Poster Abstracts: Monday

Temperature controlled microfluidic valve system fabricated from thermosensitive poly-NIPAM-DEGMA hydrogel copolymer

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Hydrogels, crosslinked polymer networks capable of absorbing and retaining large volumes of water [1], have emerged as a versatile class of materials with immense potential in various technological domains. Their biocompatibility, tunable mechanical properties, and responsiveness to external stimuli make them ideal candidates for applications ranging from drug delivery and tissue engineering to sensing and actuation.

Poly(N-isopropylacrylamide) (pNIPAM) and Di(ethylene glycol) dimethacrylate (DEGMA) hydrogels have gathered significant attention due to their unique temperature-responsive behavior. They exhibits a sharp volume phase transition at their lower critical solution temperature (LCST, 32°C) in aqueous solutions. Below the LCST, the hydrogel/polymer chains are hydrophilic and hydrated, resulting in a swollen hydrogel state. Above the LCST, the polymer chains become hydrophobic and opaque, leading to dehydration and a dramatic collapse of the hydrogel network. This temperature-triggered volume change is reversible and can be precisely controlled.

This study focuses on the development and characterization of a novel valve system based on pNIPAM-DEGMA copolymer integrated in the microfluidic channels. The aim was to create a reliable and efficient valve that can precisely control fluid flow by temperature adjustment. Specific microfluidic system was designed and fabricated by soft lithography technique. The hydrogel composite was injected and polymerized in the microfluidic channel by γ-radiation. The temperature dependent structural change of the copolymer was characterized by flow rate measurement in case of different pNIPAM:DEGMA ratios. By increasing the concentration of the pNIPAM in the copolymer, the valve becomes more responsive to temperature changes and allows higher flow rates due to the pore structure.

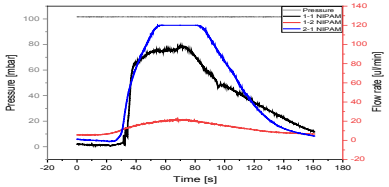

Fig. 1. Composition dependent flowrate in the microfluidic device in case of 100mbar pressure - relative ratios of pNIPAM:DEGDMA monomers ranging between 1:2, 1:1, 2:1.

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Microfluidic Impedance Tomography for Localized Microbead Mapping

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Electrical Impedance Tomography (EIT) is a well-known application of Electrochemical Impedance Spectroscopy (EIS) having widespread macroscopic use in body composition analysis while offering promising possibilities for targeted medical diagnostics, such as tumor detection and cancer research [1]. A limitation of conventional EIT is that it provides only qualitative information about tissue level parameters and lacks the resolution required for cell level analysis. This limitation can be overcome through miniaturization, which enables highresolution EIT for in situ, 3D monitoring of cell growth, structural changes, and the effects of therapeutic treatments [2].

In this work, we present a compact microfluidic platform with an integrated platinum microelectrode array for EIT measurements using a custom-designed PCB [3]. Pt electrodes were fabricated on Borofloat™ glass by vacuum sputtering and lift-off lithography. The electrode design enables two- or four-electrode measurement methods to investigate the linear mapping capability of the channel. For this, microbeads were used to examine the correlation between the number of microbeads positioned between individual electrodes and the corresponding impedance spectra. The influence of bead size and channel heights (10, 30, and 50 µm) of the spectral region was studied. Reducing the difference between channel height and particle diameter increased the correlation between the impedance profile and the local distribution of the beads.

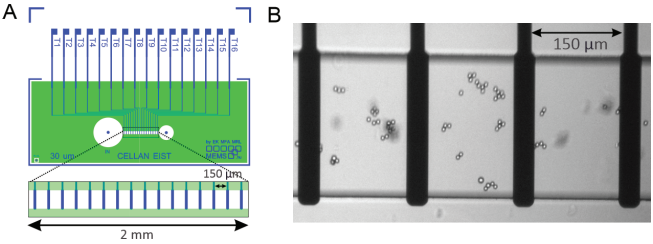

Figure 1 (A) The layout of the system and the trapped microbeads between the electrodes

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Microfluidic chamber optimization for fluorescent drug detection

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Microfluidic analytical systems have emerged as powerful tools for biochemical sensing and drug analysis due to their ability to handle minimal sample volumes with high sensitivity [1]. Additionally, microengineered OrganonChip platforms provide physiologically relevant environments for evaluating drug response and toxicity, offering valuable alternatives to traditional in vitro assays. These technologies are particularly relevant for studies of NSAID (Nonsteroidal Anti-Inflammatory Drugs) drugs such as Naproxen in Skin-on-Chip applications, where precise concentration measurement and controlled conditions are essential.

In this work, the methodological aspects of fluorescence-based drug detection in microfluidic systems were investigated. First, the absorption and fluorescence emission spectra of Naproxen were characterized using a plate reader spectrophotometer within a relevant concentration range in biological solvent. Subsequently, relevant polymer materials of microfluidic applications were evaluated by analyzing their optical properties (COC, COP, PMMA, PC, PS) with respect to optical transparency and intrinsic fluorescence background. After these measurements, commercially available microfluidic chips were used to investigate the structural parameters influencing fluorescence detection. The dependence of fluorescence emission intensity was analyzed considering different flow cell configurations, including chamber depth, optical parameters of the structural polymers as transparency, and the effect of a backside reflective metal layer deposited to enhance the optical path.

The obtained results provide important insights into the influence of material properties and microfluidic chip design on the sensitivity of fluorescence-based measurements. Based on these findings, optimized, custom designed microfluidic chambers will be fabricated using hot embossing technology to support the development of compact and integrable microfluidic platforms for optical drug analysis.

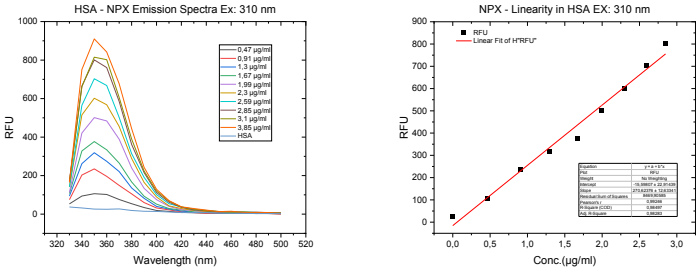

Fig. 1 Concentration dependent emission spectra of Naproxen (λ_{ex}=310nm) and its linearity in HSA containing biological solvent (λ_{em}=350nm)

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Hydrogel-Encapsulated Nano-Optodes for Mitigating Protein Interference During Direct Analysis in Human Blood

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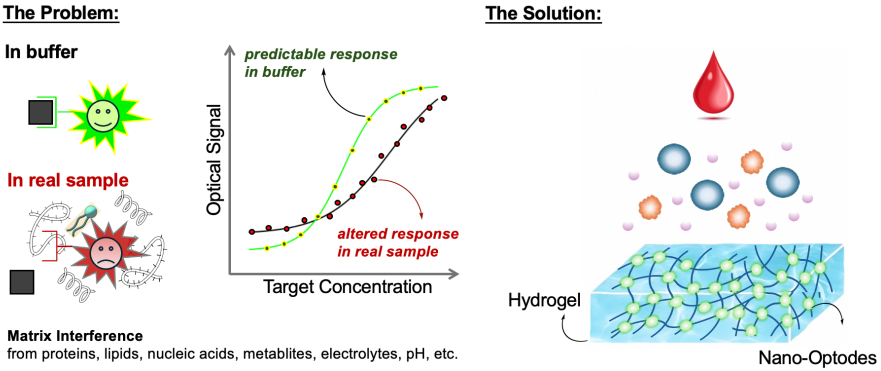
The direct detection of target analytes in complex biological fluids such as serum remains a significant analytical challenge. Traditional methodologies often necessitate elaborate sample pretreatment, including separation or centrifugal filtration, to avoid interference from the complex matrix, particularly proteins, which can compromise the specificity and accuracy of detection probes. This study aims to address the issue of protein interference in direct serum analysis by developing a series of hydrogel-based encapsulation strategies.[1,2] Using human serum albumin (HSA) as a model interfering protein, we investigated the performance of this approach in minimizing matrix effects.

To demonstrate this concept, we synthesized and encapsulated three different types of sensing probes within a gel matrix: (1) Nano-optodes loaded with an ionophore, a chromoionophore, and ion-exchanger for sodium ion (Na^+) detection; (2) FITC-modified dextran incorporated in hydrogel gel for pH monitoring; (3) Nano-optodes with surface labelling a Nile blue derivative through Click reaction for pH monitoring.

The results demonstrated that the detection discrepancy were largely minimized (around 1%-5%), as the gel matrix served as a physical shield against protein interference. Microscopic imaging revealed that ions diffuse rapidly into the gels, whereas the penetration of proteins is almost negligible. These findings indicate that the physical encapsulation of sensing probes within a gel barrier effectively restricts direct interaction with large protein molecules, thereby preserving probe fidelity and enabling more reliable direct measurement. Interference from other biological species such as globulin proteins, lipids, nucleic acids, and other metabolites will also be discussed.



Scheme. Hydrogel-encapsulated nano-optodes sensors for mitigating protein interference induring direct analysis in human blood.

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Optimization of the membrane composition of a potentiometric sensor based on a molecularly imprinted polymer modified with nanoparticles for the determination of thiabendazole

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Thiabendazole (THIA) belongs to the group of benzimidazole fungicides. Benzimidazole ring in its structure is responsible for its antifungal activity and provides effectiveness against a wide range of fungal pathogens [1]. This fungicide is commonly used to protect fruits and vegetables from infections during storage. Therefore, monitoring its concentration and possible effects on human health is important.

Ion-selective electrodes proved to be very good sensors in the determination of THIA [2,3], but to achieve even better results, a new sensor material based on a molecularly imprinted polymer (MIP) was synthesized, and then the membrane composition was optimized. MIP was synthesized based on modification of native multi walled carbon nanotubes (MWCNT) with methacrylic acid (MAA) followed by polymerization with MAA using THIA as a template to prepare MWCNT-MAA-MIP.

