids (perilymph) into the electrode interface. In case of CIs it is a platinum-iridium electrode encapsulated with polydimethylsiloxane (PDMS) which serves as a carrier material and electrical insulation. [1] In this work, the interfacial diffusion between PDMS and the electrode will be simulated. For this purpose, the software COMSOL Multiphysics is applied.

Preliminary tests were carried out to visualize the interfacial diffusion. Therefore copper and potassium polysulfide (K_2S_x with x = 2-6) were selected. The special feature of this material combination is a colour change at contact. Based on the chemical reaction, the migration along the interface of the PDMS drop and copper can be shown. This diffusion migration can be specified with the help of the Stefan Problem [2]

$$x(t) = \alpha\sqrt{t}$$

where x describes the position of the moving boundary according to time t and α is a factor including the diffusion coefficient, consumption rate and the needed concentration of potassium polysulfide for the colour change.

This equation can be implemented in COMSOL Multiphysics. So far, there is no predefined physics module for interfacial diffusion. Therefore, points are defined on the adjoining edge of the silicone rubber to copper. These are detached from the copper with the help of the command *prescribed displacement*. For this purpose, a displacement in the y-direction is carried out. To couple the displacement in y-direction with the displacement in x-direction, a ramp function is used.

Results and Discussion

By implementing a line integral, the gap length can be plotted (see figure 1). The calculated data of the gap are permanently smaller than the experimental data. This could be due to the fact that it was not possible to visualize interfacial diffusion experiments without bulk diffusion in that simple test setup.

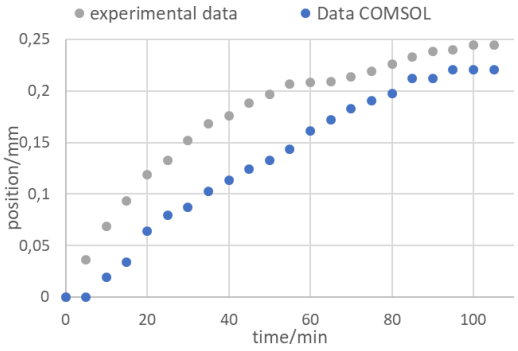

Figure 1: *Position x of the interfacial diffusion front depending on the time t; grey points describe the experimental data and blue ones the data calculated from COMSOL Multiphysics*

Conclusions

In order to obtain a model for life time prediction, more failure mechanism have to be implemented. Other mechanisms such as the bulk diffusion or thermal stresses are considered.

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Acknowledgements

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C3 - Two-photon polymerized microarrays for membrane protein smFRET

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Abstract: We demonstrate that a commercial multiphoton laser scanning microscope can be used for microscale 3D printing via two-photon polymerization. This is achieved via a custom STL slicer implementation that can automate a Zeiss LSM880 NLO microscope. We fabricate planar microaperture arrays and demonstrate formation of pore-spanning membranes by way of lipid painting, with the aim of enabling single-molecule studies of membrane proteins.

Keywords: Two-photon polymerization, lipid membrane array

Introduction

Two-photon polymerization (2PP) is a lithography method where a photoresist is selectively polymerized using a high intensity pulsed laser focused on a sample using a microscope objective. Dissolving away the un-crosslinked resist the yields the final structure [1].

Single-molecule Förster resonance energy transfer (smFRET) measurements allow fluorescence-based readout of protein structural dynamics [2]. In this work, we demonstrate two-photon polymerization on a commercial multiphoton laser scanning microscope (LSM) to fabricate microarrays for smFRET studies of membrane proteins.

Results and Discussion

A laser scanning microscope is typically capable of selective blanking during frame scanning, allowing for illumination of arbitrarily defined regions of interest. We use a custom Python script to convert slices of 3D models to these regions of interest and expose the slices using a multiphoton laser, thus allowing illumination of arbitrary 3D structures within the microscope's field of view.

Both 2D and 3D structures were fabricated using two-photon polymerization, showing a writing resolution finer than 400 nm.

We used two-photon polymerization to fabricate planar microaperture arrays in SU-8 photoresist on a glass coverslip substrate. We then formed phospholipid membranes on the microarrays by the lipid painting method. Osmotic pressure differences caused the membranes to indent and protrude, indicating a watertight sealing of the apertures.

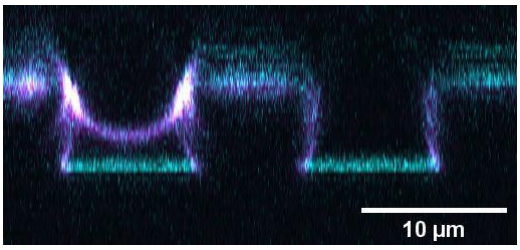

Figure 1: *Optical section of lipid membrane formed across a microaperture (left). Confocal microscopy with both reflectance (cyan, showing optical interfaces) and fluorescence (magenta, showing labelled phospholipid) channels. Membrane is indented into the aperture by hypertonic conditions above the membrane.*

Conclusions

The Zeiss LSM880 NLO, a commercial multiphoton LSM, is fully compatible with 2PP lithography. This is especially attractive for multidisciplinary institutes that already have a multiphoton LSM available for biomedical imaging applications, allowing microfabrication with minimal additional investment.

The microarrays will allow for studies of membrane protein molecules by smFRET, by confining the motion of the protein to the focal plane of a microscope. This will allow both longer observation times and a higher level of parallelization than traditional burst smFRET experiments allow[2].

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Acknowledgements

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C4 - Design of a precise electrophoretic delivery system for simultaneous chemical stimulation and electrical recording of cells

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Abstract: Organic electronic ion pumps (OEIPs) enable high spatial and temporal resolution and electrophoretic delivery of bioactive substances without fluidic transport using ion-exchange membranes (IEMs) as channels. Therefore, this technology is promising for drug-delivery systems, neural implants, and cell-signaling research. We designed a system with four release sites for the delivery of different substances, able to elicit cell reactions. It is planned that additional PEDOT:PSS electrodes record the cells' responses to the local chemical stimulation.

Keywords: ion-exchange membranes, micro-fabrication, organic electronic ion pumps, neural stimulation.

Introduction

OEIPs make use of the co-ion exclusion of polyelectrolytes in IEM-materials. Applying a voltage between two electrolytes, separated by an IEM, leads to a unidirectional flux of ions from the source electrolyte through the ion-selective channel to the target electrolyte. By using a three-reservoir system, the channel can be pre-loaded in order to shorten the distance the ions travel to the target reservoir once the transport is turned on, which reduces the stimulation delay significantly. [1] Both over-oxidized Poly(3,4-ethylenedioxythiophene) (PEDOT:PSS) and Poly(4-styrenesulfonic acid-co-maleic acid) cross-linked with Polyethylene glycol (PSS-co-MA/PEG) are suitable cation exchange membrane materials for photolithographic patterning with the ability to transport different alkali-ions and neurotransmitters. [2] For simultaneous recording of neurons, PEDOT:PSS electrodes can be integrated.

Results and Discussion

Lithography masks have been designed to fit one central and eight external electrolyte reservoirs on a 1.6 x 1.6 cm^2 chip (Figure 1a), thus allowing for four pre-loadable delivery channels that can transport different combinations of neurotransmitters to four sites in a cell culture. PEDOT:PSS electrodes in the reservoirs can be used to translate electric to ionic current. Nine PEDOT:PSS electrodes contacted by gold contact lines were arranged around the four release sites to be able to measure reactions by the cells (Figure 1b). Both over-oxidized PEDOT:PSS and PSS-co-MA/PEG were used as IEM-channels. The devices can be passivated with SU-8 or Parylene-C, reservoirs for containing electrolytes with neurotransmitters and cell cultures.

Conclusions

Lithographic patterning of the IEM materials was successful on glass wafers with structures as small as 20 µm (Figure 1c). First measurements have been carried out that prove the ability to transport ions through the IEM channels. These experiments lay the foundation for future cell-culture and tissue experiments. The goal then will be to integrate the OEIPs in multi-functional setups with microfluidics and electrode arrays.

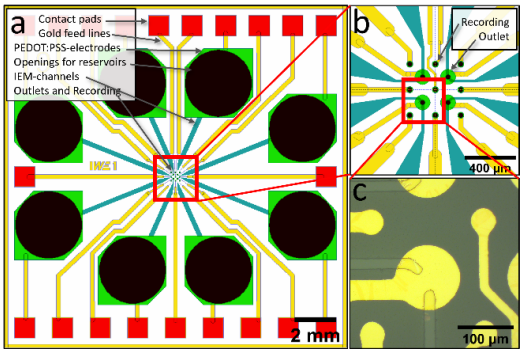

Figure 1: *(a) mask design of the whole chip with all layers. (b) zoom to the outlets and recording sites; (c) microscope image of fabricated gold microelectrodes with IEM-channels (bottom left)*

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Acknowledgements

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C5 - Viscoelastic properties of non-Newtonian fluids measured by the magnetic pL – droplet deformation method

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Abstract: The viscoelastic properties of non-Newtonian fluids are of particular interest because of their similarity to soft tissues and cells. Here we present a magnetic setup and use pL-droplet deformation method for measuring rheological properties of corn starches with different concentrations.

Keywords: Viscoelastic properties, ferromagnetic droplet, non-Newtonian liquid, creep curves

Introduction

Today non-Newtonian fluids are associated with the development of biomechanics, biohydrodynamics, and the food industry [1]. There is a widespread interest to characterize these non-Newtonian fluids with respect to their viscoelastic properties.

Results and Discussion

We used a magnetic setup that can determine rheological properties of soft materials by applying a homogeneous magnetic field to ferrofluid droplets, which are injected into the material (Fig 1a). By measuring the time-dependent droplet deformation under an applied constant magnetic stress, the creep regime can be determined (Fig 1b).

For proof-of-concept, the setup was used to characterize the viscoelastic properties of starch. Starches of different concentrations from normal corn (NC) and waxy corn (WC) were purchased from Sigma-Aldrich and prepared according to [2]. Measurements were carried out at 37 °C.

Ferrofluid droplets were injected into the starches by micropipettes. After applying constant magnetic stress, the time-dependent strain was calculated from measuring the minor and major radius of the elliptically deformed droplet. The obtained creep curves are shown in Fig 1b. The creep behavior of starch can be well described by an appropriate mechanical equivalent circuit, for example, the generalized Kelvin-Voigt model (GKV) or generalized Maxwell model (GM) [3]. While the GM model describes viscoelastic liquids, it would be better suited for a precise physical description of the experiment. Therefore, the GKV is easier to calculate and can be analytically described by equation (1) [2],

$$\varepsilon(t) = \frac{\sigma}{E_0}\left(1 + \frac{E_0}{E_1}\left(1 + e^{-\frac{t E_1}{\eta_1}}\right) + \frac{E_0}{E_2}\left(1 + e^{-\frac{t E_2}{\eta_2}}\right)\right)$$

The extracted coefficients (E_0, E_1, η_1, E_2, η_2) from the fitted function (1) can be transformed to the respective coefficients in GM (E_0^m, E_1^m, η_1^m, E_2^m, η_2^m) according to the known relations between the two models [3]. Values of elasticity and viscosity at two retardation time constants are presented in Fig. 1b. The high value of E_1^m and the low values η_1^m represent the instantaneous impact of the ferrofluid droplet on the starch. E_2^m and η_2^m represent delayed elasticity and viscosity, respectively. A comparison with oscillatory tests according to reference [2] allows us to consider the delayed elasticity E_2^m and the viscosity η_2^m as the Young's modulus and the viscosity of the starch.

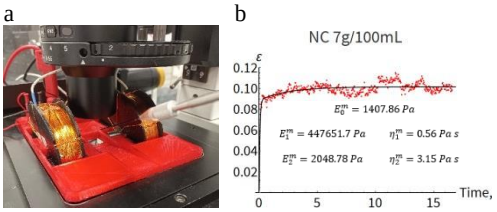

Figure 1. *(a) Photograph of the magnetic setup. (b) Creep curve of NC 7 g/100 mL (dots) and fitted function (line). E_0^m is the capillary stress from the ferrofluid droplet, E_1^m and η_1^m describe the instantaneous elasticity and viscosity, while E_2^m and η_2^m denote the delayed elasticity and viscosity, respectively.*

Conclusions

The combination of a novel magnetic test setup with a micro-sized measurement probe offers the unique opportunity to determine local viscoelastic properties. The system is now qualified can be applied to biological tissues and cells.

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C6 - Molecularly imprinted polymer based dye displacement assay for the detection of amphetamine

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Abstract: Traditionally the rapid sensing of drug compounds relies upon the use of chemical reagents, enzymes, antibodies, and electrochemical methods. These technologies are however limited and frequently provide false positives/negatives and require specific conditions to operate under. We therefore propose a Molecularly Imprinted Polymer (MIP) based dye displacement assay that is capable of providing a rapid colorimetric response in the presence of a target drug, while also being able to perform in more challenging environments.

Keywords: Molecularly Imprinted Polymers, Displacement, Colorimetry, Amphetamine, Sensing

Introduction

Discovered in 1887, amphetamine has been notoriously a drug of abuse over the decades with its uses varying from a cognitive enhancer to even an aphrodisiac. Current rapid detection methods (e.g. immunoassays, ELISA) struggle to differentiate between amphetamine and other compounds (e.g. tricyclic antidepressants, ibuprofen, pheniramine), resulting in a desperate need for more selective forms of rapid analysis[1]. Molecularly Imprinted Polymers (MIPs) are a possible solution, operating on the same binding principles of enzymes and antibodies, but offering higher physical stability and greater tunability[2]. These synthetic receptors can be transformed into a rapid assay for amphetamine detection by coupling the MIP with a dye that can be displacement upon the binding of amphetamine to the polymeric structure [3, 4].

Results and Discussion

The sensor was developed by initially analysing various MIP compositions for an optimum polymer for the specific binding of amphetamine. The resulting methacrylic acid and ethylene glycol dimethacrylate based polymer had an imprint factor (IF) of 4.4 and a maximum binding capacity of 93.13 µmol g^{-1}, making it perfect for binding amphetamine. Various dye molecules were then tested against the MIP, incubating increasing concentrations of each molecule with known masses of MIP powder to monitor their binding to the polymer. It was subsequently found that the MIP had a high affinity towards crystal violet while simultaneously holding a lower IF value (1.7), making it the optimum dye to be displaced from the polymer when amphetamine was introduced to the system. Crystal violet when then incubated with the MIP and excess dye removed by vigorously washing the dye loaded MIP powder with water. The response of the generated assay was then determined by incubated 20 mg of crystal violet loaded MIP-powder with increasing concentrations of aqueous amphetamine (0.01 – 1 mg mL^{-1}) and monitoring the concentration of dye displaced into the surrounding aqueous medium (Figure 1).

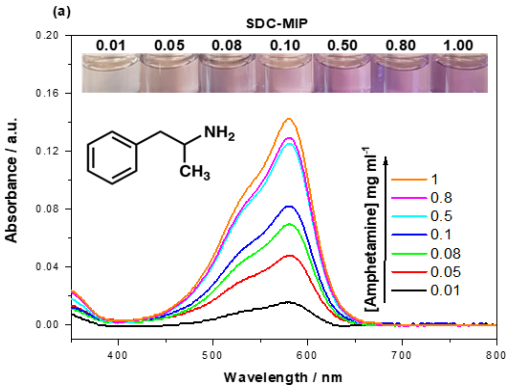

Figure 1: *Dose response of the MIP-based dye displacement assay in the presence of increasing cocnentrations amphetamine (0.01 – 1 mg mL^{-1})*

The resulting assay yielded an excellent sensitivity towards amphetamine, with a clear visual confirmation of the compound above 0.05 mg mL^{-1} in a quantitative fashion.

Conclusions

Overall, the research highlights how a MIP can be converted into a colorimetric tool that offers huge potential in the field of rapid, low-cost, and field analysis of compounds.

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C7 - Concept of multi-layer flexible microelectrode arrays with active electrode addressing for future epiretinal implants

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Abstract: An innovative, multifunctional, and flexible epiretinal implant is developed especially for blind patients suffering from Retinitis Pigmentosa (RP). In our project, a new generation of implants with an active stimulation electrode array should be integrated into a flexible substrate. As a first step, new designs of foldable arrays were realized in Parylene-C with the aim, to enhance the resolution and field of view with the new concept.

Keywords: microelectrode array, high stimulating electrodes, flexible multilayer substrate

Introduction

The 260 different hereditary retinal diseases, such as RP, affect approximately 1.5 million people worldwide [1]. In the retina, RP damages the photoreceptors resulting in complete blindness. Restoring the vision with the help of generic implants, however, is very challenging. In the past, some of the commercial visual prosthetics were showing optimistic results, but limited resolution and field of view [2]. For instance, the previous VLARS project (very large electrode arrays for epiretinal simulation) in our institute addressed different implant designs and the complications during surgery [3]. Therefore, our aim is to design and fabricate a flexible microelectrode array, which could be adapted for a high stimulation electrode count and resolve the major limitations of resolution and field of view. The implants should utilize a high number of stimulation electrodes, which can be addressed, individually [4, 5].

Figure 1: *The new concept for foldable and flexible epiretinal implants with multiple functionality. First test structures were realized in Parylene-C.*

Results and Discussion

We designed a flexible foil that could accommodate the large number of stimulation electrodes (> 1000). The foil is foldable like the former VLARS designs, allowing the foil to be inserted into the eye via a small incision of only 5 mm in the cornea, avoiding major surgical complications. In a first test, different structural designs were fabricated by using Polyimide (PI) or Parylene-C. After first handling tests and implantation tests into cadaver eyes, the arrays will be contacted with tri-layer gold interconnects and covered with iridium oxide (IrOx), which is known to exhibit excellent stimulation properties for neuronal tissue. For an active addressing of an electrode matrix active elements like thin silicon transistors, switching matrix, and solar cells for power harvesting will be integrated.

Conclusions

The first concepts and test structures of the flexible implants will be presented, which will be capable of integrating the multifunctional, active elements in the stimulation electrode area contacting the retina. The results of the implantation test for these structures will determine the final design for our next generation retina implants.

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C8- 2D Tellurium-based transistor for biosensor applications

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Abstract: Electrochemical biosensors hold great promise for portable, low-cost and label-free detection of clinically or environmentally relevant targets. Here, few-layer tellurium nanoflakes were prepared by facile liquid-phase exfoliation. AFM, TEM and EDS techniques were utilized to characterize the presence of tellurium nanoflakes and their morphology. The electrical characterizations revealed an improved electrical contact between tellurium and Au after thermal annealing at 100°C for 10 min. Meanwhile, the stability of tellurium nanoflakes was evaluated in ambient environment and in aqueous solution.

Keywords: tellurium nanoflakes, field-effect transistor, biosensor, electrical characterization.

Introduction

2D tellurium is a p-type semiconductor, which has recently attracted intensive interests due to its facile preparation and its excellent optoelectronic and electronic transport properties [1-3]. These appealing properties make it a promising candidate for sensors, in optoelectronics and in integrated circuits, etc. In this work, we aim to develop a biochemical sensor based on 2D tellurium and therefore characterized it in a liquid-gate configuration.

Results and Discussion

The tellurium nanoflakes were prepared by the typical liquid-phase exfoliation method [3]. A series of characterization techniques including AFM, EDS and SEM were performed to verify the quality of the tellurium nanoflakes. Interdigital electrodes (IDEs) were fabricated by Ti/Au evaporation on Si/SiO_2 wafers using photolithography and a lift-off technique. A parylene C layer was deposited to passivate the metal contact lines of the devices. After that, 2D tellurium flakes were spin-coated on IDEs followed by baking at 60°C for 30min.

The electrical measurements indicated Ohmic contacts between tellurium and the Au contacts. After a second annealing treatment at 100°C for 10min, a clear enhancement of the electrical performance was observed (figure 1). In subsequent stability tests, the tellurium devices showed a satisfactory stability in aqueous solutions and kept their good electrical conductivity after 15 days storage in air. These results reveal that 2D tellurium has a promising potential to be applied in electronic devices. In the next step, tellurium-based field-effect transistors (FETs) will be fabricated with our technique to explore their possible application for the detection of pH, DNA, etc.

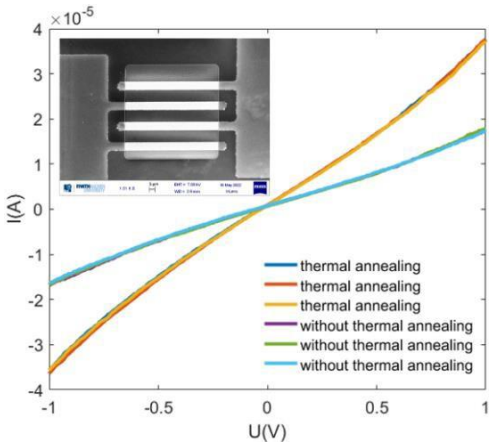

Figure 1: *Electrical repeatability measurements of tellurium-based devices with and without thermal annealing at 100°C. The insert shows an SEM image of an exemplary tellurium device.*

Conclusions and Outlook

Tellurium nanoflakes can be obtained by a facile liquid-phase exfoliation method. Electrical characterizations exhibited good Ohmic contacts to Au, a favourable stability in aqueous solution and a good electrical conductivity after 15 days of storage. In the future, we aim to develop 2D tellurium based FET sensors for chemical and biomedical sensing applications.

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C9 - Selective treatment of seizure-like activity in brain slices with capillary ion pumps

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Abstract: Polymer-based ion exchange membranes (IEMs) are used for numerous applications, including electrophoretic drug delivery devices such as the organic electronic ion pump (OEIP). These devices can be used to locally deliver molecules and neurotransmitters to neuronal tissue in order to prevent malfunction or failure of signal transmission. Local application of γ-Aminobutyric acid (GABA) can help to suppress epileptic activity and will eventually provide an alternative to conventional treatment methods.

Keywords: ion exchange membranes, neuronal disease, drug delivery device

Introduction

Epilepsy is one of the most common chronic neurological disorders, with approximately 5-10 cases per 1000 population. Current treatment options for epilepsy are mainly based on symptomatic therapy with drugs which must be taken for life, while causing side effects in just under half of the patients [1]. An optimal solution would be to deliver drugs directly to the exact brain area in which they are needed. Results of previous studies have shown that planar OEIPs are able to deliver enough GABA to quickly and locally suppress epileptic activity [2].

Results and Discussion

Human cortex slices from epilepsy patients are examined with a 256-electrode multielectrode-array (MEA) and the Multichannel Systems (MCS GmbH, Reutlingen, Germany) recording system. The ion-conducting material that transports GABA is integrated into glass capillaries with an outer diameter of only 60 - 300 µm [3]. The capillary and the medium around the cortex slice are biased with a voltage of 2 V to ensure ion-electronic molecular transport. The setup of the experiment with the individual components is shown in Figure 1.

Conclusions

In this study, we want to demonstrate a highly precise local application of GABA to affect individual areas of a cortex slice. The comparison of GABA administered globally, in the medium and locally, via capillary OEIPs, shall demonstrate the precise application.

This proof-of-concept study lays the foundation for further developments of chip-integrated OEIPs toward implantable drug-delivery devices.

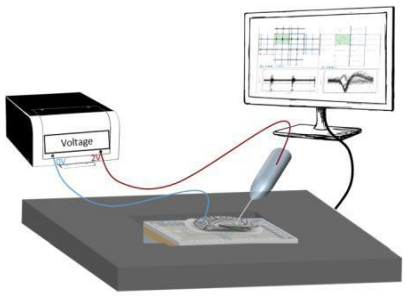

Figure 1: *Schematic drawing of the MEA structure with a cortex slice, a capillary OEIP, the voltage supply, and evaluation of the recording of the neuronal signals.*

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C10 - Polyphosphate hydrogels for drug delivery applications

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Abstract: Hydrogels are 3D mesh-like network polymers with the ability to retain substantial amount of water. Due to this feature, hydrogels have been proposed as excellent candidates for various biomedical applications. Polyphosphate-based hydrogels have been gaining substantial attention due to their enhanced cytocompatibility, mechanical properties and ability to function as drug delivery materials. In this work, a library of polyphosphate-based hydrogels is presented. The materials were prepared *via* free-radical polymerization of bis[2-(methacryloyloxy)ethyl] phosphate (BMEP) and two co-monomers. The hydrogels displayed an unprecedented elastic modulus (E') of 0.19 MPa, good hydrolytic and enzymatic stability, cytocompatibility and drug loading/release in wound-like pH conditions.

Keywords: polyphosphodiesters, polyphosphates, hydrogels, drug-delivery, mechanical properties.

Introduction

Recently, a class of synthetic, phosphodiester polymers has received considerable attention due to their great functionality.[1] The phosphodiester bond constitutes one of the most relevant chemical bonds for humans, given that its unique stability allows the formation and preservation of DNA.[2] The introduction of phosphodiesters into polymer backbones has therefore led to materials with outstanding biocompatibility and hydrolytic stability compared to polyesters, hemocompatible, or (bio)degradable materials.[3] However, to the best of our knowledge there are no main-chain phosphodiester polymers that are focused towards potential wound-dressing applications. Here, we describe the synthesis of two different phosphodiester-based hydrogels (Figure 1) and investigate their potential as a suitable wound-dressing candidates by testing their mechanical properties, swellability, enzymatic biodegradation, cytotoxicity, and anti-inflammatory drug absorption/release in wound-like pH conditions.

Results and Discussion

The hydrogels displayed a maximum compression elastic modulus (*E'*) of 0.91 MPa, which corresponds to a 1000-fold increase in comparison to previous literature. Moreover, the hydrogels were cytocompatible in presence of BFs and were hydrolytically stable under wound-like pH and enzymatic conditions for 32 days and 10 days, respectively. Finally, the hydrogels were able to release two anti-inflammatory drugs (DS and LHCl) in a prolonged and controlled manner in different wound-like pH conditions.

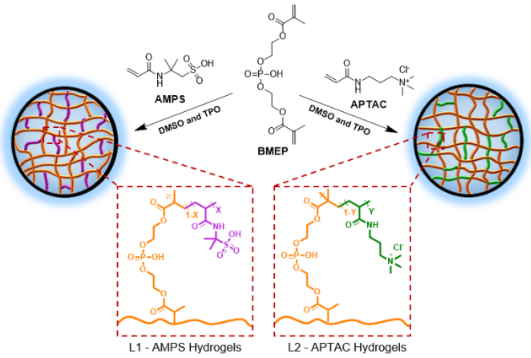

Figure 1: Synthesis of hydrogels containing BMEP and APTAC (L1) or AMPS (L2), where X and Y ≤ 0.25.

Conclusions

A series of phosphate-based hydrogels is presented, due to the inherent properties these materials are suitable candidates for wound dressing and drug delivery applications. This *in-vitro* study opens the possibility to further study this materials *in-vivo*.

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C11 - Liquid Identification in a Microplate Format based on Thermal and Electrical Sensor Data Fusion

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Abstract: Multi-device synchronous measurement and thus a fusion of data from multiple sensor sources is becoming a fundamental but non-trivial task. Essentially, different sensors have their own limitations and uncertainties; the fusion of the data serves to increase the accuracy of performance. This research aims to expand the possibilities of multi-parameter sensing by integrating impedance and thermal sensors into a microplate format for the simultaneous assessment of electrical and thermal properties.

Keywords: Electrochemical Impedance Spectroscopy, liquid identification, thermal sensing, microplate format

Introduction

Multi-sensor fusion and integration refers to the technology to combine data from multiple sensors to achieve inferences that are not feasible from each sensor individually. Multi-device synchronous measurement and thus fusion of data from multiple sensor sources is becoming a fundamental aspect in research. Essentially, different sensors have their own limitation and uncertainties; the fusion of the data serves to increase the accuracy of performance [1], [2]. In this research the possibilities of multi-parameter sensing is expanded by combining the impedance and thermal sensing techniques into a microplate format.

Results and Discussion

Seven different fruit juices were measured using the thermal and impedance technique. Different data clusters can be achieved, indicating the different juices. In turn, Fig. 1 highlights the most important feature of multi-sensor data fusion; the distinctive capacity increases drastically when combining two different techniques to analyse the same liquids. Even when used separately, both sensing techniques can distinguish between most tested juices. However, based on solely the thermal data, it is not possible to distinguish between Pear, Apple, and Orange juices. On the other hand, based on solely the EIS data, it is not possible to distinguish between Orange and Pineapple juices. Only by combining both datasets, all juices can be differentiated from each other.

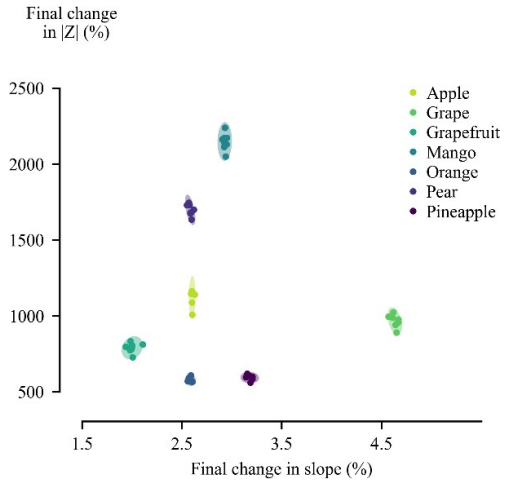

Figure 1: *Liquid identification of fruit juices based on combined thermal and impedance analysis. Confidence ellipses (2x SD) were plotted*

Conclusions

To demonstrate the power of multi-sensor data fusion, a proof-of-application experiment was executed. The results highlight the most important feature of multisensory fusion; the distinctive capacity increases drastically when using two different read-out methods to analyse liquids simultaneously. Cluster analysis clearly shows the distinct juices.

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Acknowledgements

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C12 - Curing parameters of a silicone-free carbon electrode screen- printed on a biodegradable fibroin substrate for future biosensing

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Abstract: Wearable electronics in healthcare represent an emerging field of research, allowing the real-time monitoring of the patient's health. For such applications, the utilized materials have to fulfill strict requirements such as skin-friendliness, non-inflammation, biocompatibility and flexibility. In this work, the influence of the curing time and curing temperature of a silicone-free, screen-printed carbon electrode on top of a biocompatible and biodegradable silk-fibroin substrate was studied with regard to its biosensor properties using glucose oxidase as a model enzyme.

Keywords: biocompatible, biodegradable, biosensor, silk-fibroin, screen-printing, carbon electrode.

Introduction

Recently, research on biocompatible and biodegradable electronic devices for personalized medicine has been greatly advanced [1]. A suitable material for this purpose might be the silk-fibroin from the silkworm *Bombyx mori*. It combines skin-friendly and non-inflammatory properties with superior mechanical characteristics such as a high tensile strength, large breaking strain and flexibility [2]. In addition, silk-fibroin is also a viable substrate for the screen-printing process [3], however, the sensor performance is strongly depending on the applied curing temperature and curing time.

Results and Discussion

Amperometric measurements in a 3-electrode configuration (consisting of a carbon-based working electrode, a Ag/AgCl-reference electrode and a Pt counter electrode) have been performed for different-cured, screen-printed carbon working electrodes on a fibroin substrate. Functionalization of the working electrode was achieved by immobilization of the enzyme glucose oxidase via drop-coating. An exemplary amperometric measurement is shown in Figure 1. Additionally, the influence of the curing time and curing temperature on the carbon electrode was investigated by optical microscopy and scanning electron microscopy as well as cyclic voltammetry.