The new sensor material was embedded within the liquid-type membrane of the sensor. The investigation was carried out by direct potentiometry. The membrane composition was optimized by varying the percentage of sensor material, the amount of incorporated MWCNT, and the type of plasticizer (dibutyl phthalate (DBP), dibutyl sebacate, and *o*-nitrophenyloctyl ether). The best properties were achieved with a sensor containing DBP, 3% sensor material, and 2% MWCNT. This sensor exhibited a slope of 59.7 mV, a detection limit of $3.2 \cdot 10^{-7}$ mol dm^{-3}, a wide measuring range ($6.2 \cdot 10^{-7} – 1.0 \cdot 10^{-3}$ mol dm^{-3}).

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Two-in-One 3D-Printed Microneedle-Based Sensors for *In-planta* Ca^{2+} Monitoring

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Calcium ions (Ca^{2+}) are key second messengers in plant stress signaling, yet real-time, quantitative in-planta detection remains challenging and often relies on destructive methods [1]. Here, we present a two-in-one 3D-printed microneedle (MN)-based potentiometric sensor that integrates a Ca^{2+}-selective working electrode (WE) pillar and a solid-state reference electrode (RE) pillar within a single MN body. Both the WE and RE pillars are printed via fused-filament fabrication using commercial carbon black/polylactic acid (CB/PLA) filaments. A polyurethane-based membrane is added to the WE pillar to provide ion-selectivity, while the RE pillar is modified with Ag/AgCl paste followed by a PVB-based membrane. The MN body is manufactured separately by stereolithography, using a commercial acrylate-based resin that improves mechanical robustness. The sensor exhibits a near-Nernstian slope for Ca^{2+} ion (~27 $mV \cdot dec^{-1}$) and a plant-relevant linear response range in artificial sap (10^{-4}–10^{-1} M), together with high stability (~0.2 $mV \cdot h^{-1}$ over 24 h). Ex-vivo sap measurements across three species of plants agree well with a colorimetric assay (differences < 10%). After verification of high insertion resiliency with slope differences of less than 4%, *in-planta* measurements of both short (100 s) and extended periods (> 30 min) were performed with stable local Ca^{2+} readouts. The overall workflow is shown in FIGURE 1. Collectively, the developed MN platform enables spatiotemporally resolved Ca^{2+} quantification in plants and offers a versatile architecture adaptable to other analytes for plant monitoring.

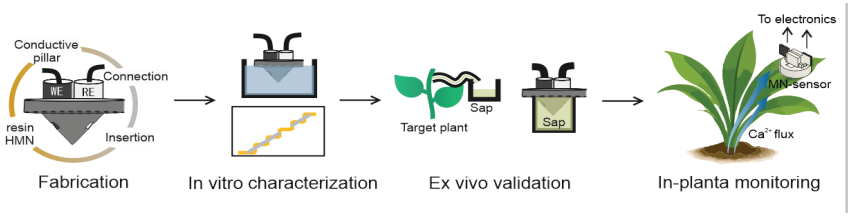

FIGURE 1. Workflow of the two-in-one 3D-printed MN-Based Sensors for in-planta Ca^{2+} monitoring.

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Potential-Controlled Electrochemical Sensing of Polystyrene Nanoplastics

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Nanoplastics, defined as particles smaller than 1 µm, are commonly present in aquatic environments and pose serious ecological and health risks, especially due to their ability to cross biological barriers [1]. Reliable in-situ monitoring remains challenging because conventional spectroscopic and separation methods are often time-consuming, costly, and poorly suited for the in-field and on-site applications [2]. Herein, we introduce a novel electrochemical sensor that enables capture and detection of polystyrene nanoplastics directly from water bodies through potential-controlled electrostatic accumulation on a proline-functionalized mesoporous silica thin film (MSTF), electrodeposited onto screen-printed gold electrode.

Sensor fabrication used electrochemically assisted self-assembly to deposit a CTAB-templated mesoporous silica layer, followed by surfactant removal and covalent proline attachment via epoxy silane, resulting in the final Au-MSTF-proline platform. Step-by-step modification was evaluated by cyclic voltammetry and electrochemical impedance spectroscopy with hexacyanoferrate redox probe, showing expected changes in peak currents and charge-transfer resistance due to pore blocking, opening, and surface functionalization. Negatively charged polystyrene nanoparticles were accumulated on the positively polarized working electrode at +0.8 V vs. Ag quasi-reference electrode for 5 minutes, leading to adsorption within and onto the porous electrode structure. This coverage blocked redox probe diffusion and caused a concentration-dependent decrease in anodic peak current. Differential pulse voltammetry offered higher sensitivity and revealed clear size-dependent responses for particles with nominal molecular weights of 34, 564, and 2530 kDa, corresponding to hydrodynamic radii of approximately 177–495 nm, as measured by dynamic light scattering. The smallest particles showed the highest sensitivity of –1.19 µA mL/µg in the 10–20 µg/mL range, with two linear ranges reflecting progressive surface saturation. Larger particles displayed lower sensitivity and a single linear range up to 80 µg/mL. Interference study showed negligible influence and preliminary measurements in real bottled water samples confirmed the sensor's ability to detect polystyrene nanoplastics in environmental matrices with the use of standard addition method.

This approach integrates simplified on/off sampling and electrochemical detection into a single portable platform, providing a promising tool for on-site, real-time monitoring of nanoplastics in water bodies.

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Self-calibrated potentiometric sensors

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Potentiometric ion selective electrodes (ISEs) have shown significant potential in a wide range of applications, allowing rapid analysis with exceptional selectivity. Their high suitability for healthcare and environmental monitoring has driven the development of these sensing devices, leading to massive commercial impact [1]. The emerging interest in ISE development is bringing important advancements, but further drastic simplification goes unfortunately at the expense of accuracy, which is analytically unacceptable. A major drawback in potentiometric measurements is that each interface within the electrochemical cell can produce potential uncertainties, promoting unpredictable electromotive force (EMF) drifts and negatively affecting accuracy. Thus, ISEs must be calibrated using standard solutions before and/or after each measurement. This task can be time-consuming and requires complex instrumentation, which is undesired.

Figure 1. assembled setup for dry a) and c) wet measurements; current pathway in dry b) and wet d) measurements.

The group of Wang introduced a capillary solution bridge between the two electrodes that allows a measurement to be performed before sample exposure, which is an elegant approach to compensate potential uncertainties [2]. We propose here an alternative self-calibrated potentiometric sensing principle that aims to eliminate the need for fluid-handling and calibration, thereby enhancing data reproducibility and accuracy. A membrane bridge is cast between two electrodes so that a dry measurement is performed before exposure to the sample solution, allowing one to measure the potential between the two membranes in a dry state (Fig. 1a-b). The device is then exposed to the sample for the actual measurement. The current path through the solution is now dominant as the resistance of the solution is significantly smaller (<1000 x) than the resistance of the membrane bridge (Fig. 1c-d). One may now subtract the EMF baseline of the dry measurement from that of the final measurement to compensate potential variations at the membrane/electrode interface. As a proof of concept, we explore the application of this new approach in the development of pH sensing devices.

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Potentiometric Ion-Selective Membranes Integrated into Solid-Contact Electrodes for Bilirubin Detection

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Bilirubin is a clinically relevant biomarker of hepatic function. In blood, it exists as water-soluble conjugated bilirubin (CB) and water-insoluble unconjugated bilirubin (UCB), the latter being present either bound to albumin or in its free form. Elevated levels of free UCB may lead to hyperbilirubinemia and, in neonates, if free bilirubin crosses the blood-brain barrier, it can cause kernicterus, resulting in irreversible neurological damage [1]. Therefore, reliable and early monitoring of bilirubin levels during the first days of life is essential.

Current non-invasive screening relies on transcutaneous bilirubinometry, which estimates bilirubin levels based on skin coloration (jaundice), but suffers from limited sensitivity and may be affected by skin pigmentation. Total serum bilirubin is more accurately determined by spectrophotometry; however, this approach is invasive since requires blood sampling and depends on centralized laboratory facilities and trained personnel. Other analytical techniques, including fluorimetry, amperometry, enzymatic, and chromatographic methods, often involve complex instrumentation [2], [3]. Consequently, there is a growing demand for simple and reliable strategies suitable for point-of-care testing.

Herein, we report the development of ion-selective membranes (ISMs) integrated into solid-contact potentiometric electrodes for the selective detection of free bilirubin in serum. The membrane composition was optimized to enhance affinity toward UCB while minimizing interference from other ions present in serum. The sensors exhibited Nernstian responses, good reproducibility, and operational stability. Validation in real serum samples showed good agreement with reference laboratory methods. Besides, the use of solid-contact transducers eliminates the need for internal filling solutions, improving mechanical stability, miniaturization capability, and suitability for portable applications. These results highlight the potential of solid-contact ion-selective membrane electrodes as a sensitive, minimally invasive, and cost-effective platform for free bilirubin monitoring. Moreover, the proposed approach represents a promising step toward point-of-care devices for early diagnosis and management of neonatal hyperbilirubinemia.

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Synthesis and characterization of TEMPO grafted poly(vinyl chloride) as potential ion to electron transducer in solid-contact ion-selective electrodes

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Polymer-based ion-selective electrodes (ISEs) are a versatile class of electrochemical sensors used in various fields such as clinical diagnosis, environmental analysis and biomolecule sensing. Poly (vinyl chloride) (PVC) is a commonly used polymer for electrode membrane preparation due to its favorable mechanical properties and compatibility with other membrane components such as ionophores and ion-exchangers. Additionally, a transducing layer is an essential part of these electrodes, to ensure an effective ion-to-electron transfer between the ion-selective membrane and the metallic electrode surface [1].