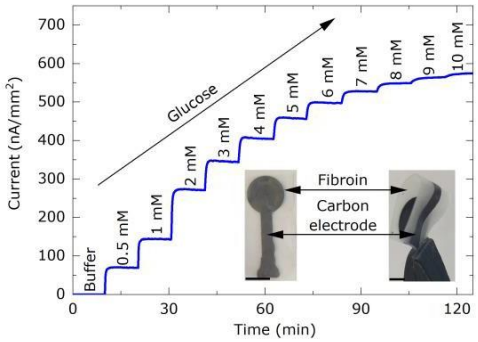

Figure 1: *Chronoamperometric response of the biosensor to glucose titrations from 0.5 mM to 10 mM in phospate buffer solution, pH 7.4 with an applied potential of 1.2 V vs. the Ag/AgCl-reference electrode and a Pt-wire as counter electrode. The photos show a carbon electrode on the fibroin substrate under planar (left) and bend condition (right). The scale bars correspond to a length of 4 mm.*

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C13 - Measuring Flow Rate or Mixture Ratio by Means of Thermal Conductivity Measurement in a Y Shape Mixing Microchannel

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Abstract: Measuring thermal conductivity (K) of a continuous flow sample has been proven to be a valuable factor in microfluidics for quality control and process monitoring. Available methods for measuring K are limited to the use of stagnant samples. In this study a novel in-house designed sensor and method is presented for measuring K for different mixtures in flow. The so called Transient Thermal Offset working principle is demonstrated numerically and experimentally using multiple single resistive metal structures.

Keywords: Microfluidics, Thermal conductivity, Flow rate, Transient Thermal Offset (TTO), Mixture.

Introduction

The ability of measuring thermal conductivity (K) inside a microfluidic device is of great importance for quality control and process monitoring, e.g., for in-line monitoring of mixture, or clogging detection inside microchannels. Most current methods measure K inside a microfluidic device employing a separate heating and sensing element. In our previous work [1] it has been shown that reading K for flowing liquids is achievable using a single resistive metal structure. In the current study multiple single resistive structures are used to measure K inside a Y shape microchannel.

Results and Discussion

Figure 1(a) shows the in-house designed sensor. The silver resistive structures are deposited on a glass substrate. Microchannels are made by grooving a PDMS plate. To prevent electrical short-circuits, metal structures have been insulated with a thin layer of Silicon Dioxide (SiO_2) from liquid.

By applying current pulses to the metal structure, it heats up regarding the Joule heating effect; the electrical resistance of the metal structure increases as determined by Eq. 1. The change in electrical resistance achieved by simultaneously measuring the voltage whilst applying the current [2].

$$R = R_{ref}[1 + \alpha(T - T_{ref})] \qquad (1)$$

Figure 1(b) illustrates that the temperature response of the sensor structure is affected by either the mixture ratio of a glycerol/water solution or by the flow rate. The temperature gradient of the sensor structure will decrease by increasing K or flow rate. The mixture ratio is changed by keeping the outlet flow rate constant and modifying the inlets flow rate.

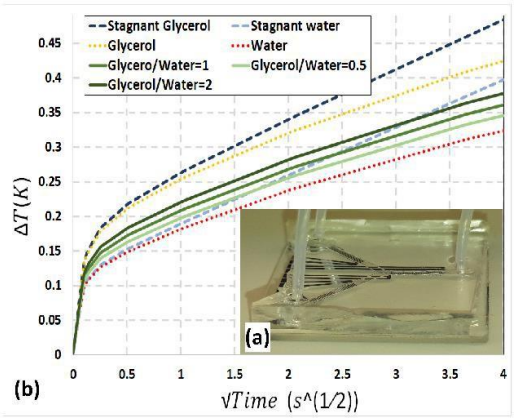

Figure 1: *(a) A picture of the presented sensor device (b) Transient thermal response of the metal structure for simulated measurement on stagnant and under flow glycerol/water mixtures.*

Conclusions

Employing the in-house designed sensor with multiple single resistive structures, measuring the flow rate is possible where the thermal conductivity of the liquid is known. In the same way, by knowing the flow rate, measuring thermal conductivity of liquids with different mixture ratios is achievable.

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C14 - Early Diagnosis of Childhood Asthma using Functionalized Diamond Substrates

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Abstract: This project aims to generate a non-invasive, diagnostic medical device that can discriminate between "viral wheezing" and childhood asthma by developing functionalized diamond surfaces capable of detecting asthma biomarkers, which is implemented into a point-of-care breathalyser. Consequently, it should be possible to diagnose children more early and accurately, limiting overtreatment of children with a viral wheeze or viral airway infection. This in turn results in better medication and care, which improves the patient's quality of life.

Keywords: Asthma, Breathalyzer, Gas Sensor, Volatile Organic Compounds, Respiratory Diseases, Childcare.

Introduction

Asthma is a condition in which patients have difficulties breathing due to narrowing or swelling of their airways, and is one of the most prevalent chronic diseases in children worldwide.[1] **Yet,** there is currently no accurate tool to predict if children will develop asthma. In fact, only a small proportion of preschool children with recurrent wheeze, cough and/or dyspnea, will be diagnosed with asthma by the age of five years.[2] In other words, asthmatic children are often undertreated, leading to more asthma attacks and hospital/care admissions, or even permanent loss of lung function. Hence, the patient's quality of life will decrease and the health care budget rises. It would therefore be extremely beneficial to develop a diagnostic, medical instrument to discriminate between asthmatic children and viral wheezers. In this work, we propose a one-stop breath analyser, which can detect volatile asthma markers (VOCs) in exhaled breath, by making use of functionalized diamond substrates.

Results and Discussion

Boron doped diamond (BDD) on silicon dioxide (SiO_2) is functionalized to selectively capture VOCs. The substrates are prepared via hydrogenation (or oxidation), followed by the (*photo*)attachment of functional groups (Figure 1).

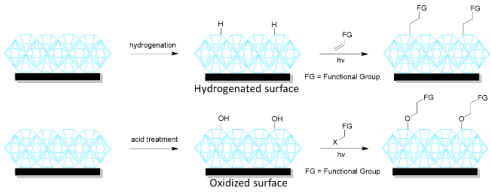

Figure 1. Preparation of functionalized boron doped diamond substrates following the hydrogenation (top) or oxidation (bottom) route.

The successful formation of functionalized diamond substrates was confirmed by XPS analysis and contact angle measurements. The functionalized substrate is then incorporated into a metal oxide semiconductor field-effect transistor (MOSFET), which should display a different electrochemical response upon receptor-analyte interactions.

The overall design of the sensor (Figure 2) is comprised of three components: pre-treatment filters and sensors for the exhaled air, the adjustable flow setup and the functionalized diamond MOSFET.

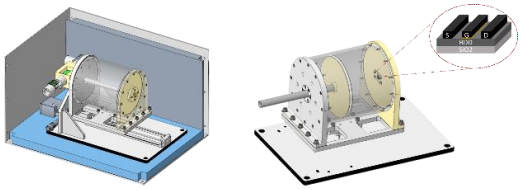

Figure 2. Representation of the asthma sensor setup.

Conclusions

The XPS results corroborate the successful formation of receptor layers on diamond surfaces, which can be integrated into a potential point-of-care device. Further experiments are in progress to verify the viability of the functionalized substrate and measurement setup for asthma diagnosis.

C15 - Towards 4D-Printed Self-folding Cuff Electrodes to Interface Peripheral Nerves

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Abstract: Cuff electrodes are often used to stimulate and record from peripheral nerves. However, they are difficult to attach to smaller nerves in the range of 100 µm. Therefore, we developed a flexible cuff electrode that can fold itself around the nerve. We 3D printed the substrate using a self-developed superabsorbent resin, which deforms on water exposure. This printing of stimuli-responsive materials for shape-shifting structures is commonly called 4D printing.

Keywords: 4D printing, superabsorbent, cuff electrode, self-folding, peripheral nerve.

Introduction

Peripheral nerve stimulation and recording with electrodes has, besides fundamental research, also potential application in controlling diseases like epilepsy, high blood pressure, or chronic pain. Several implementations of such electrodes are cuff electrodes equipped with a zip tie like closing mechanism or surgical threads to fix them on the nerves.[1] This procedure works well on larger nerves with diameters of several hundred micrometers. However, on smaller nerves in the range of 100 µm and below, the closing mechanisms are often too bulky, and the manual attachment increases the risk of rupturing the nerve. An alternative solution could be a cuff electrode that closes and wraps itself around the nerve, like a tiny grabbing hand. Additive manufacturing with soft "smart" hydrogels, which deform a device over time because of an external trigger (4D printing), represents a new way to fabricate such electrodes.[2]

Results and Discussion

Here, we present a 3D-printable strongly swelling hydrogel based on sodium polyacrylate for this application. The superabsorbent properties of sodium polyacrylate materials are already used in baby diapers or as fake snow. Our printed structures show a swelling over 20 times their printed weight in water and maintain the swelling movement even against an externally applied pressure. A bilayer with a flexible, not swelling polymer can achieve directional folding. The swelling under load is an advantage to other reported smart hydrogels, which allows folding down to small radii of the printed bilayer structure in the size of the targeted nerves. We used the developed superabsorbent resin to print an electrode substrate that folds after exposure to electrolyte solution like a tiny hand. With integrated electrodes, the system forms a soft self-folding cuff electrode, which can grab, hold on to, stimulate, and record from a small peripheral nerve.

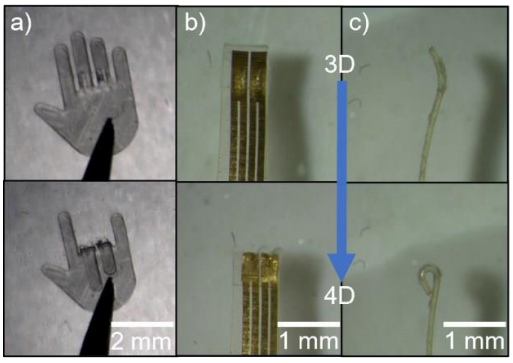

Figure 1: *Self-folding upon immersion in water. a) folding hand, b) electrode top view, c) side view.*

Conclusions

Our self-folding electrodes provide a new class of devices that can be used by surgeons and researchers for small-nerve interfacing.

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Acknowledgements:

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C16 - Electrically enhanced microbial hydrogen production at the intersection of energy, biotechnology and digitalization

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Abstract: Hydrogen (H_2) is a promising energy carrier for mobility and a source of excessive energy storage, due to its simple production and emission-free combustion. However, current H_2 production technologies are cost intensive and complex, as well as limited in terms of flexibility. The aim of this research is a new type of bioreactor based on electrofermentation for continuously H_2 generation using regenerative feedstocks.

Keywords: *hydrogen production, dark fermentation, electrofermentation, microbial electrosynthesis of hydrogen*

Introduction

Hydrogen (H_2) is considered to be one of the main energy sources of the future for the industry and the mobility sector. Currently, the industrial processes to produce H_2 involve steam reformation of compressed natural gas, coal gasification and electrolysis. Directly or indirectly, these processes are associated with carbon dioxide formation; water used for electrolysis requires extensive purification and demineralization. Biological production of H_2 is a very promising, less energy-intensive and climate friendly alternative. Here, dark fermentation of energetic feedstock streams using anaerobic bacteria has shown great promise. However, a major limitation of present dark fermentation is its incomplete H_2 yield. Due to a lack of electrons, a maximum of 4 moles of H_2 can be formed from 1 mole of glucose. Theoretically, if more electrons for the reaction were available, up to 12 moles of H_2 could be obtained [1]. During electrofermentation, the additional electrons cause a change in the metabolism of numerous microorganisms, which alters the product formation. By using electrical energy from regenerative sources, it is therefore possible to increase the hydrogen yield [2].

Results and Discussion

The principle of the anaerobic hydrogen reactor is illustrated in Figure 1. The conversion of water (H_2O) into oxygen (O_2) and hydrogen ions (H^+) takes place at the anode (A). The microoganisms (thermophilic bacterium *Thermotoga neapolitana*) acquire electrons (e^-) via the cathode (C). Inside the microorganisms, the electrons reduce the oxidized form of nicotinamide adenine dinucleotide (NAD^+) to NADH, which is converted back into H_2 due to the microbial metabolism. In order to further improve the H_2 yield, among other things, the process parameters such as substrate dosage, pH value and temperature are being optimized and different electrode materials can be characterized in terms of efficiency and lifetime for electrofermentation. Furthermore, neutral red as an electron mediator will be investigated due to its ability of reducing NAD^+, thus increasing the hydrogen production rate.

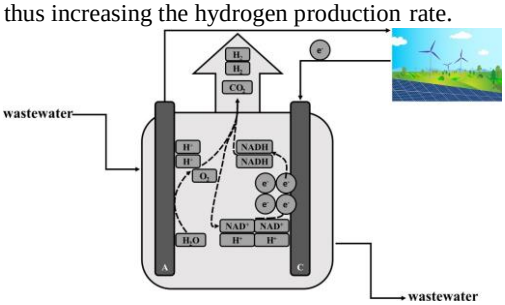

***Figure 1**: Illustration of the platform technology based on anaerobic hydrogen production from wastewater by electrofermentation.*

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Acknowledgements

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C17 - Towards monitoring implant induced inflammation: hydrogen peroxide sensing based on nanostructured Pt/Au and on-chip iridium oxide reference electrodes

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Abstract: H_2O_2 is an important marker linked with inflammatory processes following implant induced trauma. This work reports the use of electrodeposited gold/platinum (Au/Pt) nanocomposites in combination with an electrodeposited, miniaturized iridium oxide (IrOx) reference electrode for detecting H_2O_2 down to clinically relevant levels of 1 μM. These sensing layers are deposited on a cochlear implant like electrode array and evaluated in vitro. An LOD of 0.3 μM and sensitivity of 2530 nA $\mu M^{-1}cm^{-1}$ was achieved.
Keywords: Hydrogen peroxide, Electrochemical sensor, Pt/Au nanocomposite, Iridium oxide reference electrode

Introduction

Hydrogen peroxide (H_2O_2) is an important signalling molecule in biological organisms since it is a side product of various enzymatic reactions and a marker for local inflammation [1]. Many electrochemical sensors have been developed to monitor H_2O_2 in vitro and in vivo but their long-term use in contact with cells and tissues is limited due to sensor biofouling, reference electrode instability and degradation of the biorecognition layer (often based on peroxidases) [2] [3]. In this work we replaced biological peroxidases by an electrodeposited Pt/Au nanocomposite, which increases the electrodes surface area and acts as a H_2O_2 catalyst, and used an electrodeposited IrOx film as a miniaturized on chip reference electrode.

Results and Discussion

Au micro/nano dendrites (DENs) and Pt nanoparticles (NPs) were electrodeposited onto platinum electrodes by electrodeposition from an aqueous solution. The deposition of Au DENs, Pt NPs and their combination increased the electrodes surface area by respectively 76, 5 and 164 times. Cyclic voltammetry revealed a significant increase in H_2O_2 reductive current starting from 0.1 V (Potentials are always denoted vs Ag/AgCl unless noted otherwise) and lower as a result of these modifications, whilst only Pt NPs and combination of Pt NPs and Au DENs increased the oxidative current starting from 0.5 V and higher. Calibration experiments for H_2O_2 based on chronoamperometry in stirred phosphate buffered saline (PBS) at 0.6 V for Pt NPs and Au DENs/Pt NPs modified electrodes yielded respectively a sensitivity 1958±78 nA $\mu M^{-1}cm^{-1}$ and 4409±58 nA $\mu M^{-1}cm^{-1}$ and LOD of 0.65 μM and 0.25 μM.

IrOx was electrodeposited based on a protocol proposed by Yamanaka [4]. It resulted in smooth (roughness ~ 5 nm) and 100 nm thick films as verified via Atomic Force microscopy. The IrOx-modified electrode held a stable and reproducible potential in PBS of 308±13 mV with an average maximal drift of 26 mV over a 35 day period in PBS at 37°C.

The iridium oxide and Au/Pt nanocomposite electrodes were combined in a sensor chip design mimicking the CI electrode size (250x500 μm) and separation used in cochlear implants. The iridium oxide modified electrode was used as the reference electrode and a calibration for H_2O_2 was performed at 350 mV vs IrOx in a flow cell. The sensor had a sensitivity of 2530 nA $\mu M^{-1}cm^{-1}$ and LOD of 0.3 μM.