Various conducting, redox-active materials have been explored as transducing layer, including carbon-based materials [2] such as carbon nanotubes (CNTs) [2] and graphene [2]. Conducting polymers such as poly(3,4-ethylenedioxythiophene) (PEDOT) [3], poly (pyrrole) (PPy) [3] and poly (aniline) (PANI) [3] have been popular options due to their efficient ion-electron signal conversion and robustness but exhibit poor mechanical properties. Other strategies also include redox-active lipophilic ferrocene derivatives dissolved in the membrane as suggested by Samec et al. [4] but this is prone to leaching and ferrocene exhibits poor stability in the presence of chloride. Similarly, Pawlak et al. [5] chemically attached ferrocene groups to modified PVC to create a redox polymer alternative.

We describe here the synthesis of a new compound, PVC-TEMPO, as a potential ion-to-electron transducing material for solid-contact ISEs. An alkyne-modified TEMPO molecule was grafted onto an azide-modified PVC backbone by click chemistry, using the simple, high-yielding, copper-catalyzed azide-alkyne cycloaddition reaction. The resultant polymer obviates the need for an additional conducting, redox-active layer, with the possibility of being applied as a single membrane, potentially resulting in numerous practical potentiometric and ion transfer voltammetric applications.

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MIP-Based Interdigitated Gold Electrode for Selective Electrochemical Sensing of Carbonaceous Nanoparticles

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Air pollution has emerged as a significant environmental issue in recent decades, primarily due to the excessive release of particulate matter (PM) into the atmosphere [1] which has adverse effects on both the environment and human health [2]. Among these particles, carbonaceous nanoparticles, with a diameter < 1 µm, play a major role. The lack of simple, user-friendly devices for detecting these nanoparticles has created a need for innovative sensing approaches. A combination of molecularly imprinted polymers (MIPs) with interdigitated electrodes (IDEs) offers a promising solution, enhancing selectivity, simplifying operation, and enabling rapid, real-time monitoring [4]. Herein, we demonstrate MIP thin film synthesis via reversible addition–fragmentation chain transfer (RAFT) thermal polymerization in the liquid phase, using 4-vinylpyridine (4-VP) as the functional monomer and divinylbenzene (DVB) as the cross-linker, and carbon nanoparticles (CNPs) as template on the IDE (Figure 1 (a)). A non-imprinted polymer (NIP), prepared under the same conditions, but without a template, was used as a reference. The results in Figure 1(b) and (c) show the Differential Pulse Voltammetry (DPV) response of the MIP-based IDE sensor, demonstrating concentration-dependent current changes upon exposure to CNPs. The current responses of MIP- and NIP-coated electrodes demonstrate that the MIP sensor has a larger current shift than the NIP sensor at all tested concentrations. This enhanced response corresponds to an imprinting factor (IF) of approximately 4.5, confirming the successful imprinting effect.

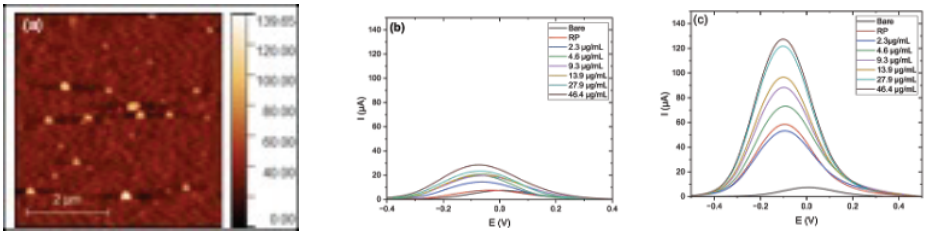

Figure 1. (a) AFM image of MIP; (b) DPV of NIP at various concentrations of CNPs (µg/mL); (c) DPV of MIP at various concentrations of CNPs (µg/mL) (RP: redox probe (Ferrocyanide-ferricyanide).

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Lipophilic salt/IL membranes for reference electrodes without liquid junction: equilibrium and transient modeling for design improvements

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In recent years many novel reference electrode designs have been reported. This is due partly to the longstanding limitations of conventional reference electrodes, and partly to emerging applications requiring, for example, miniaturized, wearable or maintenance-free sensor systems. Reference electrodes without liquid junction represent an elegant solution. These devices are often similar to membrane-based ion-selective electrodes, but ideally their membrane is nonresponsive to changes in sample composition. The active membrane material is typically a lipophilic salt or ionic liquid. Experimental studies have repeatedly pointed out the lack of an adequate theoretical framework to support electrode optimization. Modeling these systems is challenging, however, because of the large number of variables that must be considered.

The equilibrium potential of such electrodes has been analyzed by formulating the equilibrium equations and investigating parameter effects through numerical simulations. In contrast, studies of their time-dependent response have only recently begun, mainly through the work of the Egorov group.

The present work provides a unified treatment of both the equilibrium behavior and the time response of these electrodes. It shows that introduction of a tolerance limit for the deviation of the electrode potential as measured in a sample relative to that measured in pure water makes the treatment of both equilibrium and kinetics much more transparent. It is demonstrated that the equations obtained for equilibrium and kinetics have the same form, differing only in a single variable. The results define the limits of the main design parameters required for near ideal behavior, without the need for non-thermodynamic assumptions. The importance of the - aqueous solution to membrane - phase ratio for the time response is also demonstrated; to the best of our knowledge this factor has not been addressed previously. The necessary conditions for fast response combined with potential stability over more than 24 hours are presented. Simulations based on numerical solution of the Nernst-Planck-Poisson equation support the validity of the design rules derived from the theoretical treatment.

Advancement and Integration of a Wearable Sweat-Based Glucose Sensor into a Multi-Parametric ICU Digital Monitoring Platform

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Continuous monitoring of biomarkers is essential for transforming patient care into intensive care units (ICUs), where frequent blood sampling increases workload and patient burden. Sweat presents a powerful, non-invasive alternative, offering easily accessible biomarkers that provide real-time insights into a patient's physiological state [1, 2].

This work presents outcomes from the European IRHIS project (21 partners, spanning 13 EU regions), which is developing a next-generation ICU remote monitoring platform within an interoperable remote care framework. The system combines multiple key sensing modalities including glucose, lactate, and humidity sensors, into the platform of a device for wireless vital signal monitoring. Powered by AI-driven predictive analytics, it will enable continuous multi-parametric health monitoring. To complement the platform, a disposable wearable skin patch for continuous sweat glucose monitoring was developed, seamlessly integrating into the ICU monitoring ecosystem. The patch features an enzyme-based electrochemical glucose sensor with high sensitivity, a linear response within the physiological sweat glucose range (5–200 μM), and specificity under physiological conditions. Its design combines a disposable biosensor, a microfluidic sampling, wireless electronics, and a user-friendly application.

Clinical data will be acquired in three stages involving cohorts of 120 patients each: (1) monitoring of vital parameters and humidity, (2) monitoring of vital parameters, humidity, and lactate levels, and (3) combined analysis of all parameters, including glucose. The study will be conducted in collaboration with the Intensive Care Unit of Hospital Santa Lucía and in full compliance with EU medical device regulations. It will demonstrate the clinical and technological feasibility of integrating wearable biosensing with AI-driven analytics, enabling earlier interventions, improved patient safety, and more efficient critical care management.

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Pyrene-PEG Functionalized Laser Induced Graphene Electrode for Lactate Biosensing

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Sepsis is a life-threatening condition that requires rapid and reliable diagnostics, with blood lactate levels serving as an important biomarker for disease severity and progression. In this study, a commercially available 3D laser-induced graphene (LIG) electrode from iGii was used for lactate sensing, offering high surface area, reproducibility, and faster translation toward practical applications. The LIG electrodes were functionalized with pyrene-PEG-COOH (1 kDa approximately 3nm PEG length) at different concentrations (100 mM, 10 mM, 1 mM, and 0.1 mM). Subsequently, enzymes were covalently immobilized via EDC/NHS-mediated amine coupling, in which surface carboxyl groups were activated to react with enzyme amine residues, forming stable amide bonds [1]. Flavin mononucleotide (FMN)-dependent lactate dehydrogenase (LDH) was immobilized overnight onto the modified electrode surface. The electrochemical performance of the biosensors was evaluated by cyclic voltammetry in phosphate-buffered saline (PBS), in both the absence and presence of L-lactate. The aim of this study is to evaluate direct electron transfer (DET) using PEG as a linker and to investigate its effect on DET efficiency. According to the literature, the effective DET distance is typically around ~1.4 nm [2] from the electrode surface; however, despite the estimated PEG linker length (~3 nm), DET effects were observed, reflected in the increasing current with lactate concentration. Additionally, PEG serves as a flexible linker that interacts with the porous LIG structure, improving enzyme orientation and effective surface area while reducing interfacial resistance and improving electron exchange at the electrode surface, and helping to minimize interference from electroactive species (e.g., ascorbic acid, uric acid, paracetamol) [3]. Initial results of PEG linker surface engineering yielded DET currents; however, at high PEG loading (100 mM), we observe the insulating effect of the PEG layer, leading to a reduced electrochemical response. Therefore, in further experiments, the concentration was decreased. Future studies will investigate the effect of PEG chain length of pyrene-PEG-COOH/pyrene-PEG-NHS with varying molecular masses (1, 2, and 5 kDa) to further optimize DET performance. We expect a linker-length dependence, where shorter linkers (e.g., 1 kDa) enable DET, while longer linkers may limit electron transfer, indicating a balance between accessibility and insulation.

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CRISPR/Cas12-assisted DNA sensing: filter paper as a scaffold material to immobilize substrate ssDNA reporter

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CRISPR/Cas-assisted nucleic acid sensing has been widely investigated owing to its capability of single nucleotide polymorphism discrimination and enzymatic turnover reaction enhancing assay sensitivity[1]. While immobilization of substrate ssDNA reporters on scaffold materials has greatly enhanced the flexibility of CRISPR/Cas-assisted assays, conventional materials such as nano/microparticles and two-dimensional materials suffer from some drawbacks, including the need for separation steps or a limited surface area.

To address these issues, we focused on the chemical characteristics of filter paper. Compared to the other scaffolds mentioned above, filter paper offers unique advantages such as a large surface area and separation-free handling, thereby providing the potential to simultaneously achieve high sensitivity and operational simplicity. In this context, we propose filter paper as a new alternative scaffold material for CRISPR/Cas-assisted DNA sensing.

As a basic characterization, fluorescein-modified DNA was used to evaluate both the immobilization efficiency of DNA on paper and the release of fluorescein by the CRISPR reaction. Among various options of immobilizing biomolecules on cellulosic materials, four DNA immobilization methods were selected and compared: 1. Periodate oxidation method, 2. TEMPO oxidation combined with EDC/NHS coupling, 3. divinyl sulfone (DVS) method, and 4. streptavidin (SA)-biotin method. Overall, the SA-biotin method yielded the highest immobilized DNA density as well as highest S/N ratio for the CRISPR reaction (**Table 1**). This is mainly attributed to the abundant number of reactive amine groups on SA and its relatively large molecular size, which helps to reduce steric hindrance by BSA (applied in order to prevent non-specific adsorption of Cas enzyme on the surface) during the CRISPR reaction. Furthermore, this method was successfully applied to an electrochemical signal acquisition system by labeling DNA with methylene blue instead of fluorescein, demonstrating the versatility of the proposed immobilization method.

Table 1 Comparison of immobilized DNA density and S/N ratio of CRISPR reaction among four different immobilization methods

Method	1. Periodate	2. TEMPO	3. DVS	4. SA-biotin
DNA density (pmole/cm^2)	29.1	12.0	16.4	192
S/N ratio	4.2	2.7	3.6	7.5

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A Wearable Single-Needle Sensor for Continuous Lactate Monitoring

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Background: Continuous lactate monitoring (CLM) is crucial for evaluating athletic performance and preventing overtraining[1]. While sweat lactate is heavily researched, interstitial fluid (ISF) lactate exhibits a stronger correlation with blood lactate and shows greater commercial viability[2], [3]. However, existing ISF sensors heavily rely on complex microneedle arrays, which suffer from poor long-term stability, and limited application scenarios—often detaching during rigorous exercise due to shallow insertion depths (< 0.5 mm)[4]. Herein, we present a wearable CLM system integrating a long-lasting, single-needle minimally invasive ISF lactate sensor with a mobile application. Notably, the software features a rate-based calibration algorithm designed to optimize the physiological lag time between ISF and blood lactate. **Results:** The single-needle sensor demonstrated exceptional stability over 5 days of continuous *in vitro* testing, with a signal increment of 10% ± 5% (n = 5). A wide linear detection range from 0 to 29 mM (sensitivity: 0.89 ± 0.07 nA/mM, R^2>0.995, n = 16) was demonstrated. For *in vivo* validation, healthy athletes (n = 3) underwent graded exercise tests while wearing the CLM system. After applying the rate-based calibration algorithm, the correlation pearson r of ISF lactate and blood lactate improved from 0.90 to 0.96, and the lag time during the incremental loading phase was significantly reduced from 13 minutes to 7 minutes. **Conclusion:** Our findings demonstrate the feasibility of an integrated single-needle-based CLM system. Coupled with algorithmic lag-time correction, this system achieves clinical-grade accuracy in real-time. This breakthrough paves the way for the broader commercialization of wearable ISF biosensors in both professional athletics and digital health monitoring.

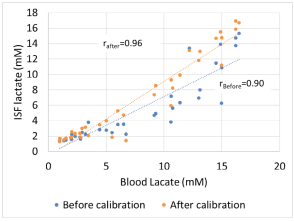

FIGURE 1. Correlation of ISF Lactate and Blood Lactate Before and After Algorithm Calibration for On-Body Testing.

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Application of a Modified Carbon Paste Electrode for Voltammetric Determination of Bisphenol A

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Bisphenol A (BPA) is an industrial, synthetic chemical compound extensively utilized in the production of polymers, epoxy resins, thermal paper, and electronics. Plastic food containers and canned foods are primary human exposure sources of this compound. The widespread detection of BPA in human urine samples is concerning due to its adverse health effects, including growth disruption, infertility, endocrine system disruption, immune system suppression, and carcinogenicity [1, 2]. In response, the European Commission established stricter criteria regarding the presence of BPA in food contact materials. Accordingly, the development of sensitive and fast methods capable of continuously monitoring BPA in different samples has been highly relevant. Besides chromatographic methods, electroanalytical methods are emerging as a relevant alternative.

Within this study, a carbon paste electrode combined with SWV was applied for BPA determination. The sensitivity was improved using different modifiers, including biochar, single- and multi-walled carbon nanotubes, with single-walled carbon nanotubes providing the best-defined signal in phosphate buffer (pH 7.0). Future work will focus on optimization and validation to obtain a sensitive methodology capable of routine monitoring in real samples.

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Background current reduction by use of sodium 4-vinylbenzenesulfonate as additive

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There are solvents having high background currents like alcohols and dimethyl sulfoxide mainly during voltammetric studies of compounds by electrooxidation. The use of sodium 4-vinylbenzenesulfonate as additive to the analyzed solutions gives an opportunity to markedly reduce the background current of selected analytes in solvents with high anodic background currents in the higher potential range. Recently we found that phenol can be determined in dimethyl sulfoxide and on the other hand the aforementioned additive caused obvious background reduction in dimethyl formamide. It seemed very useful also in solvent mixtures and addition of co-solvent itself brought advantages.

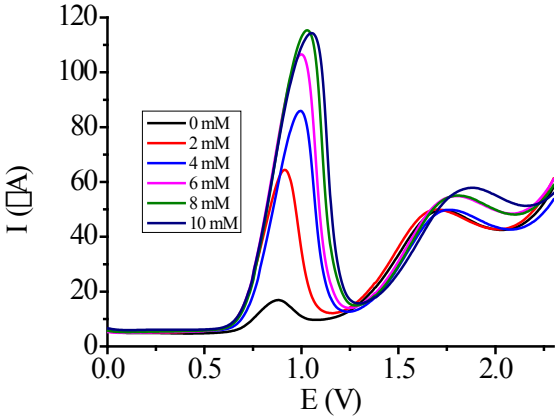

Figure 1. Differential pulse voltammetric curves of 4-methoxyphenol in 50-50 v/v% mixture of acetonitrile and methanol in presence of 8 mM sodium 4-vinylbenzenesulfonate (concentration range: 0-10 mM)

Spatial Visualisation of Ammonium Production by Urease using Voltammetric Ion Transfer Microscopy

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Our group has recently developed a new chemical imaging technique, termed Voltammetric Ion Transfer Microscopy (VITM), which enables spatially resolved ion detection.[1] Such approaches are attractive for studying heterogeneous ion distributions at the origin of various chemical processes. The imaging platform consists of a planar electrode coated with a thin ion-selective membrane (ISM). It contains a lipophilic derivative of the stable radical TEMPO as a redox probe and a lipophilic rhodamine fluorophore serving as an optical reporter. Because the radical form of TEMPO quenches the fluorescence emitted by the dye, a direct correlation between the electrochemical and optical signals can be established. Applying dynamic electrochemistry reversibly converts TEMPO between its radical and cationic forms, and triggers ion transfer between the aqueous and organic phases, while simultaneously modulating the fluorescence intensity (Figure 1a). Owing to its ability to acquire millions of spatially resolved concentration data points within a few seconds, this new approach lends itself to the study of dynamic systems. Here, by associating it with the incorporation of a new ammonium-selective tripodal ionophore into the membrane, we demonstrate the selective imaging of ammonium ions produced by the enzymatic activity of Jack bean urease at the interface between two laminar flows (Figure 1b).[2]

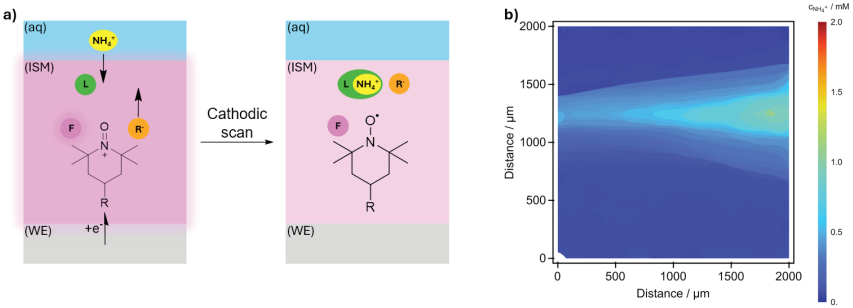

Figure 1. a) Underlying ion transfer principle and related fluorescence intensity change of the fluorophore (F) in the technique VITM. R^- represents a cation exchanger and L a NH_4^+ ionophore. **b)** Ammonium concentration density plot. Solutions of urease (top) and urea (bottom) flow over the membrane from left to right. Ammonium is produced along the central portion of the image where the two solutions meet and enzyme turnover occurs.

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Nanozymes with the record peroxidase-like activity as labels for electrochemical immunosensors

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Nanozymes, nanomaterials exhibiting enzyme-like (electro)catalytic activities, present a compelling alternative to natural enzymes for applications in medicine and analysis. The development and adaptation of nanozymes with high (electro)catalytic activity for use as labels in DNA/RNA or immunoassays represents a promising objective in the creation of personalized medical diagnostic devices.