Conclusions

This work demonstrates H_2O_2 detection down to clinically relevant levels for inflammation (1 μM) by making use of Au/Pt based nanocomposites and using IrOx as a stable reference. Future work will focus on eliminating interference and biofouling of biomolecules and replacing chronoamperometry with square wave voltammetry-based techniques to allow for detection in diffusion-limited non stirred solutions.

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C18 - The corrosion of titanium dental implants in the context of a novel explantation technique

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Abstract: The topic of this ongoing work is to develop an analytical method for the detection of corrosion on titanium dental implants subjected to a novel explanation technique. The technique involves the application of a high-frequency alternating current on the implant via an electrotome (electric surgery device). This heats the implant and therefore loosens its connection to the bone. The goal is to develop an electrochemical flow cell in which titanium samples and implants can be positioned. The samples can then be analysed electrochemically, and the electrolyte can be analysed downstream via an ICP/OES or ICP/MS for trace amounts of dissolved titanium

Keywords: titanium; corrosion; dental implants; flow cell.

Introduction

There are a number of reasons that can lead to the necessity of implant removal. Because of the strong osseointegration (connection of bone and implant), this procedure can be traumatic to the patient. By applying heat (above 48 °C) this connection is loosened and removal becomes simpler [1]. The electrical introduction of heat to the implant raises questions about the corrosion of the titanium which must the addressed. At this point of the project, common electrochemical corrosion experiments have been performed on titanium samples in different electrolytes (including artificial saliva). This was done to establish a baseline of corrosion behaviour. Further, a suitable flow cell was developed, and first steps were taken to combine its use with other analytical methods.

Results and Discussion

Corrosion experiments have been performed on titanium (Ti, 99.5 %) in 5 different electrolytes. Which were among others: A phosphate-buffered salt solution (PBS) and an artificial saliva prepared according to the formulation of Fusayama/Meyer [2]. Tafel plots were recorded in the solutions, and it was found that titanium shows a quite similar corrosion rate in all solutions. In artificial saliva however, titanium showed the smallest corrosion potential. To simulate the influence of inflammation Tafel plots were also recorded in artificial saliva with increasing concentrations of H_2O_2. The increase in corrosion rate follows a linear trend regarding the H_2O_2 concentration. The corrosion potential seems to increase as well with the H_2O_2 concentration. Cyclic voltammetry was combined with long term immersion of the samples in the electrolytes to further investigate the corrosion behaviour. This resulted in similar findings.

The designed electrochemical flow cell can be seen in Figure 1.

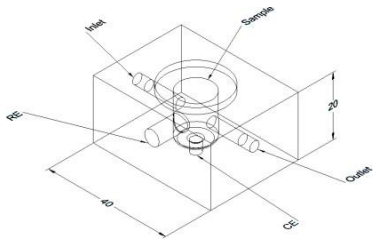

Figure 1: *Design of the flow cell. All dimensions are given in mm.*

Conclusions

The results presented give a good foundation from which the further planned corrosion experiments, using the flow cell can be conducted. With such a working setup it will be possible to determine the corrosion of titanium dental implants in real-time. Of course, further challenges concerning the saliva composition and other influences on the corrosion behaviour must be met.

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Acknowledgements

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C19 - Thin-Film Porous Microelectrode Arrays for Cell Culture Applications

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Abstract: Thin-film, porous microelectrode arrays, fabricated via laser ablation, offer a novel approach to record action potentials from electrogenic cells for improved cell-chip coupling compared to planar electrodes. The pore electrode serves as a bidirectional recording site without allowing the cells to pass through the porous film. As a proof of principle, we demonstrate the compatibility of our porous microelectrode arrays with HL-1 cardiomyocytes. The activity of cells grown on a porous electrode array is recorded electrically and verified using calcium imaging. We believe that the developed porous devices can be applied in the future for signal measurement from 3D cell cultures as well as organoids.

Keywords: microfabrication, neuroelectronics, microelectrode arrays, extracellular recording, electrogenic cells

Introduction

The coupling of biological interfaces yields various research opportunities ranging from on-chip technologies for neurotransmitter detection to extracellular recording of electrogenic cells.[1] Microelectrode arrays (MEAs) are the state-of-the-art tools for tissue-sensor communication as they allow for simultaneous extracellular recording. Hindering mechanical mismatch between MEAs and the cells is a challenge for cell-chip coupling. For this purpose, methods such as the fabrication of mesh-like conductors, 3D nano-structured surfaces and flexible thin-film electrodes exist.[2] A porous thin-film MEA device has the advantage that different cell cultures can be applied on both sides of the structure while maintaining interactions between the cells. Furthermore, if the pores are sufficiently small, they provide the possibility of cellular connections without allowing cellular migration. Here, we present a fast and straightforward process for rapid prototyping of thin-film porous microelectrode arrays based on pulsed laser ablation.

Results and Discussion

The electrodes were fabricated from evaporated gold films and the insulation was provided by Parylene C deposition. After laser patterning, the resulting electrodes combined a peripheral surface electrode and a ring electrode (see Fig. 1a, b). The profilometry measurements revealed an outer diameter of the electrode of 20,8 ± 0,4 µm and an inner diameter of 11,4 ± 0,5 µm in average. Despite the large electrode area, the pores are below the typical size of a rat cardiomyocyte [3]. As a consequence, the cells were unable to escape the porous thin-film after culturing.

In our process we avoided the use of any adhesion layer between gold and Parylence C. Laser ablation led to local delamination between the electrode and the insulation layer, effectively reducing the electrode impedance upon immersion in cell culture medium.

We demonstrated the possibility of measuring action potentials from cardiomyocyte-like HL-1 cells and analyzed the signal propagation on the chip surface. (see Fig. 1c, d)

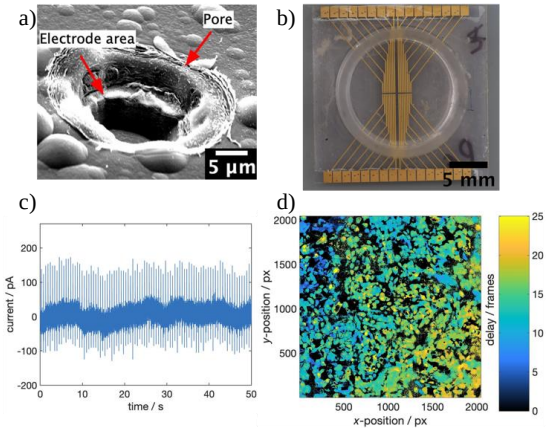

Figure 1: *a) SEM image of a pore electrode b) Image of the 32 channel MEA c) Example time trace of cell signals detected with the MEA d) Calcium imaging propagation map of HL-1 cells on the MEA*

Conclusions

The thin-film porous MEA presents a useful tool for in vitro signal recording of electrogenic cells. The porous electrode allows measuring from both sides of the thin-film and offers an environment for neurite outgrowth. Future applications of the device might be to measure from brain organoids or 3D neural cell cultures with the aid of a suitable 3D-printed structure.

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C20 - Fabrication of coils for wireless, NFC-enabled, stretchable wearables (POSTER ONLY)

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Abstract: A stretchable system-in-a-foil (SiF) epidermal electronic system is a skin-conformable, thin, lightweight, flexible wearable device that can record biophysical signals such as electrocardiograms (ECG) from the skin. Near-field communication (NFC)-enabled stretchable SiFs have a serpentine design of coils used to wirelessly record biopotentials from the skin at a certain frequency. We investigated three types of styrene-ethylene-butylene-styrene (SEBS) to fabricate the stretchable coils. Then, we applied a stationary strain to the coils, which shifts the maximum reflected power of the antenna. The impact of the shifts on the recording and signal transmission capability was characterized in this work.

Keywords: stretchable wearables, styrene-ethylene-butylene-styrene (SEBS), system-in-a-foil, epidermal electronic system, electronic patch.

Introduction

A significant market growth of disposable skin patches for medical wearables is expected by 2030 [1]. Stretchable patches can remotely capture biophysical data such as electrocardiograms (ECG) or seismocardiograms (SCG) [2] from the skin. They are very appealing as everyday consumer wearables due to their comfort and lightweight. The NFC functionality of a smartphone can be used to communicate with the electronic readout circuit embedded in the patch by inductive coupling of two planar coils, where one coil is embedded in the smartphone. In addition, the same inductive coupling can be used to power up the electronic circuit in the patch such that no disposable battery is necessary cutting costs and enabling environmentally friendly disposing of the patch after usage. In order to eliminate artifacts, a stretchable substrate material that conforms to the skin's movement is preferred. The transmitted power should not drop below a particular threshold to continuously power the electrical circuit. In this study, we applied different strains to the coils made of gold structures on three different types of SEBS [3] to characterize the use case the coils.

Results and Discussion

In the experimental characterizations, we used 5, 10, and 20 percent of strain values. The results show a resonance shift of less than 10 Hz for the maximum strain from the resonance frequency of 13.56 MHz, which is clearly in the tolerance range for efficient wireless communication and energy harvesting. The different types of SEBS material did not show a significant impact on the results. However, a value of 20% was the maximum strain to maintain a decent adhesion of the microgalvanic gold structures on SEBS. Figure 1 shows the result of the fabricated coil in a relaxed state.

Conclusions

Although SEBS material can be reversibly stretched by more than 100 percent, while the skin can only stretch around 30%, our meander-shaped coils fabricated by microtechnology processes had a limited stretch range. The coils developed and tested in our project were in the tolerance range for the application of recording ECG and SCG signals from the chest of persons, where usually the stretch values for the skin are below a 20% stretch threshold.

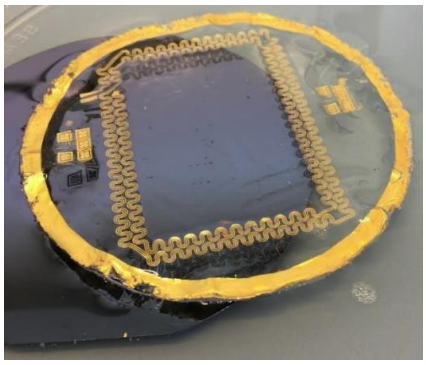

Figure 1: *The photograph shows a coil on stretchable SEBS fabricated by microgalvanics.*

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C21 - Platform for high spatial resolution measurements of in-plane thermal conductivity and diffusivity of thin films (POSTER ONLY)

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Abstract: In this work, we developed a platform to measure the in-plane thermal conductivity and diffusivity of nanometer thin films. The device consists of a microstructured platinum resistive Joule heater and five resistance temperature detectors (RTDs) on a 150 nm thin SiNx membrane. The device allows measurements of a spatial temperature profile and of material parameters using a thermal wave technique. Measurements were performed on the bare SiNx membrane and on the SiNx membrane with a 740 nm thick Parylene C thin film.

Keywords: In-plane thermal conductivity, thermal conductivity measurement, RTD, SiN membrane

Introduction

The thermal conductivity and diffusivity of materials are crucial parameters for their applications in heat-intensive environments. Various measurement techniques have been developed to characterize different materials and sample geometries [1]. In particular, measurements of the thin film thermal conductivity are challenging, since it is usually anisotropic in the cross-plane and in-plane directions. In this work, a microscale measurement device for the in-plane thin film thermal diffusivity of thin films is presented.

Results and Discussion

The devices, consisting of 5 RTDs out of Pt, were arranged at different distances from a microheater in the center. Chips were fabricated on 4"-wafers using standard lithography and KOH etching processes (Figure 1 a, b). The RTDs were calibrated in a custom-built setup. Steady-state temperature profiles were obtained by the readout of sensors, while supplying a heating current at constant chuck temperatures. The RTDs show high stability (Figure 1 c).

In the thermal wave method (Figure 1 d), sinusoidal heat is applied and the phase shift of the sensor temperature is detected [2]:

$$\Delta = \sqrt{f}\,\frac{d}{\alpha} + b \qquad (1)$$

with phase shift $\Delta\Theta$, heating frequency f, thermal diffusivity α, heater-sensor distance d and a constant phase b. The parameter α can be obtained by a frequency sweep and linear regression to the data. A thermal diffusivity value of $3.16 \cdot 10^{-6}$ m²/s for the 150 nm SiN membrane and a value of $1.01 \cdot 10^{-6}$ m²/s for the SiNx membrane coated with 740 nm Parylene C were measured. Furthermore, we also observed a dependence of the thermal diffusivity on the heater-sensor distance.

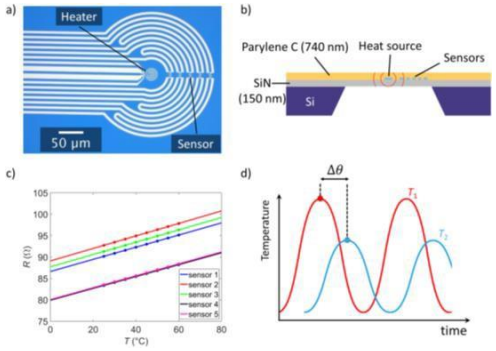

Figure 1: *Device and measurement concept. a-b): Image of the device and its cross-section. c): Calibration of the RTDs. d): Phase shift between the heater/sensor temperatures yielding the material's thermal diffusivity.*

Conclusions

A microscale platform for the measurement of in-plane thermal diffusivity of thin films has been established, which was able to measure the thermal diffusivity of a Parylene C thin film. Further investigations will be carried out to understand the influence of the sample geometries and the nanoscale structures of materials on their thermal properties.

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Acknowledgements

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Topical Session D: Surface Chemistry and Electrochemistry – Schedule

Keynote Lecture 4: Characterization of electrochemical surface activity by means of scanning electrochemical microscopy (SECM) - Prof. Dr. Frank-Michael Matysik (University of Regensburg, Germany)

Short Oral Presentations

D1 – Derick Yongabi – Synchronized, spontaneous, and oscillatory detachment of eukaryotic cells…

D2 – Xingzhen Zhang – DNA modified MSN films as versatile biointerfaces to study stem cell adhesion…

D3 – Minh-Hai Nguyen – Electro-polymerized of biodegradable and conductive polymer as inflammation…

D4 – Tom Depuydt – Catheter-based sensors for the intestinal detection of molecular biomarkers…

D5 – Soroush Bakhshi Sichani – DNA hybridization study using a novel hot-wire based thermal biosensing…

D6 – Dua Özsoylu – Magnetic cell carrier for biosensor applications

D7 – Melanie Welden – High-density immobilization of tobacco mosaic virus particles as enzyme...

D8 – Kevin A. Janus – Influence of different fibroin membrane compositions regarding their swelling…

D9 – F. Rüger – Polypyrrol-copolymer coatings as efficient surface modification of polymer-fibre…

D10 – Divagar Murugan – Optimization of surface chemistry at the silicon oxide interface for precise

D11 – Jan Wagner – Digital microfluidic platform for the investigation of catalytic microgel reactions

D12 – Marcel Tintelott – Fully integrated LoC platform for target amplification-free miRNA detection…

D13 – Edith Böhmer – Software module of diffusive failures in active implantable medical devices (AIMD)

D14 – Yuan Cao – COMSOL-based microfluidic flow optimization of a hydrodrynamic chip

D15 – Hüseyin Zengin – Corrosion behaviors of ZX, ZW, MX, and MW lean magnesium alloys

D16 – Manuel Hofinger – Determination of hydrogel properties in different electrolytes via…

D17 – Daiko Ando – The fabrication process of biopolymer-nanofiber-based electrodes by vacuum…

D18 – Inola Kopic – Rapid prototyping of 2D- and 3D-microelectrode arrays (MEAs) for *in vitro* applications

D19 – Jonathan Bier – Providing a new method of fluorescence quantification

Poster market with coffee

Characterization of electrochemical surface activity by means of scanning electrochemical microscopy (SECM)

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Abstract: Scanning electrochemical microscopy (SECM) is a scanning probe technique based on the use of an ultramicroelectrode (UME) as a probe. The SECM technique is very versatile and can be applied to studies in material science, corrosion, biological systems, and other fields. Recently our group has introduced the so-called hydrodynamic mode of SECM measurements where forced convection is implemented in the measuring configuration. The experimental approach and the benefits of hydrodynamic SECM are explained in the presentation.