We have investigated the catalytic and electrocatalytic properties of the most commonly used in the literature transition metal-based nanozymes that mimic peroxidase, a key enzyme in bioanalysis. It is shown that the half-wave potential of H_2O_2 reduction on electrodes modified with nanozymes precisely coincides with the intrinsic redox potentials of the material. Thus, the electrocatalytic activity for H_2O_2 reduction is determined by the electroactivity of the redox catalyst [1]. A comparison of the rate of the catalytic reaction (k_{cat}) of H_2O_2 reduction catalyzed by nanozymes with the redox potentials of materials and substrates shows a strong dependence. For all nanomaterials, the k_{cat} for the reducing substrate increases with an increase in the redox potential of the nanozyme itself. Regardless of the substrate, the Prussian blue-based nanozymes (PB) exhibit the highest catalytic activity and reaches values of $\sim 1 \cdot 10^8$ s^{-1} in the presence of $K_4[Fe(CN)_6]$, which is 3-4 orders of magnitude higher than for peroxidases [2]. In addition, for coatings based on PB nanoparticles, the found limit value of the electrochemical rate constant was $2 \cdot 10^{-2}$ $cm \cdot s^{-1}$, which is an order of magnitude higher than that of known peroxidase-like nanozymes and the enzyme.

The record performances of the PB nanoparticles allowed to apply them as electrochemical labels for immunosensors. PB nanozymes functionalized with azide groups were conjugated with antibodies via a “click” reaction. A sandwich-type immunosensors was realized, where the analytical response is the direct, mediator-free electrocatalytic current of H_2O_2 reduction. The exceptional electrocatalytic activity of these PB labels resulted in a limit of detection (4.3 $ng \cdot L^{-1}$) for antigen, cardiac troponin T (cTnT), more than 4 times lower than that achieved with conventional electrochemical immunosensors with peroxidase labels. The developed biosensor allows for the detection of cTnT in concentration range from 4.3 to 14,400 $ng \cdot L^{-1}$ in 15 μL of blood serum. We believe the combination of a fundamental understanding of nanozymes catalysis opens up new opportunities for the development of even more effective labels promising for use in compact analyzers and single-use diagnostic tests.

This work was supported by the Russian Science Foundation (project № 24-73-10015).

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Voltammetric Determination of Moniliformin Using a Modified Carbon Paste Electrode

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Moniliformin (MON) is an emerging *Fusarium* mycotoxin that may occur in cereals and cereal-based products, making its reliable determination important for food and feed safety assessment [1]. In this study, a voltammetric approach for MON determination using a modified carbon paste electrode was investigated. Several electrode modifiers were examined in order to improve the analytical performance of the carbon paste electrode, including different carbon-based nanomaterials and metal nanoparticles, ranging from carbon nanotubes to gold nanoparticles. Their influence on the electrochemical response of MON was evaluated and compared, and the most promising modification was selected for further study. The electrochemical behavior of MON was then investigated in comparison with the bare electrode using cyclic voltammetry and pulse voltammetric techniques. The results showed that electrode modification significantly affected the voltammetric response of MON, indicating improved electron-transfer properties and enhanced analytical performance compared with the unmodified electrode. Experimental conditions, including supporting electrolyte and measurement parameters, were optimized in order to establish suitable conditions for MON determination. The applicability of the proposed approach was further assessed through precision and selectivity studies. The obtained results indicate that the developed voltammetric method has potential for MON detection in complex matrices and may represent a simple, rapid, and cost-effective alternative for screening purposes. In addition, the study confirms the importance of electrode surface modification in the development of electrochemical methods for mycotoxin analysis.

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Oxygen Detection in Dermal Interstitial Fluid with Microneedles based on Platinum Nanoparticles

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Oxygen is essential for cell metabolism and tissue function, where abnormal levels can lead to organ failure, serving as a key indicator for infections, metabolic disorders, and cancer. Although arterial blood gas test is the gold standard for its measurement, it is invasive and unsuitable for continuous, real-time monitoring. Dermal interstitial fluid (DISF) can be easily accessed with microneedles (MNs), offering a painless route for real-time monitoring of oxygen. DISF oxygen can be measured optically via phosphorescent MNs-based sensors or electrochemically with Clark-type MNs sensors, relaying on phosphoresce lifetime for high-resolution measurements or on gold-sputtered electrodes for the oxygen reduction by applying a negative potential [1, 2]. These techniques require complex equipments and can lead to interferences with other electroactive species.

Herein, we report a novel MN-based sensor patch for minimally invasive, real-time, and continuous oxygen detection in dermal ISF. The platform comprises a working MN modified with electrodeposited platinum nanoparticles (PtNPs), and an Ag/AgCl-based reference MN. *In vitro* characterization demonstrated superior analytical performance, exhibiting a fast response time (9s), wide detection range (10-254 μM), high repeatability (RSD = 5.2%), reversibility (RSD = 3.4%), acceptable reproducibility (6.6%), medium-term stability and adequate resilience during repeated skin insertions. Notably, the selectivity studies showed that the sensor response is unaffected by common electroactive metabolites or physiological pH fluctuations, underscoring its suitability for complex biological environments. Cytotoxicity assessments confirmed good biocompatibility of the microneedle patch, supporting safety *in vivo* application. Additionally, temperature dependence was also characterized to ensure accurate calibration. Finally, *in vivo* evaluations on euthanized and anesthetized rat models demonstrated highly accurate *on-body* measurements and a strong positive correlation (Pearson's r = 0.83) between ISF and blood oxygen concentrations, underscoring the clinical utility of the proposed oxygen microneedle sensor patch.

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Poster Abstracts: Tuesday

Distance-Based Microfluidic Analytical Devices for On-Site Coffee Analysis

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Coffee is a globally consumed beverage that requires monitoring for both safety and quality. It is a major exposure source for Ochratoxin A (OTA), a highly toxic mycotoxin [1], and the main source of dietary caffeine, which can induce adverse health effects at high intake levels despite its benefits in moderation [2]. Conventional detection methods rely on sensitive but complex and time-consuming instrumental approaches like high-performance liquid chromatography (HPLC). Besides, while lateral flow immunoassays are rapid, they still require external readers for quantitative result interpretation. Therefore, there is an urgent need for on-site, user-friendly analytical devices to achieve equipment-free quantification of analytes in coffee.

To address this problem, we propose a novel microfluidic analytical device via a distance-based, naked-eye readout strategy. The integrated device has three functional modules: a liquid control module for automated reagent delivery, an immunoassay module for target recognition, and a readout module for signal transduction. Mechanistically, the assay utilizes gold nanoparticles conjugated with specific antibodies and horseradish peroxidase (Ab-HRP@AuNP). The analytes are first captured by Ab-HRP@AuNP, after which the unbound probes are captured on an antigen-coated test line. Subsequently, a solution containing alginate-tyramine (Alg-Tyr) conjugates, H_2O_2, and a dye is introduced. The HRP on Ab-HRP@AuNP on the test line catalyzes the cross-linking of Alg-Tyr, altering the microfluidic permeability and thereby translating the analyte concentration into a visual distance signal. This automated, user-friendly platform has significant benefits for point-of-need food safety monitoring by end-users.

In this work, we designed a capillary-driven film-based microfluidic device as a liquid control module to achieve timed, sequential liquid delivery. Then, we synthesized alginate-tyramine (Alg-Tyr) conjugates and investigated the effects of different EDC/NHS concentrations on the conjugation process. The synthesized conjugates exhibited responsiveness to horseradish peroxidase (HRP), and it was confirmed that gelation could be successfully achieved under conditions where hydrogen peroxide was present in the liquid phase, Alg-Tyr was dried on a glass fiber pad, and HRP was immobilized on a nitrocellulose (NC) membrane. Furthermore, we optimized the ratio of HRP to antibody (Ab) during probe synthesis. As the proportion of HRP increased, both the catalytic activity of the probe and its sensitivity toward the target analyte (caffeine) improved. However, the colorimetric intensity decreased when the Ab proportion became too low. Consequently, an Ab:HRP ratio of 1:20 was selected as the optimal conjugation ratio. Next, we will further optimize the assay parameters and integrate the system for the equipment-free quantification of analytes in coffee.

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On-demand sweat stimulation and visual quantification of chloride via a wearable integrated paperfluidic sensor for resource-limited cystic fibrosis screening

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The quantification of chloride ion concentration in sweat is recognized as the gold standard for the early diagnosis of cystic fibrosis, underscoring the diagnostic significance and clinical relevance of sweat as a biofluid.[1] Sweat-based diagnostics offer a non-invasive, clinically valuable approach to continuous health monitoring, enabling real-time analysis of physiological and biochemical markers directly from the skin without complex or uncomfortable sampling.[2] In this study, we present a wearable paper-based sensor that enables colorimetric detection of chloride ions (Cl^-) in sweat for cystic fibrosis (CF) screening. Unlike conventional wearable CF sensors that require complex fabrication and sophisticated instrumentation, our low-cost, disposable device integrates a hydrophobically patterned paper substrate with an overlaid paper-fluidic channel impregnated with a chloride-sensitive reagent for direct, and visual quantification of Cl^- levels. To facilitate efficient and consistent sweat collection, we developed an iontophoresis system that delivers a controlled electrical current to stimulate localized sweat secretion, with an Arduino-based module integrated for real-time monitoring of output current and elapsed time. The device was validated using artificial sweat samples for chloride quantification and further tested on human volunteers to demonstrate its effectiveness in stimulating sweat production. The sensor exhibited a clinically relevant detection range, with a strong correlation between color intensity and chloride concentration, confirming its accuracy and reliability for CF diagnostics. By combining low-cost fabrication, on-demand sweat stimulation, and colorimetric analysis, this instrument-free, user-friendly wearable platform presents a promising alternative to traditional sweat testing methods, particularly for point-of-care diagnostics in resource-constrained healthcare settings.

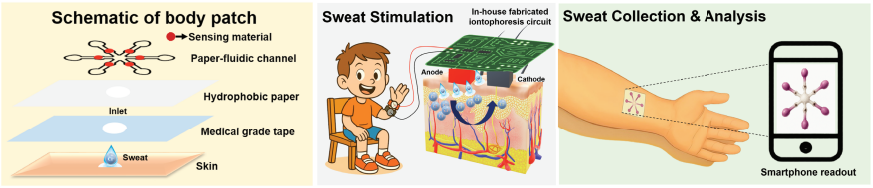

Fig. An iontophoresis-driven paper-based body patch enables non-invasive sweat stimulation, collection, and smartphone-based colorimetric analysis for cystic fibrosis monitoring.

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From Water-Soluble Dyes to Lipophilic Sensors: The Potential of Acidochromic Ionic Liquids

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Due to a number of advantages, ion-selective optical sensors are one of the most promising tools for solving complex analytical problems. Their optical response is generated by chromoionophores – highly hydrophobic acid-base indicators contained in a plasticized polymer membrane. The synthesis yield of these substances is extremely low, the process itself is very complex, and the variety of indicators obtained is limited. Therefore, the development of new, simple, and inexpensive methods for producing indicators with high affinity for the polymer phase is a pressing issue. As an alternative to traditional synthesis, the lipophilization of water-soluble indicators through the formation of an ion pair with a quaternary ammonium cation can be used [1].

In continuation of our previous research [2], in this contribution we explored the use of acidochromic ionic liquids (ILs) based on water-soluble indicators (e.g., bromothymol blue) in optical sensors containing other ion-selective components. The optical response of pH/Cl-selective optodes was studied spectrophotometrically and by means of digital colorimetry over a wide range of pH (Fig. 1) and electrolyte concentrations.

Since the response of the proposed IL-based optodes was comparable to that of conventional optical sensors, we can conclude that lipophilic ion pair dyes are a viable alternative to traditional chromoionophores. Combined with the wide variety of precursors and the ease of synthesis, this makes acidochromic ILs a highly promising platform for future optical sensor development.

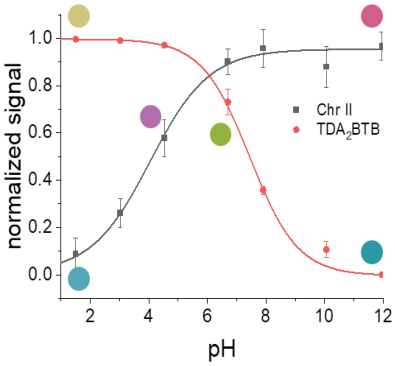

Figure 1. pH-response of pH/Cl-selective optodes containing conventional chromoionophore ETH 2439 or acidochromic ionic liquids. Concentration of background electrolyte C_{NaCl} = 0.01 M.

This work was supported by the Russian Science Foundation, grant number 25-23-00568.

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Toward pH-Independent Ion-Selective Optodes through Spectroelectrochemical Integration

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Sensors for detection of ionic species such as Na^+, Ca^{2+}, Cl^-, or NH_4^+ are highly important analytical tools in clinical, environmental, and industrial analysis [1]. Among these, ion-selective optodes (ISOs) can offer low detection limits, high sensitivity, non-invasive remote readout, and the potential for two-dimensional visualization. However, as the optical response of ISOs is based on the equilibrium between the sensor and sample phase involving both the target ion and H^+, conventional ISOs based on chromoionophores are intrinsically pH dependent. As a result, applications are most reliable in samples with controlled/stable pH, or when pH is measured externally for correction. However, this remains a significant challenge in complex and dynamic systems, such as soils and biological samples, which limits the broader adoption of ISOs as a robust standard method for sensing ionic species.

Limitations in measuring capabilities for ion-selective electrodes have been addressed by utilizing non-zero current and spectroelectrochemical (SEC) methods to widen analytical concentration ranges and improve sensor sensitivity [2]. Here we extend these methods for ISOs as a strategy to move beyond pH-dependent analysis. Integration of SEC for ISOs is implemented using transparent screen-printed electrodes based on an indium tin oxide / PEDOT:PSS / ISO membrane as a working electrode to enable spectrophotometric monitoring of the optical response under a controlled phase-boundary potential at the membrane / sample interface. In this work a sodium-selective optode based on a neutral chromoionophore and ionophore is used to investigate the relationship between the optical signal (i.e., color change, intensity, or absorbance) and applied membrane potential in both transient and steady-state modes. Measurements are performed across a range of NaCl concentrations and pH levels, allowing the dependence on both the target ion and H^+activity in the sample to be critically assessed. Moreover, the experimental results obtained are compared with equilibrium-based theoretical simulations of the sensor response mechanism. The combination of optical readout with electrochemical control provided by the SEC platform for ISOs provides a promising route toward reducing pH crosstalk and advancing applications in complex samples.

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Portable 3D-Printed Hollow Microneedle-based Platform for in Planta Multi-ion Sensing

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Continuous and minimally invasive monitoring of ionic species in plants is essential for precision agriculture, plant physiology studies, and early stress detection [1]. In addition, conventional methods are often destructive and requires central laboratory analysis. Many in situ devices, including microneedle-based (MNs) platforms, still focus on single or dual ions, which may not fully capture the full picture of ionic dynamics. Therefore, developing an in situ, minimally invasive platform for parallel multi-ion measurements is essential to deliver a complete spatiotemporal view of plant ion fluctuations and enable timely, targeted interventions in precision agriculture.

Herein, we report the development of a multi-ion sensing platform based on 3D-printed hollow microneedles (HMNs), for the simultaneous monitoring of relevant ionic species (K^+, Na^+, Ca^{2+}, Cl^-, pH) related to early stress detection [2]. The MN architecture is composed by: i) non-conductive skeleton (i.e. acrylate-based resin MN skeleton) fabricated by Digital Light Processing, and ii) conductive pillars (Carbon black dispersed in polylactic acid) fabricated by Fused Deposition Modelling. *In vitro* characterization demonstrates that the sensors exhibit linear response ranges that cover the physiologically concentration ranges (i.e. mM for all ions) in plants. Also, fast response times (t_{90} ≈1.5–3 s), good repeatability, reproducibility and resiliency to the insertion are obtained. Finally, the sensor is coupled to a miniaturized high-input-impedance potentiostat and integrated into a custom-designed 3D-printed clamp for multichannel potentiometric readout, enabling stable, minimally invasive long-term measurements in planta.

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Planar solid-contact nanopore-based potentiometric ion sensors

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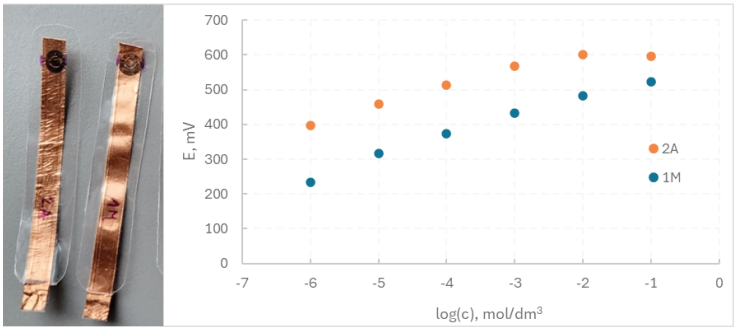
We have long focused on the development of surface-modified nanoporous materials—namely single- and multipore gold nanopore membranes—as alternatives to conventional bulk membrane materials for ion sensing. This architecture offers inherent advantages, including a solvent-free design in which all active components are covalently retained within the membrane, as well as unprecedented nanoscale miniaturization [1].

However, many practical applications require a planar solid-contact configuration, which has not previously been attempted with such membranes. Although the recently introduced, cost-effective lamination approach may be compatible with flexible nanoporous gold membranes [2], establishing a suitable solid contact is far from straightforward.

In this work, we therefore aimed to develop a reliable solid contact to directly interface nanoporous gold membrane–based ion-selective membranes with copper electrodes. Several materials and approaches were evaluated. We found that a water-based silver colloid solution, deposited by simple drop-casting and subsequent drying onto either the membrane or the electrode substrate, provided effective electrical contact while preserving the desired potentiometric response.



Laminated Ag^+-selective nanopore-based solid-contact planar electrodes and their calibration curves in $AgNO_3$ solution.

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BUN Sensors Based on Novel Ammonium Ionophores

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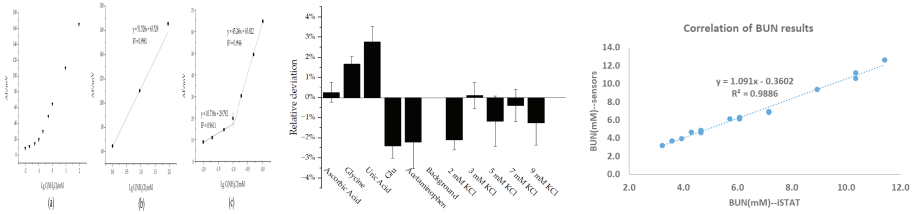
Accurate detection of Blood Urea Nitrogen (BUN) is critical for clinical diagnosis of chronic kidney disease and point-of-care testing (POCT) [1]. This study developed a high-performance potentiometric urea biosensor based on a novel ammonium ionophore which was first synthesized by Selectoprobe (https://www.selectoprobe.com). The structure of this new NH_4^+ ionophore was derived from the 6-fold substituted benzene tripodal scaffold [2].

The ammonium ion-selective PVC membrane was optimized, and urease was immobilized to construct an integrated "enzyme catalysis-ammonium ion recognition" system. Characterizations revealed the novel ionophore exhibited near Nernstian response (slope ≈45 mV/decade) and high anti-interference against $K^+$and other blood matrix components. The biosensor achieved a wide linear range of 1–1000 mM for urea, a low detection limit of 0.03 mM, good reproducibility, and long-term stability. This new ammonium ionophore offers another choice for building BUN sensors for blood analysis besides nonactin. After assembling the BUN sensors into cartridges and running tests of blood samples using Eaglenos Blood Gas analyzer, the results showed good correlation with Abbott iSTAT system with relative error <6% meeting CLIA2024 requirements.



(a) (b) (c)

Fig.1 (a). NH_4^+ response in Whole blood sample, (b) BUN results bias after added interference in blood samples (n=5), (c) Correlation of BUN results against Abbott iSTAT system.