Keywords: surface characterization, scanning probe technique, electrochemistry, ultramicroelectrode, hydrodynamics

Introduction

Scanning electrochemical microscopy, introduced at the end of 1980s by Bard and co-workers [1], has evolved as a versatile electrochemical tool for imaging of topography and surface (re)activity. The SECM configuration consists of an electrochemical cell where the substrate of interest is fixed at the bottom of the measuring cell. The cell is filled with electrolyte containing an electroactive species (mediator). In addition, the cell is equipped with a reference and a counter electrode. The probe is typically an UME operated in the amperometric mode. In contrast to many physical scanning probe techniques there is a direct (electro)chemical interaction between the probe and the sample surface. In this way SECM is essentially a method based on chemical communication between probe and substrate. The most common measuring modes are the feedback mode, substrate generation / tip collection (SG/TC), and tip generation / substrate collection (TG/SC) experiments. Conventional SECM experiments are performed in quiescent solution. However, if a substrate electrode is used as sample to investigate electrochemical reactivity, SG/TC experiments are complicated due to the growth of the diffusion layer thickness with time. This problem can be avoided by the introduction of forced convection. The present contribution gives an overview on new methodical possibilities in the field of hydrodynamic SECM.

Results and Discussion

Figure 1 shows the typical configuration for hydrodynamic SECM experiments. Convection is introduced to the measuring cell by means of a high-precision stirrer. In case of SG/TC experiments the diffusion layer of the substrate electrode can be adjusted corresponding to the rotation speed of the stirrer.

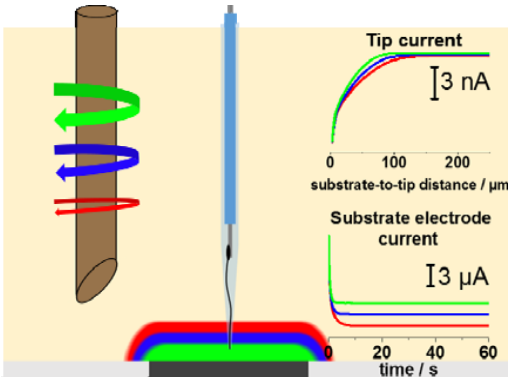

Figure 1: *Principle of hydrodynamic SECM and its application to SG/TC experiments with a large amperometric substrate electrode [2].*

As an alternative flow cell configurations can be used for hydrodynamic SECM experiments [3].

This novel methodical approach was applied to studies of gas evolution reactions [4], semi-conductor samples, and enzymatic structures [5].

Conclusions

The novel measuring mode of SECM under forced convection paves the way for a wide range of applications in material science, electrocatalysis, and life science.

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D1 - Synchronized, spontaneous and oscillatory detachment of eukaryotic cells: A new tool for cell characterization and identification

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Abstract: Despite the importance of cell characterization and identification for diagnostic and therapeutic applications, developing fast, and label-free methods without (bio)-chemical markers or surface-engineered receptors remains challenging. Here, we exploit the natural cellular response to mild thermal stimuli and propose a label- and receptor-free method for fast and facile cell characterization.

Key words: Heat-transfer method, cell detection, cell characterization, spontaneous cell detachment, glycolytic oscillations

Introduction

Identifying eukaryotic cells without using microscopy- and fluorescent-based approaches or exploiting genomics, or proteomics information remains an open quest.[1] Techniques for cell identification are generally invasive, often requiring (bio-)chemical agents or physical cues such as electrical fields and mechanical forces that may affect the native cell behavior.[2] Especially, dielectric and micromechanical characteristics are not sharp discriminators that allow phenotyping cancer cells or distinguishing microorganisms down to strain level.[2] Here, we show that this fine-tuned information is easily derived from the detachment kinetics of cell ensembles from a substrate surface in the presence of a minimal temperature gradient.[3]

Results and Discussion

At a constant substrate temperature, T (*e.g.*, 37 °C), cells detach spontaneously and collectively at a highly reproducible time, t_d, identified from a step-like drop in the thermal resistance of the substrate-to-liquid interface.[4] This phenomenon is hitherto unknown from literature. The detachment time, t_d, decreases exponentially as a function of T, with scaling parameters that allow discerning reliably between three different yeast strains and two human cancer cell lines. We show that cell metabolism plays a key role: t_d becomes shorter with nutrients (sucrose) and longer with DMSO and blebbistatin. Using a resazurin assay, we reveal a one-to-one correlation between t_d and cell metabolic activity kinetics. Under specific conditions, we observe synchronized glycolytic-type oscillations during detachment of mammalian and yeast-cell ensembles, providing additional cell-specific signatures. The high sensitivity of these effects to metabolic activity means that, from a broader perspective, one may expect applications in cell viability analysis and pharmacology, in which spontaneous detachment serves as a fast, straightforward tool for assessing drug response at cellular level.[5]

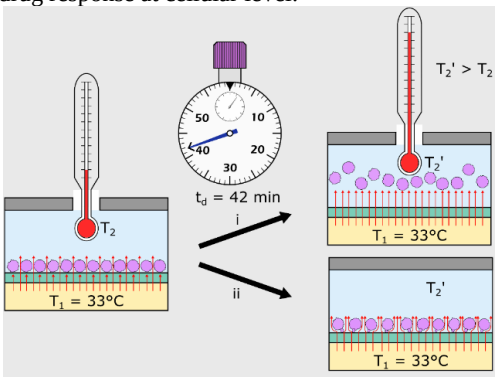

Figure 1: Schematic of spontaneous cell detachment and thermal monitoring detection principle.

Conclusion

The results show that spontaneous cell detachment can be used to effectively characterize eukaryotic cells, including human cancer cells.

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Acknowledgement

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D2 - DNA Modified MSN Films as Versatile Biointerfaces to Study Stem Cell Adhesion Processes

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Abstract: Stem cell fate is regulated by their interaction with extracellular matrix (ECM), mainly through integrin-mediated cell adhesion. 2D biointerfaces that selectively present ECM-derived ligands can be used as valuable tools to study stem cell adhesion processes. Here we developed a new type of biointerface based on mesoporous silica nanoparticles that are modified with DNA using PEG linkers of varying size (MSN-ssDNA). Cell adhesion tripeptide RGD was conjugated to a complementary DNA strand, which could specifically bind to MSN-ssDNA to create MSN-dsDNA-RGD films. We showed that the presence of RGD on films could promote hMSCs adhesion and spreading, but its functionality was PEG-length dependent.

Keywords: stem cell adhesion, biointerface, mesoporous silica nanoparticle, DNA, ligand presentation

Introduction

Stem cells have great potential in the regenerative medicine field. However, an ongoing challenge in their clinical translation is control over their behavior once transplanted. Stem cell fate is regulated mainly through integrin-mediated cell adhesion, which not only provides stem cells anchoring points but also directs their fate such as stem cell differentiation. 2D biointerfaces that offer high control over ECM derived-ligand presentation have been developed to study stem cell adhesion.

MSN have promising characteristics to develop biointerfaces such as easy surface functionalization and high control over their size and shape. Here we developed a new type of biointerface based on MSN to study cell adhesion [1].

Results and Discussion

MSN-ssDNA with varying PEG linker length (n=6, 8 or 12) were developed and designated as MSN-L_6-ssDNA, MSN-L_8-ssDNA, MSN-L_{12}-ssDNA. TEM images show that MSN-NH2, MSN-L_6 and MSN-L_6-ssDNA have a spherical shape and a porous structure. DNA surface modification resulted in a less visible porous structure (Fig.1a-b). SEM showed that DNA modified MSN could be homogenously spin coated to form a continuous layer of nanoparticles over the glass substrate (Fig.1c). The water contact angle (WCA) measured on MSN-ssDNA films was lower than that measured on glass, which indicated an increase in surface hydrophilicity due to hydrophilic PEG and DNA modification (Fig.1d). Fluorescent microscopy images showed that MSN-dsDNA-RGD filmscould promote hMSCs adhesion and spreading, whereas MSN-dsDNA films without RGD resulted in poor cell spreading with round morphology, and low cell adhesion (Fig.2). In addition, we showed that cell adhesion to the films is PEG length-dependent.

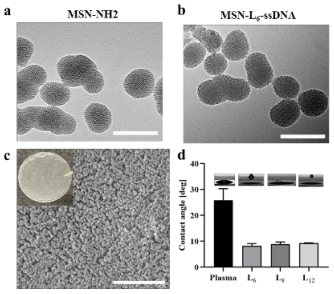

Fig.1 TEM images (a and b) (scale bar=200 nm). c) SEM images of MSN-ssDNA films (scale bar=2 μm). d) WCA results.

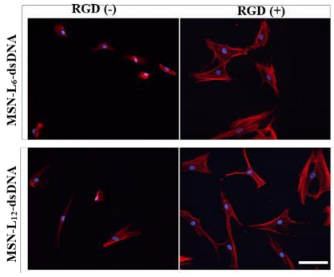

Fig.2 Representative fluorescence micrographs of hMSC cultured on MSN-L-dsDNA films with and without RGD for 1 day. Scale bar represents 100 μm.

Conclusions

In conclusion, DNA can be successfully surface grafted to MSN using various PEG linkers. MSN modified with PEG and ssDNA can be spin coated to create homogenous, stable and biocompatible films, which can be used as a novel and versatile 2D biointerface to study ligand-induced stem cell adhesion processes.

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D3 - Electro-polymerization of biodegradable and conductive polymer as inflammation sensing for the cochlear implant

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Abstract: For the use of the cochlear implant (CI), the molecular imprinted polymer (MIP) should be a polymer that is biodegradable, biocompatible and conductive. There are voids in the polymer that have a form of IL-6. When the IL-6 dock to the MIP and fill the voids, the impedance of the polymer changes due to the structural change. In this work, the conduction polymer layer was deposited on an electrode by electro-polymerization and was characterized by impedance measurement.

Keywords: Molecular imprinted polymer, electro-polymerization, PEDOT, ibuprofen, impedance measurement

Introduction

In the first few months after the implantation of the CI, it can lead to postsurgical inflammation that can be treated with medication [1]. Sometimes the inflammation is recognized too late, which is leading to damage to the ear. The CI can be upgraded to indicate the inflammation in good time. To indicate the inflammation, the inflammation marker e.g. IL-6 may serve. MIP deposited on the electrode of the CI can detect the IL-6. MIP is a polymer with cavities, which have a shape of IL-6. When the IL-6 dock to the MIP and fill the voids, the MIP impedance changes, due to the structural change [2]. The change in impedance can be used to recognize if the CI caused inflammation or not. Since the cochlear implants can cause inflammation only in the first few months, the MIP is not needed thereafter. Therefore, a biodegradable and biocompatible material that can be used as a MIP needs to be identified. For good sensitivity, the polymer must be additional conductive, but conductive polymers are not biodegradable. The idea is to create a polymer-composite, which contains a conduction polymer and a biodegradable polymer by electro-polymerization [3].

Results and Discussion

The electro-polymerization was used, because the deposition takes place in one-step and the adhesion of the polymer on the electrode is very strong. For the first tests, PEDOT was selected as a conductive polymer, due to its high biocompatible and stability. Ibuprofen was selected as template instead of IL-6. The measurement setup consisted of a three-electrode configuration in 20 mL water, 0.01 mM Na:PSS, 15 mM EDOT and 5 mM ibuprofen (see Figure 1). Na:PSS is needed to dissolve the EDOT in water and is used as a counter anion. The same solution content, but without ibuprofen was used for the deposition of the NIP, which served as a reference to the MIP. After the deposition, the MIP was washed in 10 mL ethanol and 10 mL water for 20 minutes and in water for 10 minutes to remove the ibuprofen from the MIP. Impedance measurement was used to indicate ibuprofen in a solution. For the impedance measurement, the same measurement setup and two solutions were used. The solutions contain 50% water and 50% phosphate buffered saline. One of the solutions contain additional 20 mM ibuprofen. The impedance of the NIP measured in the two solutions showed no difference. The MIP, on the other hand, showed a difference from 20 Ω between the two solutions (see Figure 1).

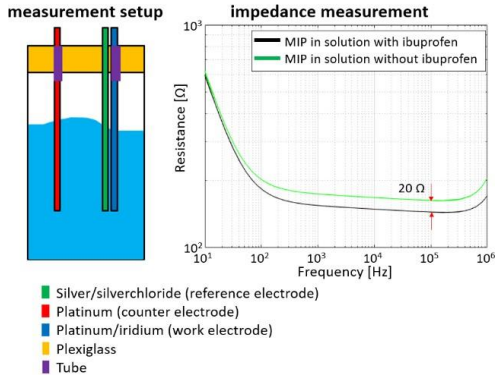

Figure 1: *Measurement setup (right) and impedance measurement (left).*

Conclusions

The reason for the small change may be that only part of the ibuprofen on the surface of the MIP was dissolved by washing. In order to produce MIP with many cavities, other washing methods e.g. acid-base washing must be used.

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Acknowledgements

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D4 - Catheter-based sensors for the intestinal detection of molecular biomarkers in the context of functional bowel disorders

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Abstract: This project aims at the development of catheter-based sensors that detect molecules released into the duodenum of patients suffering from irritable bowel syndrome (IBS). This diagnostic tool will detect the target molecules histamine and serotonin. The receptors are molecular imprinted polymers (MIPs) that will be coated on gold microwires by electro-polymerization and the concentration of the target molecules will be determined by impedance spectroscopy.

Keywords: electro-polymerization, molecular imprinted polymers, impedance spectroscopy

Introduction

In this project, a catheter-based sensor is developed, which will be used to detect histamine (His) and serotonin (5-HT) in the duodenum of IBS patients. His occurs in allergies and is involved in chronical inflammations. 5-HT is a neurotransmitter, and its level in the blood is known to increase in blood in the case of certain IBS patients [1]. The sensor used in the catheter will have three pairs of gold microwires as electrodes. Two electrode pairs are functionalized to detect His and 5-HT, respectively. These electrodes are coated by molecular imprinted polymers (MIPs). To correct for false positive effects by electrode fouling, we will use a third electrode couple that is coated with non-imprinted polymer (NIP). Both MIPs and NIPs are synthesized by the electro-polymerization process. After the electro-polymerization, template molecules, which are trapped in the MIP layers, are removed by acid-base washing. The MIPs then result in a layer of cavities in which the His or 5-HT molecules can rebind through hydrogen bonding and π-π stacking (Figure 1a). Therefore, the impedance amplitude of the electrode pairs changes, that is corresponding to the concentration of the target molecules.

Results and Discussion

In preparatory work, an electro-polymerization process on titanium (Ti) wires resulted in well-functioning MIPs and NIPs to determine the His concentration *in vitro* (Figure 1b). The impedance of the MIP increased by 60% over a concentration range of 10 nM – 1 μM His in bowel fluid, while the NIP only increased by about 10% over the same concentration range [1]. Also, the results show a good selectivity of the MIP layer for His in comparison with the structurally similar molecule histidine [1].

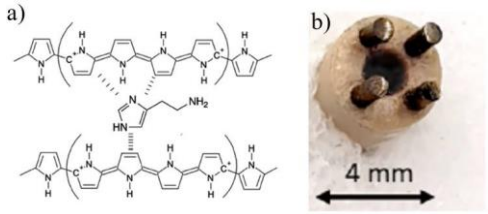

Figure 1: *a) His H-bonding and* π-π stacking *with a polypyrrole (PPy) MIP. b) PPy layer on Ti wires representing the MIP and NIP. [1]*

In the present project, we start with the *in vivo* measurements in healthy volunteers and in patients with functional bowel disease. The catheter will be inserted through the nose, therefore, miniaturization of the catheter to an outer diameter of 4 mm is necessary. Furthermore, an extra electrode pair is needed such that the catheter can detect not only His, but also 5-HT. We will use gold microwires as electrodes and are finalizing the process to polymerize MIPs on these wires using electro-polymerization. Polypyrrole can already serve for His [1], for 5-HT a new synthesis protocol is being developed, based on polymer blends.