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Beyond Mussel-Inspired Polydopamine Chemistry: Surface Modification of Polymeric Membrane Ion-Selective Electrodes with a Nature-Derived Material

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As a popular tool for rapid and timely ion sensing, polymeric membrane potentiometric ion sensors have been extensively utilized in the fields of clinical diagnostics, industrial analysis, and environmental monitoring owing to their intrinsic merits of excellent selectivity, fast response, and simple operation. Surface modification could function as an effective way to enhance biocompatibility and fabricate biosensors through biomolecule immobilization [1,2]. However, surface functionalization of polymeric membrane potentiometric ion sensors is still a significant challenge due to their chemically inert polymeric membrane surfaces (e.g., poly(vinyl chloride), PVC). Recently, mussel-inspired polydopamine (PDA) has emerged as a promising candidate for surface modification [3,4]. Nevertheless, PDA coating is mainly suitable for cation-selective electrodes. The negatively charged groups in the PDA polymer may hinder the transfer of anions from the aqueous phase to the membrane phase through electrostatic repulsion, resulting in a long response time for anion detection [5].

Herein, we report a universal surface functionalization strategy based on the self-polymerization of a naturally derived compound, 3,4-dimethoxyphenethylamine, which was found in human urine and originally regarded as a diagnostic marker for schizophrenia. Similar to PDA, the proposed poly(3,4-dimethoxyphenethylamine) (PDMPE) coating can be readily formed and tightly deposited on virtually any substrate surface. More importantly, after PDMPE modification, both anion- and cation-selective electrodes exhibit unchanged sensing performance in terms of Nernst slope, response time, and linear range compared to the corresponding pristine electrodes. As a proof-of-concept experiment, the anion-selective electrodes, CO_3^{2-}-ion-selective electrode (ISE) and Cl^--SE, and cation-selective electrode Ca^{2+}-ISE have been chosen as models of potentiometric ion sensors. Experiments showed that both anion- and cation-selective electrodes could be surface modified by a PDMPE coating and further functionalized by the antifouling agent glutaraldehyde, while retaining original potentiometric ion response properties. We believe that this work provides a general strategy for surface modifications of various polymeric membrane electrochemical sensors.

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EMF behaviors of carbonate melt oxidized lithium iridate as a pH sensor

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Iridium oxide formed by the carbonate melt oxidation method has been reported to exhibit excellent pH response characteristics [1]. Based on the X-ray diffraction analyses, iridium oxide prepared with lithium carbonate melt was assigned to be lithium iridate, Li_2IrO_3 [2, 3]. The pH sensor prepared based on this material showed drifts of electromotive force (EMF) upon pH changes in the buffer solutions [3]. In the present study, Ir wires were oxidized with Li_2CO_3 powder at 750 °C in air for 150 min. After cooling to room temperature, the oxidized wires were rinsed with ultrapure water for about 10 hours to dissolve the remaining Li_2CO_3. The grains of the lithium iridate layer were distributed from several tens of nanometers to a few hundred nanometers as shown in Fig. 1 [4].

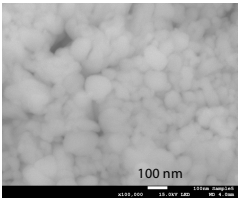

Fig.1 Surface morphology of lithium iridate

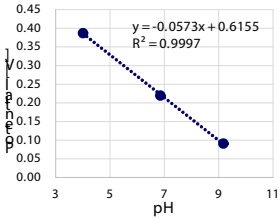

Fig. 2 Calibration curve

The slope sensitivity was -57.3 mV/pH as shown in Fig. 2, which exhibited near Nernstian slope (-59.16 mV/pH at 25 °C). However, we found that the lithium iridate electrode showed initial EMF drifts when measured pH responses just after rinsing the electrode with ultrapure water. When the pH responses were intermittently measured over time for more than 250 days, the EMF drifts decreased during the first month and then approached nearly a few tenths of mV/min. We will discuss the reason for the drift of the lithium iridate electrode.

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Development of potentiometric microelectrodes for the determination of bacterial contamination

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The presence of pathogenic bacteria in drinking water and food is a major public health concern, requiring the development of rapid and highly selective detection methods. The gold-standard plate culture method is cumbersome with long incubation times [1]. Molecular, immunological, and optical techniques offer high accuracy but are often hindered by the cost of instrumentation, significant time requirements, and complex sample preparation. Recently, methods such as paper-based analytical tools and chemiluminescent tools offer portability but lack selectivity for complex matrices [2,3].

Potentiometric detection is a compelling alternative for bacterial sensing due to its simplicity, low cost and rapid response. In this work we introduce a novel electrochemical platform using potentiometric ion-selective electrodes for the real-time monitoring of bacteria in aqueous samples. Our potentiometric approach offers label-free detection, requires minimal sample preparation and short incubation, and is suitable for point-of-care applications, as demonstrated using commercially available probiotic capsules.

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Novel Carbon Nanotube-Based Potentiometric Sensor for Ascorbic Acid Detection. Unveiling Evidence on Surface Interactions

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Ascorbic Acid (AA) is an important molecule in the body, responsible for maintenance of the soft tissues, and Reactive Oxygen Species scavenger, reducing oxidative stress in the body. Recently AA has been at the center of a lot of controversial studies in cancer research, though recently it has gained interest as an anti-tumor agent. Here, we present a methodology to experimentally determine AA based on a new fundamental finding: the reversible interaction of AA with carbon nanotubes (CNTs) under zero-current measurements (potentiometry). This interaction was systemically studied, including different types of carbon nanotubes, such as unmodified, modified with exposed carboxylate groups, and modified with $–CO–NH–CH_2(CH_2)_{16}CH_3$ groups to pinpoint the origin of the interactions. With the addition of a thin-layer plasticized polymeric membrane (ca. 300 nm in thickness), the sensor shows a consistent sensitivity towards AA of $–33.53 \pm 2.57$ mV/decade ($n = 17$), with a linear range in both the physiological and pharmacological concentration ranges of interest (10–200 μM and 0.2–1 mM, respectively). Interferences from uric acid (UA) which is normally oxidized electrochemically at the same potential as AA was negligible, and interestingly provided a response opposite that of AA, while common ions interferences in potentiometry such as sodium and lactate were mostly excluded by the addition of the membrane. To combine theory and experimental results, computational simulations of AA and UA on a graphene-based model provided insights to describe the distinct experimental responses observed. Furthermore, the suitability to perform AA analysis in real samples was demonstrated in serum, saliva, and urine.[1]

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Laser-Induced Double-Layer Capacitance Amplification for High-Stability 3D-Printed Solid-Contact Ion-Selective Electrodes

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Additive manufacturing offers precise control over electrode architecture and has recently enabled architectural amplification strategies in 3D-printed potentiometric systems [1]; however, the influence of geometric design and surface accessibility on the electrochemical response in 3D-printed solid-contact ion-selective electrodes (SC-ISEs) remain underexplored.

In this work, carbon black–PLA (CB-PLA) solid contacts were systematically engineered through controlled infill ratios (25–75%) to modulate porosity and electrochemically accessible surface area, followed by CO_2 laser activation to further enhance interfacial exposure. Varying infill geometry revealed that double-layer capacitance does not increase monotonically with geometric surface area, but instead exhibits an architecture-dependent maximum, indicating that ion transport and pore accessibility govern effective transduction. While intermediate porosities preserved diffusion-controlled electrochemical behavior and Nernstian potentiometric slopes (57–58 mV/dec for K^+-selective valinomycin-based membranes), long-term potential drift remained limited by restricted interfacial accessibility. Subsequent laser activation dramatically increased double-layer capacitance by up to 61-fold relative to untreated electrodes, confirming substantial enhancement of charge storage at the solid-contact/membrane interface. This capacitance amplification translated directly into improved potentiometric stability, reducing drift from ~0.62 mV/h to ~0.09 mV/h without compromising analytical performance (LOD down to $10^{-5.8}$ M). Electrochemical impedance analysis supports that stability enhancement originates primarily from increased interfacial capacitance rather than changes in membrane selectivity.

Overall, these findings demonstrate that electrochemical stability in 3D-printed SC-ISEs is governed by a combination of geometric architecture and post-print surface activation, highlighting interfacial accessibility as the dominant design parameter controlling capacitive transduction and long-term potential stability, and establishing a scalable framework for the rational design of high-capacitance, drift-resistant potentiometric sensors.

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Electronic Profiling of Neuronal Extracellular Vesicles Enables Early Prediction of Parkinson's Disease

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Misfolded alpha-Synuclein (α-Syn) accumulation is the defining molecular pathology of Parkinson's disease (PD), yet blood-based assays remain challenged by the high background of peripheral α-Syn originating mainly from red blood cells. Neuronal extracellular vesicles (EVs) circulating in blood offer a biologically enriched source of brain-derived α-Syn proteoforms, but their ultralow abundance has hindered reliable detection[1, 2]. Here, we introduce an organic electrochemical transistor (OECT)-based multi-parametric diagnostic assay that simultaneously detects total, aggregated, and serine-129–phosphorylated α-Syn proteoforms in serum L1CAM$^+$ EVs. The platform achieves low femtomolar sensitivity in buffer and robust analytical performance in clinical specimens. In a cohort of 66 individuals, including prodromal and clinically diagnosed PD patients, combining the three proteoform readouts distinguished PD from controls with 90.9% accuracy (88.6% sensitivity and 90.9% specificity). By electronically amplifying and resolving multiple neuronal α-Syn signatures in blood, this assay enables a minimally invasive diagnostic tool for early-stage PD and provides a path toward therapeutic intervention during the window when disease-modifying treatments are likely to be most effective.