Conclusions

Functional MIP layers were already developed for Ti wires. The same principle will be adapted to gold microwire electrodes to develop sensors that will be used in the nasopharyngeal catheter. The catheter has new dimensions and will undergo tolerability tests before being used on patient.

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Acknowledgements

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D5 - DNA hybridization study using a novel hot-wire based thermal biosensing platform

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Abstract: In this study, a single sensing element as a thermal biosensing platform can detect analytes based on a change on thermal interface conductance through 3ω method. The core of this sensor is a 30 µm aluminium micro-wire serves as an immobilization platform for receptors, a heat source, and a temperature sensor together. For this proof-of-concept, we studied the heat-transfer efficiency between the wire and the surrounding medium (PBS buffer and air) for four different coatings including the native oxide layer, a self-assembled silane monolayer, single stranded DNA linked covalently to the silanes, and complementary duplexes of oligonucleotides.

Keywords: Label-free bio- and chemosensor, Nucleic acids, 3ω principle, Thermal waves.

Introduction

In the 3ω method, an alternating current of angular frequency ω causes power and corresponding temperature oscillations with 2ω based on Joule heating phenomenon. The existing 3ω signal in the voltage across the wire can be measured by a lock-in amplifier that corresponds to the product of the resistance and the current through the wire [1]. In this method the voltage at the third harmonic of the triggering frequency ($U_{3\omega}$) is a direct measure for the thermal interface resistance between the wire and the ambient. Interestingly, $U_{3\omega}$ alters systematically with the coating type and the effect sizes are large in relation to the very low noise levels [2]. Starting from this proof-of-concept, we are currently exploring whether this 3ω-based "hot-wire" technique offers the same functionality as the heat-transfer method (HTM) with its static temperature gradient [3].

Results and Discussion

Four additive wire coatings (native oxide, silanes, ss- and ds-DNA) represent four physically different interfaces between aluminum and the surrounding air or PBS. Since the medium is always the same (either air or PBS), changes in $U_{3\omega}$ due to a specific coating directly indicate a change in the heat-transfer mechanism between the wire and the medium. Figure 1 shows four different wire coatings in contact with either air or PBS has been measured in the frequency range from f = 7 to 100 Hz. The amplitude of $U_{3\omega}$ decreases systematically with increasing f . As a practical result, we found that silane monolayers enhance heat transfer from the wire to the buffer considerably due to an overlap in the molecular vibration modes of the silanes' carboxyl group with water molecules. Single-stranded DNA layers with their entangled morphology strongly impede thermal transport while hybridization to stiff double helices makes heat transfer again more efficient.

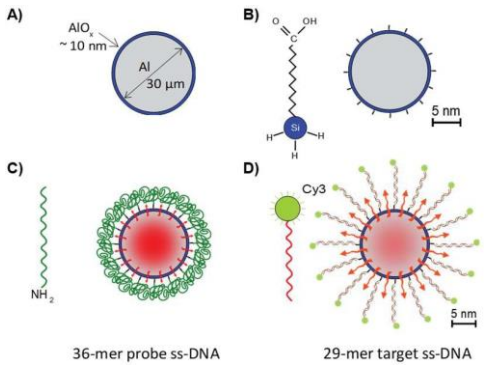

Figure 1: Scheme of the aluminium wire cross section. B) Functionalization with the silanes used as the cross linker. C) Attachment of single-stranded probe DNA. D) Hybridization with complementary target DNA.

Conclusions

In this work, the 3ω hot-wire concept is explored as a prospective biosensing platform with a single sensing element that can detect analytes based on a change in the thermal interface conductance

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D6 - Magnetic Cell Carrier For Biosensor Applications

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Abstract: In this work, we present a way to transport immobilized cells (*e.g.*, after cryopreservation) from their growth and storage position to different sensor positions. Accordingly, we introduce how a cell culture coverslip has been modified with superparamagnetic nanoparticles embedded in a photopolymer resin as a carrier and how this construct can be magnetically actuated.

Keywords: cell-based biosensor, superparamagnetic nanoparticles, photopolymer.

Introduction

Different types of biosensors exist of which cell-based biosensors are one class. As a cell is a "living" component it remains a challenge to keep these sensors "ready-to-use" between sensor preparation and subsequent measurement. This fact might hinder their practical application and commercialization, especially for "on-field" measurements. One suitable way to preserve these sensors is to perform cryopreservation steps after manufacturing and to keep them frozen until later use. The general principle of "on-sensor cryopreservation" has been previously shown in [1]. Herein, we will extend the knowledge [2] about a way to carry the cells from storage towards the biosensing measurement.

Results and Discussion

A commercially available polymer cell culture coverslip was modified as a cell carrier device. For that, a layer of photopolymer or photoresist with added superparamagnetic nanoparticles was spin-coated on its surface. By applying photo-lithography, specific structures were patterned in this polymer layer, to design transparent microscopic observation windows within the magnetic carrier. It could be demonstrated that the position of the constructed carriers could be manipulated in planar directions, as well as induce a rotation around its axis by applying specific external magnetic fields. A schematic overview of the carrier manipulated by an external magnetic field is depicted in Figure 1.

Conclusions

The carriers provide the movement of cells grown on them, for example, from a storage area towards the sensor surface. As it was possible to use superparamagnetic particles for this purpose, which lose their magnetic field after removing the external magnetic field. Hence, the growth and behaviour of cells (*e.g.*, by interacting with internal magnetosomes), as well as the sensor performance, are not affected due to a remaining magnetic field after the manipulation of the carrier. In addition, the utilised polymer-nanoparticle mixture we used here could enable direct 3D printing of the magnetic structures onto a coverslip.

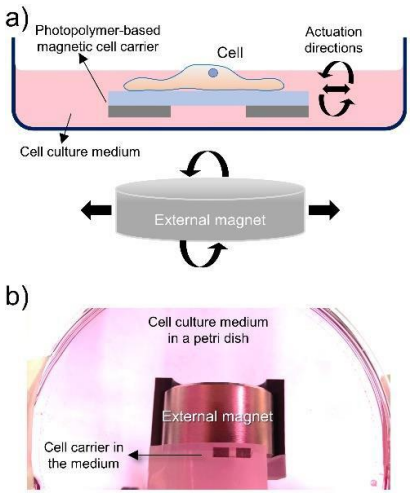

Figure 1: *a) Schematic representation of the magnetic cell carrier and actuation principle. b) Obtained magnetic cell carrier based on a cell culture coverslip and photopolymer composite containing magnetic nanoparticles.*

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Acknowledgements

The authors would like to thank R. Welden for support in laser cutting, H. Iken for profilometric measurements, B. Schneider for assistance in 3D printing and D. Rolka for SEM images.

D7 - High-density immobilization of *tobacco mosaic virus* particles as enzyme nanocarriers on a polyelectrolyte-modified field-effect biosensor

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Abstract: A novel immobilization strategy using a polyelectrolyte and *tobacco mosaic virus* particles as enzyme nanocarriers immobilized via layer-by-layer technique on capacitive field-effect sensors is presented. The sensor structure is characterized by scanning electron microscopy and electrochemical capacitance-voltage and constant-capacitance measurements. The results indicate a successful high-density immobilization of TMV particles.

Keywords: *Tobacco mosaic virus*, polyelectrolyte, enzyme nanocarrier, capacitive field-effect sensor.

Introduction

For enzymatic biosensors, an appropriate enzyme-immobilization strategy is important for a reliable sensor performance. We recently introduced a novel method for enzyme immobilization based on *Tobacco mosaic virus* (TMV) particles as enzyme nanocarriers on capacitive electrolyte-insulator-semiconductor (EIS) sensors [1,2]. In the present work, the sensor is extended by a layer of the positively charged polyelectrolyte poly (allylamine hydrochloride) (PAH) as Al/p-Si/SiO_2/Ta_2O_5/PAH/TMV/enzyme structure. Since both the Ta_2O_5 surface and the TMV particles are negatively charged at neutral pH, electrostatic repulsion could restrict TMV adsorption on the Ta_2O_5 surface. The positively charged PAH could lead to electrostatic attraction and enhance the density of immobilized TMV particles to increase the number of possible binding sites for enzyme immobilization.

Results and Discussion

Different enzyme immobilization protocols with penicillinase are studied via scanning electron microscopy (SEM), capacitance-voltage and constant-capacitance measurements. SEM images revealed a significantly higher TMV density on the PAH-modified Ta_2O_5 compared to bare Ta_2O_5 (figure 1), underlining the high potential of this novel immobilization method for the fabrication of various enzyme biosensors.

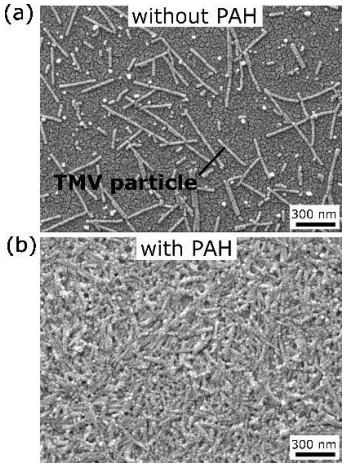

Figure 1: *SEM images of the Ta_2O_5-sensor surface modified with (a) only TMV particles and (b) a PAH/TMV bilayer.*

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Acknowledgements

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D8 - Influence of different fibroin membrane compositions regarding their swelling behavior

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Abstract: In this work, the swelling behavior as well as the loss of unbound fibroin components of casted fibroin membranes was studied by measuring their weight change. A correlation between membrane composition and swelling ability was elaborated.

Keywords: biocompatible, biodegradable, swelling, silk-fibroin.

Introduction

Silk-fibroin represents a promising material for biomedical applications due to its advantageous properties such as biocompatibility and biodegradability, as well as mechanical characteristics [1] and versatility [2]. An important factor determining its application as a sensor-substrate material defines swelling behavior in solution.

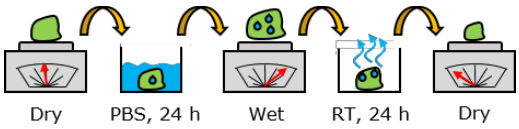

***Figure 1**: Schematic experimental design. The sample (green) was weighted in a dry state and afterwards placed in phosphate buffer solution (PBS), pH 7.4, for 24 h. The sample was carefully blotted and weighted again, afterwards the sample was left to dry at room temperature (RT) for 24 h and weighted again.*

Results and Discussion

Different fibroin membranes have been studied. A mixture of 2-eq. PureSilk®, 1-eq. ethanol and 1-eq. glycerol was prepared with varying weight and volume percentage (the used percentages of each component are separated by a "/" in Figure 2). The membranes were casted as described in [3]. Some membranes have been additionally modified with horseradish peroxidase (HRP). Additionally, polylactic acid (PLA) and polyimide (PI) membranes were used as a reference. The experimental procedure to measure the weight gain and weight loss is sketched in Figure 1. The results (Figure 2) show that the casted fibroin membranes have a high capacity of water storage (up to almost 3-times of their own weight). Additionally, the results show that chemically cross-linking with HRP reduces this swelling behavior.

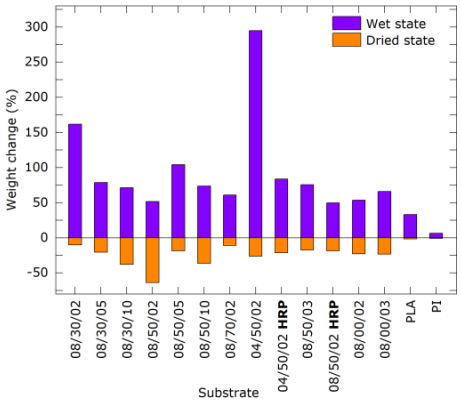

***Figure 2**: Weight change of different tested samples in wet and dry state in percentage. The mean value for each membrane composition (n=3) is depicted. 0% represents the initial starting value.*

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D9 - Polypyrrol-copolymer coatings as efficient surface modification of polymer-fibre-substrates.

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Abstract: The ability to modify basic substrates like polymers, or even polymeric fibres (e.g. in clothes), generates a multitude of possibilities to fine tune objects to specific tasks like wettability or functional groups. Here we present a fast and efficient method to modify polymer fibres and solid polymer substrates, like poly propylene (PP), with pyrrole-based polymers to generate modifiable surfaces, featuring the exemplary development of a simple optical histamine sensing device.

Keywords: Polypyrrole (PPy), polymer tuning, chemical polymerization, surface modification, sensors.

Introduction

The ability to tune and modify solid surfaces is a crucial point during the development of many products and systems. Especially in fields like pharmacology, medicine and biomaterials surface modifications receive growing attention from the scientific community [1, 2]. Polypyrroles (PPy) are a unique class of polymers featuring significant intrinsic conductivity, interesting optical properties, alongside a high stability of the films. These properties make PPy´s advantageous for a multitude of applications ranging from biosensing to anti-corrosion coatings [3, 4]. Histamine intolerance is strongly associated with the inability to metabolize ingested histamine mainly via Diamine oxidase (DAO), this condition has gained recent increasing interest and recognition [5].

Results and Discussion

6-(1*H*-pyrrol-1-yl)hexanoic acid (PHA) - pyrrole (Py) mixtures were successfully polymerized onto polypropylene fibers (PP) from surgical masks using $FeCl_3$ aq. within 10-30 minutes, yielding brown to dark grey colored composites (PPy-PP), controlled by the concentration of the pyrrole-mixture ranging from 10 – 30mg (Fig. 1 and 2).

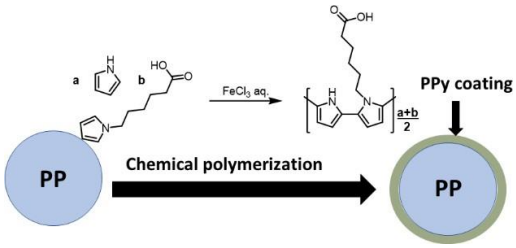

Figure 1: *Schematic illustration of polypropylene fiber coating using PHA-Py mixtures;*

Higher concentrations of pyrroles than 30 mg/mL did not change the apparent color of the modified fibers; the optical homogeneity of the PPy layers could be improved by a spraying protocol, albeit still having minor edge effects. Immobilization of biomolecules was accomplished by EDC coupling chemistry, leading to functional surfaces (Fig. 1) The activity of enzymes immobilized on this PPy-PP composite was successfully evaluated using a peroxidase (HRP) (Fig. 2).

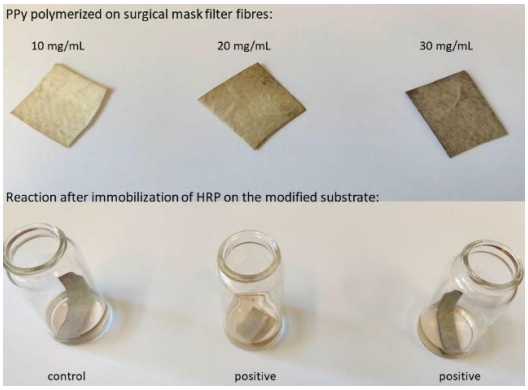

Figure 2: *Top: substrates after chemical polymerization of the PHA/Py mixture; Bottom: PPy-PP + TMP (pH: 5) left: control without immobilized HRP, center: HRP immobilized without NHS, right: EDC/NHS immobilization.*

Conclusion

Functional PPy's surfaces were successfully manufactured and grafted with HRP, generating a histamine sensor in combination with DAO. The final sensor-layout, in this case, could either be optical or electrical. The electrochemical properties of the PPy's are still under investigation. A future usage of cellulose as sensor carrier gives the opportunity to produce inexpensive single-use analytical devices.

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D10 - Optimization of surface chemistry at the silicon oxide interface for precise monitoring of rolling circle amplification of DNA

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Abstract: Rolling circle amplification (RCA) is a potential isothermal nucleic acid amplification test (NAAT) with high specificity, multiplexing, and amenability to integrate into point-of-care (PoC) devices. Ideally, precise real-time monitoring of the amplification process is crucial for practical applications. In order to carry out the RCA in a heterogeneous bioassay format and to study the amplification process, the silicon oxide (SiO_2) surface is investigated for silanization (amino and epoxy silanes) using wet-chemical and vapor-phase processes. The established protocols are utilized to observe the amplification process through padlock probing and/or surface plasmon resonance (SPR) platform.

Keywords: Silicon oxide, pre-treatment, oxygen plasma, vapour phase silanization, DNA-hybridization, rolling circle amplification.

Introduction

A stable, uniform layer of bioreceptors is essential for reproducible and sensitive results, especially in near-field sensing techniques like SPR [1]. Typically used silane chemistries involve the condensation of surface silanol groups (≡Si-OH) and silanol groups formed by hydrolysis of amino or epoxy silanes with a small quantity of water. Hence, for the formation of self-assembled monolayers of silane, an optimal density of surface silanol groups and water molecules are essential. The surface silanol groups are typically generated using strong acids (sulphuric acid), oxidizing media (Piranha, methanol:HCl, hexavalent chromates) [2], or plasma chemistry [3]. Subsequently, the hydroxylated surface is utilized for the condensation of silane. Despite using organic solvents (ethanol, methanol, toluene), the formation of multilayers has always been a drawback of the wet chemical silanization process. As an alternative, a gaseous or vapour-phase silanization is explored to achieve a monolayer of silane on the sensor substrate.

Results and Discussion

This study explores three pre-treatment procedures, namely piranha, methanol: HCl, and oxygen (O_2) plasma, to generate silanol groups on the silicon wafers with a thin layer of SiO_2. The hydroxylation process is evaluated through contact angle and ellipsometry measurements. Subsequently, the activated chips are silanized using wet-chemical and vapour phase silanization using amino (APTES) and epoxy (GPTMS) silanes. The efficiency of the silanization process is assessed primarily through the hybridization of complementary DNA oligos on an SPR platform and successively real-time monitoring of RCA, as shown in **Figure 1**.

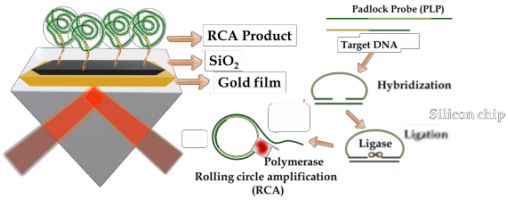

Figure 1: *Schematic representation of rolling circle amplification through padlock probing and proposed SPR platform.*

Conclusions

In this functionalization approach, the amino silane requires a linker, while epoxy silane facilitates the direct binding of amine-terminated DNA-oligos. Hence, the difference in the proximity of DNA hybridization and its effects are assessed to establish an optimal surface functionalization process.

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Acknowledgements

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D11- Digital microfluidic platform for the investigation of catalytic microgel reactions

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Abstract: Digital microfluidic platforms based on electrowetting allow the manipulation of discrete liquid volumes in the form of nanoliter droplets. Simply by programming, a variety of e.g. biological or chemical assays can be carried out in the same system. Thus, digital microfluidics are a promising approach for the systematic investigation of catalytic reactions at the interface of immiscible liquids. Specifically, the focus is on microgels employed as surface-active catalyst carriers. Precisely controllable reaction times and defined interface areas between individual droplets are a prerequisite to a quantitative analysis of the reaction kinetics.

Keywords: digital microfluidics, electrowetting, microgels, organic synthesis

Introduction

A typical electrowetting-on-dielectric (EWOD) device consists of two parallel glass slides as shown in figure 1. The bottom chip features individually addressable path electrodes covered by a dielectric layer. The top chip contains, at minimum, a transparent counter electrode. Polytetrafluoro-ethylene (PTFE) is commonly used as a hydrophobic coating on top and bottom chips, ensuring high initial contact angles of the droplets. Voltages are applied between path and counter electrodes for droplet actuation.

PortaDrop is a portable, all-in-one-box digital microfluidic platform. Besides droplet actuation by EWOD, it also allows integrated electrochemical measurements [1]. In the present project, further development of the platform will address the unique challenges arising from the necessity to actuate both water droplets with dissolved microgels as well as oil droplets of 1-octanol.

Development goals

The driving force acting upon the droplet for EWOD depends on the applied voltage as well as the thickness and permittivity of the dielectric layer. For devices using relatively thick (~ 5 µm) polymer dielectrics such as Parylene C ($\varepsilon_r \approx 3.1$), it is, therefore, necessary to apply high voltages (> 200 V) to actuate the droplets. The presence of microgels acting as surfactants and reducing the initial contact angle of droplets further complicates the situation. Thus, we aim to prepare thin ceramic dielectric layers by reactive sputtering of Ta_2O_5 ($\varepsilon_r \approx 25$), which will allow to use lower driving voltages and achieve higher droplet velocities.

Since EWOD requires conductive liquids, and due to the low surface tension of 1-octanol compared to water resulting in low contact angles, it is generally challenging to actuate 1-octanol in EWOD platforms. However, the relatively high dielectric constant of 1-octanol ($\varepsilon_r \approx 10.3$) means that

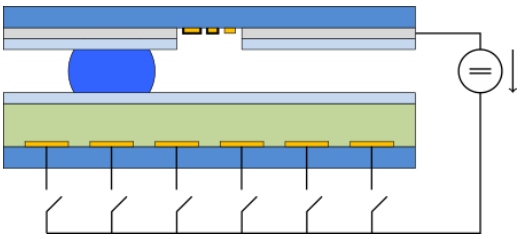

Figure 1: *Schematic overview of a typical EWOD device, additionally incorporating electrodes for electrochemical measurements in the top chip.*

dielectrowetting derived from liquid dielectrophoresis (L-DEP) can be a viable approach to actuate the droplets [2]. Therefore, it will be necessary to develop a chip design that is suitable for both EWOD and L-DEP.

Further development goals include the incorporation of suitable inlets and outlets to the EWOD chips for sample loading and off-line analysis of reaction products, a revised reservoir design for accurate droplet dispensing, and techniques to avoid adsorption of microgels at the hydrophobic layer.

Conclusion

Catalytic reactions at the interface of immiscible liquids are crucial for organic synthesis. Due to the unique characteristics of digital microfluidic systems, they are ideally suited to the systematic investigation of reaction kinetics, thus allowing insights into the relation between microgel structure and catalytic performance.

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D12 - Fully integrated LoC platform for target amplification-free miRNA detection via implementation of biochemical reaction networks

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Abstract: In this work, we present a fully integrated Lab-on-a-Chip (LoC) sensor platform for the target amplification-free detection of miRNA-based biomarkers. A biochemical reaction network (BRN) is used to recognize the presence of miRNAs in biological media and implemented the synthesis of highly concentrated and short ssDNA sequence as a 'logic' output of the BRN. The onset of this DNA output of the BRN depends on the miRNA target concentration and therefore can be used for quantitative detection.

Keywords: silicon nanowire field-effect transistor, molecular programming, SARS-CoV-2 virus, neurodegenerative diseases, medical diagnostics

Introduction

The specific detection of target molecules is of high interest in the field of molecular diagnostics. Silicon nanowire (SiNW) biological field-effect transistors (BioFETs) are classified as ultra-sensitive biological transducers [1]. However, limitations such as the Debye screening effect in physiological liquids (e.g. blood) and non-specific molecular interactions limit the sensitivity and accuracy of BioFETs as Point-of-care (PoC) biosensors. To overcome these limitations, we propose a novel concept, where a miRNA target is converted into an exponentially amplified ssDNA outputs using BRNs [2]. The DNA output is then detected by the BioFETs as illustrated in figure 1(a). Due to the high concentration of the ssDNA output, larger signal amplitudes are detected by the SiNW BioFETs. Depending on the miRNA concentration, the onset of the output will start sooner or later. Therefore, the miRNA target concentration can be estimated by the signal onset.

Results and Discussion

A fully integrated LoC platform was fabricated in a CMOS-compatible "top down" fabrication process with post-CMOS integrated features like local temperature sensors and on-chip pseudo-reference electrodes. The LoC platform can be operated at a desired temperature with high stability (< ± 1°C), which is of paramount importance for the BRNs. As illustrated in figure 1(b), a molecular program has been used for the selective conversion of miRNA targets (has-miR-22-3p), which are involved in SARS-CoV-2 or Parkinson's disease.

Conclusions

Our novel miRNA detection scheme has the potential to overcome the fundamental limitations of BioFETs by combining specialized BRNs with our highly stable and temperature-controlled LoC platform. In future, we will tailor our integrated platform towards different applications, where highly specific and highly sensitive detection in physiological media is needed.

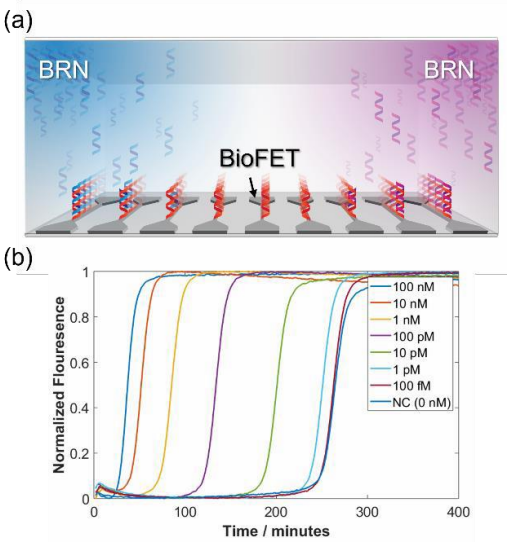

Figure 1: *(a) Illustration of the sensing principle: The BRN molecular program produces a highly concentrated ssDNA diffusion front, which is detected dynamically by the SiNW BioFETs. (b) Optical detection of varied concentrations of hsa-miR-22-3p.*

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Acknowledgements

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D13 - Software module of diffusive failures in active implant medical devices (AIMD)

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Abstract: Lifetime prognosis or simulation is a cheaper alternative to lifetime test. Material properties and parameters of the body fluids can be taken into account in a simulation. Sorption and delamination are the main failure mechanisms in cochlea implants. These were simulated in ANSYS and after analysing the results in MATLAB a conclusion about the failure and the lifetime prediction of the implants could be made.

Keywords: ANSYS, AIMD, MATLAB, PDMS, body fluids, lifetime prediction

Introduction

Life cycle tests e.g. soak tests and endurance tests according to Arrhenius' law are not effective in the long run [1]. Therefore, new methods are being researched. In many fields, simulation tools are used to simulate and analyse component failure. Due to the high complexity of the interaction between body reactions, component failure and other mechanism, which occurs in implants, it has not yet been possible to make lifetime predictions using software modules. This work shall contribute a small step towards the development of sufficient models. In the context of this work the failure of the cochlear implant (CI) is simulated. A failure of the CI caused by a diffusive infiltration of perilymph, the inner ear fluid, into the interface between polymer and electrode serves as a basis for the simulation [2][3].

Approach

In our simulation, we enter the parameters e.g. material properties and variables of the inner ear fluid into a MATLAB program that communicates with ANSYS. The parameters for the simulation were determined by a previous experiment by Mao et al. [3]. Failure simulation is done with ANSYS, then the results are passed to MATLAB, which is used to plot a chart (see Figure 1). Failure can be classified into failure, slight failure and no failure. The following equation was used to subdivide the failure in MATLAB.

$$\lambda(x,t) = a \cdot 7t - \frac{x - x_7}{V}1$$

a represents the progression of delamination and sorption form ANSYS, V is the velocity parameter, x the length of the interface and x_7 the start position.

Results and Discussion

The sorption and delamination of PDMS and platinum/iridium due to perilymph penetration was investigated. It was found that the probability of failure increases with exposure time. After perilymph sorption in the interface has taken place, a continuous progress of delamination can be observed. Figure 1 shows the implant failure simulation.

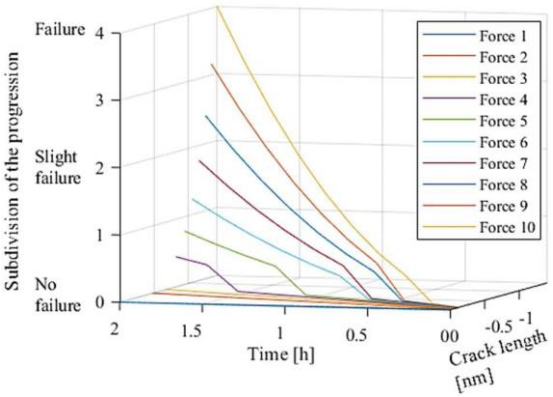

Figure 1: Shows the progression of delamination over time. The different colours are representing the various forces form the perilymph on to the interface. The Z-axis subdivides the progression, the X-axis shows the crack length and the Y-Axis the Time.

Conclusions

It turned out that many simplifications and assumptions had to be made, because the software and hardware are limited and the exact behaviour mechanisms are not fully understood yet. But the foundations were successfully laid for simulating and evaluating the failure mechanisms of sorption and delamination. Through further studies, research and experiments, it will be possible in the future to simulate the failure of implants more accurately.

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Acknowledgements

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D14 - COMSOL-based microfluidic flow optimization of a hydrodynamic chip

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Abstract: Microfluidic systems are established for the manipulation of single microparticles or cells. With regard to the hydrodynamic trapping method, no external fields have to be applied in contrast to dielectrophoretic, optical, or acoustic trapping devices. Recently, we developed a microfluidic chip with hydrodynamic trapping structure, in which an aperture in the channel's coverlid was combined with an underlying suction channels. However, the flow velocity around the aperture was determined not to be homogeneously distributed. Here, we improved the flow characteristics around the aperture by COMSOL Multiphysics. For validation, we fabricated a chip with advanced microsystem technologies. Experimental results confirm the theoretical considerations.

Keywords: microfluidic, FEM, COMSOL, hydrodynamic trapping, single cell, dry film photoresist.

Introduction

Nowadays, microfluidic systems are established for the manipulation of microparticles or cells. Here, no external fields have to be applied for the manipulation as it is the case of dielectrophoretic, optical or acoustic trapping devices. In hydrodynamic trapping approaches, traps are typically embedded in microfluidic channels as constrictions, pockets or obstructions [1,2]. We recently developed such a system, which can trap large single micro spheres successfully [3]. However, first COMSOL Multiphysics Finite Element Method (FEM) simulations revealed that the flow velocity around the aperture is not distributed homogeneously but appears significantly higher at the side facing the outlet and decreases sharply at the opposite side. The objective of this work is to overcome the weaknesses mentioned above by establishing a radially symmetrical flow field distribution around the aperture.

Results and Discussion

The final channel design is depicted in Fig 1a. Compared to the original design, the channel around the aperture was significantly expanded to a disc-shaped area. In addition, obstacles were inserted in the channel to feed the flow to the right side of the aperture and support the ceiling of the channel. The position and the shape of the obstacles were optimized with regard to a constant mean flow velocity along the perimeter of the aperture. To validate the final design, a microfluidic chip was fabricated by lamination of two 25 µm thick SUEX® K25 dry film photoresists in combination with lithographical patterning [3,4]. A top view of the improved channel is shown in Fig. 1b. Video recordings of the microfluidic channel filling with ink were taken and they confirm the simulation results of the flow behavior, experimentally.

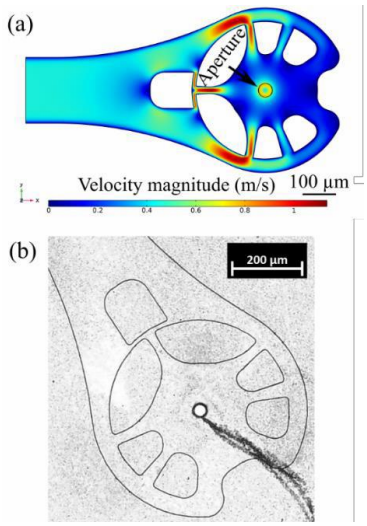

Figure 1: *(a) FEM simulation of flow velocity inside the optimized channel design. (b) Top view photo on fabricated channel with optimized design.*

Conclusions

In general, our approach demonstrates an efficient method by applying CFD simulations to visualize and optimize the flow behavior in combination with micro obstacles to direct flow in complex 3D channel systems.

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Acknowledgements

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D15- Corrosion behaviors of ZX, ZW, MX and MW lean magnesium alloys

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Abstract: In the present study, the corrosion properties of extruded Mg-1.04Zn-0.14Ca, Mg-0.51Zn-0.59Y, Mg-0.66Mn-0.14Ca and Mg-0.61Mn-0.17Y (wt.%, hereinafter referred to as ZX10, ZW00, MX00 and MW00, respectively) were investigated in 0.5 wt.% NaCl solution. Results showed that the Ca-containing alloys exhibited less and more uniform degradation than the Y-containing alloys. Ca addition enhanced the formation of more protective oxide film whereas the addition of Y led to microgalvanic corrosion caused by the presence of undissolved second phase particles which are more cathodic than α-Mg matrix. ZX10 alloy exhibited the best corrosion resistance among the studied alloys.

Keywords: magnesium alloy, microstructure, corrosion, electrochemistry

Introduction

In recent years, the concept of alloying with low amount of alloying elements has gained importance in the metal industry [1]. This design approach is to obtain maximum efficiency from the alloying elements together with the design of processing conditions [2]. Regarding this, wrought lean magnesium alloys in structural and biomedical applications have come into focus. Thus, it is of great importance to clarify the relationships between the microstructure and properties of these alloys.

Results and Discussion

Extruded microstructures in Figure 1 were composed of equiaxial, dynamically recrystallized grains with mean grain sizes of 8.8 ± 0.6 µm, 11 ± 0.8 µm, 7.6 ± 0.5 µm, 7.6 ± 0.4 µm for the alloys ZX10, ZW00, MX00 and MX00, respectively.

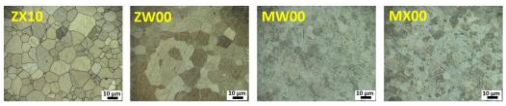

Figure 1: *Optical microstructures of the alloys.*

The open circuit potential (OCP) curves in Figure 2(a) indicated that the initial OCP increased in the order of ZX10 < MX00 < MW00 < ZW00. The OCP for ZX10 climbed and reached the most positive potential with continuing immersion. The cathodic current densities derived from Figure 2(b) showed a decrease in the order of MW00 > ZW00 > MX00 > ZX10. ZX10 also showed an obvious film breakdown potential in the anodic branch of polarization curve, indicating a formation of more protective surface film. The impedance spectra for all specimens in Figure 2(c,d), showed two well defined time constants after immersion for 1 h. ZX10 alloy exhibited the largest capacitive loop at medium and low frequencies among the studied alloys. The cross-section microstructures in Figure 3 shows uniform corrosion propagation in ZX10 and MX00 alloys and more localized corrosion attacks in ZW00 and MW00 alloys. The strongest corrosion attack was observed on ZW00 alloy, which can be attributed to the microgalvanic coupling between Mg-Zn-Y ternary and α-Mg matrix phases.

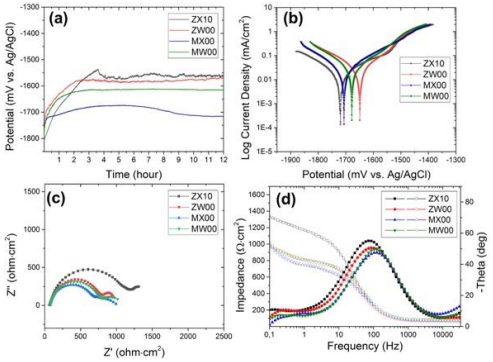

Figure 2: *Electrochemical test results: (a) open circuit potential, (b) potentiodynamic polarization, (c) Nyquist and (d) Bode plots.*

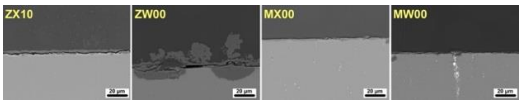

Figure 3: *Cross section SEM microstructures after immersion in 0.5 wt% NaCl for 48 h.*

Conclusions

The cathodic reaction was kinetically retarded on Ca-containing alloys. Y addition led to more localized corrosion whereas Ca-containing alloys exhibited much uniform degradation.

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D16 - Determination of hydrogel properties in different electrolytes via electrochemical impedance spectroscopy

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Abstract: In this work the electrochemical properties of different hydrogels with varying electrolytes were investigated. The focus was on agar-based hydrogels with different electrolytes in physiological conditions for mimicking the electrochemical properties of synovial fluid. It was attempted to establish a correlation of the electrochemical property with the thickness of the hydrogel at different areas of overlapping electrode surface and on temperature dependency. Also, the correlation of these properties with different ion concentrations were investigated.

Keywords: Agar-based hydrogel; electrochemical impedance spectroscopy; synovial fluid, implants.

Introduction

Synovial fluid is a biologically synthesised hydrogel which is present as a lubricant in articular joints in the human body. As one major reason for the mechanical failure of implants is wear, the thickness of these hydrogels plays an important role to inhibit the wear [1]. A fast and non-destructive measurement of the synovial fluid can help for an early diagnosis of this failure and may prevent failure of implants. For establishing this measurement different hydrogels with Agar as gelification agent were investigated due to their electrochemical properties on various thicknesses and areas of overlapping electrode surface.

Results and Discussion

It was found that electrochemical impedance spectroscopy is the most reliable method for the investigation of electrochemical properties on hydrogels. For the measurement of different thickness and overlapping electrode area of the hydrogel a setup and a measurement program was designed.

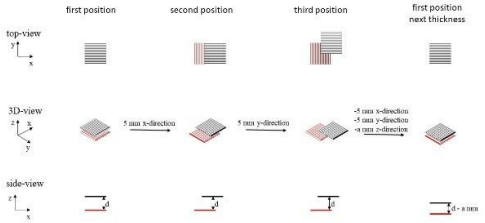

***Figure 1**: Schematic drawing of the program used for measuring different areas on one thickness seen in a top-, side and 3D view.*

This allowed to measure three different areas on each thickness of the hydrogel before switching to a different thickness. As electrode platinum squares with an edge length of 10 mm were used. Therefore, the resulting areas measured were 100 mm^2, 50 mm^2 and 25 mm^2. It was found that the mathematical growth model of the electrolyte resistance in dependency of the thickness of the hydrogel varied in different electrolytes. The reasons for this different growth model are the nature of the ions, due to different impedance answers of them and their initial concentration. As the hydrogel is pressed during the different measurements the concentration of the ions changed in the hydrogels. In electrolytes with a higher ion concentration this effect can be neglected and the hydrogel has an ohmic like behaviour.

Tests at different temperatures showed no clear trend of the resistance as the hydrogel as a sol-gel transformation was observed. Due to the change of the apparent viscosity the resistivity of the hydrogel would increase, while faster ion movement because of the temperature would decrease the resistivity.

Conclusions

A reliable and reproducible measurement method was developed to measure the resistance of a hydrogel in dependency of thickness and area of overlapping surface electrode. The mathematical growth model of the resistance in dependency of the thickness is influenced by the nature and initial concentration of ions in the hydrogel.

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Acknowledgements

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D17 - The fabrication process of biopolymer-nanofiber-based electrodes by vacuum filtration

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Abstract: The need for bioelectronic interfaces for the living body has fueled the development of materials that bridge the gap between electronic devices and biological tissues. To date, biopolymers have been investigated as next-generation materials for bioelectronic interfaces because of their intriguing characteristics. However, their application is limited due to the poor compatibility with classical processing methods. Here we demonstrate a new fabrication process for bioelectronic interfaces based on chitosan nanofibers (CSNFs) and carbon nanotubes (CNTs).

Keywords: implantable electrodes, biopolymers, high-aspect-ratio materials, bioelectronics

Introduction

Bioelectronic devices have been vigorously investigated to improve human health **[1]**. Since they come in direct contact with living tissues, the interface needs to be biocompatible and should not elicit unwanted responses. Recently, biopolymers and nanofibers have received attention as bioelectronic interfaces due to their characteristics such as high biocompatibility. However, there is a limited number of fabrication methods to integrate electrical circuits with biopolymers, especially with nanofibers. Here, we show a new fabrication method supported by vacuum filtration to produce bioelectronic interfaces using chitosan nanofibers (CSNFs) and carbon nanotubes (CNTs).

Results and Discussion

Figure 1 illustrates a simplified fabrication process of CSNF paper-based electrodes. To micropattern the electrodes, patterns of pores and grooves were fabricated in a polyimide (PI) film, and the micropatterned PI films were then used as a mask on top of the filtrated CSNF paper on a PVDF membrane. A dispersion of CNTs was filtered through the PI-masked CSNF films to provide conductive networks. Subsequently, the polyimide mask was removed resulting in a CNT patterned CSNF substrate. Subsequently, we demonstrated an optional process to provide a stable passivation layer. To this end, we applied polydimethylsiloxane (PDMS) structures for the protection of the contact pads. Afterward, a CSNF dispersion was filtered to protect the conductive material patterns and provide a passivation layer. As a proof-of-principle, we used this process to fabricate a nerve interface.

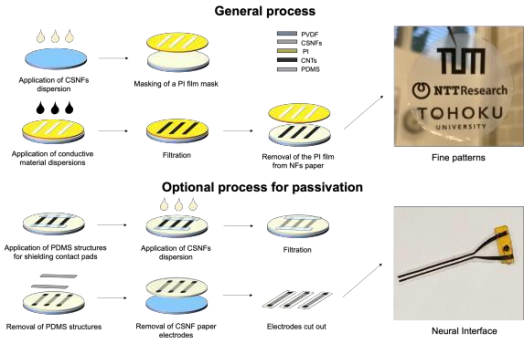

Figure 1: *The schematic of the fabrication process for CSNF/CNT electrodes.*

Conclusions

We demonstrated a process for the fabrication of nerve interfaces based on CNT fine patterns on CSNF paper. We believe this process can beapplied in future in vivo experiments requiring degradable electrode systems.

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Acknowledgments

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D18 - Rapid Prototyping of 2D- and 3D-Microelectrode Arrays (MEAs) for *in vitro* Applications

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Abstract: Recent investigations into 3D cell cultures and organoids necessitate systems that are able to record and stimulate electrically in several planes as opposed to surface recordings with conventional microelectrode arrays (MEAs). Common clean-room techniques suffer in short-term adaptation for the generation of complex 3D MEAs. In this work, we illustrate how rapid prototyping processes - laser patterning and ink-jet printing - can help to overcome these challenges. We demonstrate a laser-patterned MEA with printed 3D-electrode structures to ultimately provide means for recording signals from organoids and study disease models in vitro.

Keywords: 3D microelectrode array, additive manufacturing, laser patterning, ink-jet printing, rapid prototyping, brain organoid.

Introduction

Today's standard MEAs can only record electrophysiological signals in 2D, thus, they are not suitable to measure from emerging 3D cell cultures or organoids [1]. To overcome this challenge, we design and fabricate 3D MEAs by additive manufacturing [2]. The 3D MEAs are promising for studying neuronal function or diseases with neuronally differentiated human-induced pluripotent stem cells (hiPSC).

Results and Discussion

We demonstrate the microfabrication of 3D MEAs using laser patterning and ink-jet printing. In a first step, we printed pillars from silver ink onto a flexible polyimide foil. Then, the structures were sputtered with gold to provide a biocompatible electrode interface. Afterwards, individual electrodes and feedlines were generated via laser ablation. Remarkably, our feedlines structures can be patterned within only several minutes in contrast to conventional lift-off techniques. Subsequently, the chip was fully passivated with a parylene C layer using vapor deposition. Finally, the electrode openings at the pillar tips are generated by laser ablation. Our method provides a fast and easy adjustable fabrication approach compared to conventional clean-room techniques. The chosen design aligns the individual electrodes to be integrated with a 96-well-plate, for simplifying manual handling. The printing process allowed the fabrication of pillars featuring different heights, reaching up to 1 mm. With this highly flexible approach, we aim to record cellular signals from various planes within the targeted tissue.

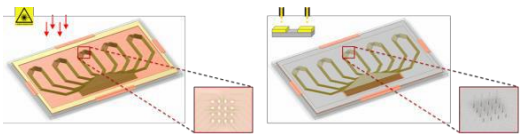

Figure 1: *Concept of the rapid prototyping process for fabrication of planar MEAs with integrated 3D-electrodes.*

Conclusions

In this work, we demonstrate a rapid prototyping process for the fabrication of planar MEAs with integrated 3D-electrodes. On a bigger scope, we aim to provide a platform that facilitates recording and stimulation within 3D cell aggregates or organoid models.

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Acknowledgements

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D19 - Providing a new Method of Fluorescence Quantification

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Abstract: A new approach is made to achieve a quantitative detection of fluorescence markers. The use of a photon-mixer-device (PMD) has been described in previous conference proceedings and a resulting paper. The present work deals with a new algorithm to calculate the concentration of a certain fluorescence marker. It is shown why two kinds of fluorophores are used and how a change in the concentration takes influence on the phase of the measured cross-correlation-function. The sensitivity of the algorithm is discussed and needed measurements to described.

Keywords: fluorescence, concentration, quantification, correlation

Introduction

In previous EnFi conferences the development of a new fluorescence detection method based on a photon-mixer-device (PMD) was presented **[1]**. The new method can determine the concentration of an Qdot™ 585 ITK™ carboxyl quantum dot while using the fluorophore Alexa Fluor™ 430 NHS Ester as a reference in the optical signal. The reason behind the use of these two optical markers is the different fluorescence lifetime.

Results and Discussion

Since the lifetime of Alexa 430 is approximately 3 – 4 ns **[2]** long and of Qdot™ 585 17 to 21 ns **[3]** they both effect the cross-correlation-function (CCF) which is generated by the used optical sensor. Depending on the concentration C_{Alexa} and C_{QD} the phase shift of the (CCF) will change. While C_{Alexa} must be a constant and known value C_{QD} is variable and must be determined.

Since a FFT can be performed on the CCF the resulting amplitude $\vec{\hat{V}}_{\text{Meas}}$ and phase φ_{Meas} of the base wave is composed proportionately of the amplitudes of $\vec{\hat{V}}_{\text{Alexa}}$, $\vec{\hat{V}}_{\text{QD}}$ and the angle φ_{QD}. While those amplitudes can be described as follows:

$$\hat{V}_{\text{Alexa}} = \text{K}_{\text{Alexa}} \cdot C_{\text{Alexa}}$$

$$\hat{V}_{\text{QD}} = K_{\text{QD}} \cdot C_{\text{QD}}$$

Taking the relationship shown in figure 1 into account, the required C_{QD} can be calculated as follows:

$$C_{\text{QD}} = \frac{K_{\text{Alexa}}}{K_{\text{QD}}} \cdot \frac{1}{\frac{sin(\varphi_{\text{QD}})}{tan(\varphi_{\text{Meas}})} - cos(\varphi_{\text{QD}})} \cdot C_{\text{Alexa}}$$

The sensitivity of this algorithm depends on the concentration of Alexa 430 and is shown in figure 2.

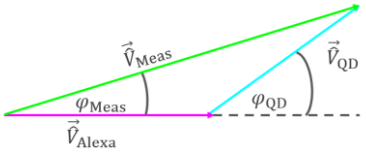

Figure 1: *The pointer diagram shows the relationship between the different signals forming the CCF.*

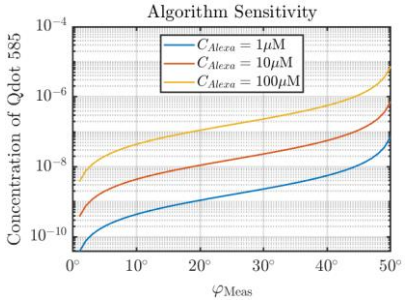

Figure 2: *Sensitivity of the algorithm, which must be evaluated via measurements.*

Conclusions

The factors K_{Alexa} and K_{QD} can be determined by measurements. If these are known, C_{QD} can be determined by the phase of the CCF´s base wave. This allows the construction of innovative optical sensors.

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