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Label-free Sensing of Oxytocin Using Supported Lipid Bilayer

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Oxytocin is a small neuropeptide playing a key role in stress regulation, lactation, and childbirth [1]. Conventional methods for oxytocin analysis are often time-consuming and costly, requiring labeled reagents and specialized laboratory infrastructure [2]. Here, we develop a supported lipid bilayer (SLB) based recognition layer on conducting polymer based electrodes for easy to use, rapid, and sensitive oxytocin detection and quantification. The SLB provides a biomimetic, low-fouling detection surface while enabling controlled antibody orientation for oxytocin binding at the electrode interface [3]. By integrating this antibody-functionalized lipid membrane with soft and low impedance organic electronic materials, we generate a platform for low concentration oxytocin detection in physiological media. This work highlights the use of lipid bilayers as tunable and biomimetic recognition interfaces for electrochemical detection of small biomolecules and conducting polymers as excellent electrode materials for impedance based monitoring of analytes.

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Designing Nanobody-Functionalized Surfaces in Organic Electrochemical Transistors Biosensors

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Demand for label-free, long-term-stable biosensors is critical for the routine diagnosis of infectious diseases, such as detecting SARS-CoV-2 during the COVID-19 pandemic. In our study, we have developed two novel immunosensor designs for detecting the SARS-CoV-2 spike protein, employing surface chemistries with nanobodies as the bioreceptor and an organic electrochemical transistor (OECT) as the transducer. The first sensor utilizes a self-assembled monolayer (SAM) of 1,6-hexanedithiol on a gold surface, facilitating high-density, orientation-controlled bioconjugation of the nanobody-SpyCatcher [1]. This configuration offers exceptional specificity and sensitivity in complex samples. The second sensor design uses a spyDirect biofunctionalization approach to enhance the sensor's long-term stability, achieving ultra-high-density oriented nanobodies and reducing the background noise when operating in saliva or untreated wastewater [2]. We use both surface designs at the gate electrode of OECT devices, which operate in aqueous media and are known for their high signal-to-noise ratios when used as sensors. The OECT current is proportional to the number of protein concentrations captured at the gate. Highlighting the advantages and drawbacks of SAM-bearing and SAM-free sensing surfaces, we discuss these innovative surface and device designs that can pave the way for the development of sensitive, rapid, and selective immunosensor-based OECTs.

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Fe_3O_4@Pt@Polylevodopa Core–Shell Nanozymes for Sensitive Detection of Chosen Antigens

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Nanozymes have emerged as promising alternatives to natural enzymes for biosensing applications owing to their high stability, tunable activity, and synthetic versatility [1,2]. Here, we report the fabrication of polylevodopa-coated, platinum-modified iron oxide nanoparticles (Fe_3O_4@Pt@Polylevodopa) and demonstrate their utility as catalytic probes for the colorimetric detection of SARS-CoV-2 nucleoprotein. Platinum was deposited onto Fe_3O_4 nanoparticles, followed by in situ oxidative polymerisation of levodopa to generate a functional polylevodopa coating. Systematic characterisation after each synthetic step verified successful nanoparticle functionalisation. Analysis of catalysis kinetics demonstrated Michaelis-Menten-type catalytic behavior, while optimisation studies identified pH as a key parameter governing antibody immobilisation efficiency. The resulting surface, enriched with reactive groups, including carboxyl functionalities, enabled covalent conjugation of a primary SARS-CoV-2 antibody (Ab1), followed by bovine serum albumin blocking to suppress nonspecific binding. These Fe_3O_4@Pt@Polylevodopa-Ab_1 nanoconjugates were integrated into a sandwich immunoassay in which the target nucleoprotein was captured between the nanozyme-linked Ab_1 and a secondary monoclonal antibody (Ab_2) pre-immobilised on a microplate. Upon addition of H_2O_2 and a chromogenic substrate (TMB), the nanozyme generated a colorimetric signal through its intrinsic peroxidase-like activity. The assay enabled the successful determination of SARS-CoV-2 nucleoprotein, highlighting the potential of this nanozyme-based platform for sensitive protein detection and for future point-of-care diagnostic technologies [3].

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Exhaled breath aerosol admittance as a diagnostic parameter for pulmonary disorders

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The condensate of exhaled breath aerosol (EBA) is a readily accessed biosample that attracts a growing interest for researchers. It contains a vast number of substances that can serve as markers for different health conditions. For lung-related diagnostics, EBA is more convenient than bronchoalveolar lavage or bronchoscopy as it collected noninvasively. Though common way is cooling (EcoScreen, RTube, TurboDECCS), the condensed water vapor deteriorates the analytical performance. Recently we elaborated a cooling-free system that condense EBA without excessive dilution with water [1].

Compared to cooling, the device provides at least one order of magnitude more concentrated sample if monitored by conductivity and hydrogen peroxide level. The condenser was applied to volunteers with post-COVID-19 syndrome and with cystic fibrosis. Compared to healthy people, groups of interest have shown substantial differences in marker levels [1].

People with cystic fibrosis (pwCF) usually suffer from lung diseases. However, the sweat test (conductivity) remains one of the gold standards in diagnostics. Previous studies on breath condensate gave controversial results about changes in ion content [2, 3]. In our recent results we present the significant difference between EBA samples of control group and two groups of pwCF (with stable disease and treated).

Thus, presented approach to sampling EBA may provide useful tools for diagnostics in respiratory medicine.

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Prussian Blue-NiHCF modified Carbon Nanopipettes: a Methodological Approach for Hydrogen Peroxide Sensing in Thin-Layer Regime

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Carbon nanopipettes (CNPs) are emerging electrochemical nanoelectrodes that enable chemical sensing in highly confined volumes, offering unique advantages in terms of spatial resolution, miniaturization, and control of mass transport [1]. Owing to the establishment of thin-layer electrochemical regimes within their nanometric inner tip, CNPs represent a powerful platform for developing next-generation miniaturized sensors [2]. In this context, translating CNP-based architectures into robust and quantitative chemical sensors requires careful control of surface chemistry and interfacial processes, which become particularly critical under nanoconfinement.

In this work, we present a sensing strategy based on CNPs modified with a Prussian Blue–Nickel Hexacyanoferrate (PB–NiHCF) hybrid system, specifically designed for hydrogen peroxide (H_2O_2) detection under nanoconfined conditions. Electrodeposition and stabilization protocols enabling the controlled growth of PB-NiHCF thin films inside the nanopipette are discussed, highlighting their compatibility with confined electrochemical architectures. Cyclic voltammetry (CV) and double-step potential chronoamperometry (DPSC) are employed to investigate the thin-layer regime established within the nanometric inner tip of the CNPs. The sensing mechanism is shown to be critically governed by the catalytic properties of the deposited materials, as well as by the open-circuit potential of the modified nanopipette and the precise control of the applied working electrode potential.

Overall, this work establishes a general methodological framework for chemical sensing in nanoconfined electrochemical systems, providing design guidelines for stable, miniaturized, and coulometric sensors, with hydrogen peroxide serving as representative target analyte.

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Improving Antifouling of Protein Biosensing Surface by Surface Optimization and Electrical Pulsing

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Surface fouling by nonspecific protein adsorption remains major challenge in limiting the performance and lifetime of electrochemical biosensors [1]. Here, we investigate a combined surface-chemical and electrochemical approach to actively regulate protein–surface interactions on indium tin oxide (ITO) electrodes. ITO substrates were functionalized using mixed aryl diazonium layers comprising 4-aminophenyl phosphorylcholine (PPC) and 4-aminophenylbutyric acid (PBA). Optimization of the PPC: PBA composition reduced antibody crowding and non-specific adsorption while preserving accessibility for target binding. Total internal reflection fluorescence (TIRF) microscopy was employed to directly visualize protein movement at the electrode interface. Electrochemical control was then applied to dynamically modulate interfacial protein behaviour. A constant cathodic bias (–0.85 V vs. Ag/AgCl) significantly suppressed protein arrival and accumulation at the surface. In contrast, alternating pulsed potentials (–0.8 V / 0 V) promoted enhanced surface mobility of adsorbed proteins, facilitating the removal of weakly bound species and reducing irreversible fouling while still permitting intermittent access of target proteins to the sensing interface. This strategy provides a pathway toward electrochemically controlling protein adsorption, where periodic electrical stimulation restores surface activity and extends operational lifetime, enabling continuous protein monitoring.

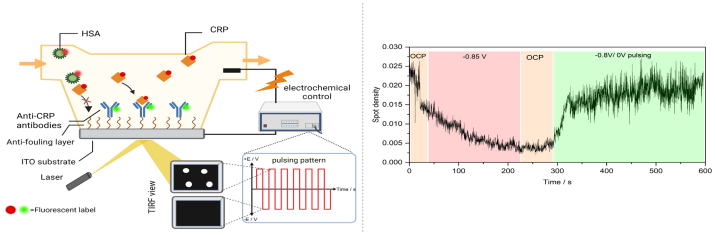

Figure 1: Experimental schematic showing PPC/PBA-modified ITO electrodes integrated with electrochemical control and TIRF microscopy, alongside C-Reactive protein (CRP) spot density versus time under OCP, –0.85 V bias, and pulsed potentials

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Trace-Level Electrochemical Detection of Carbendazim in Environmental Samples Using an NH_2-rGO/PProDOT/Au Hybrid Nanocomposite modified SPCE

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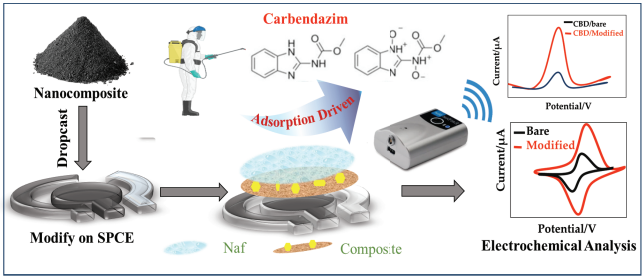
A sensitive electrochemical sensor was created to detect the fungicide carbendazim (CBD) in environmental samples. It uses a screen-printed carbon electrode (SPCE) modified with an ammoniated reduced graphene oxide/poly(3,4-propylenedioxythiophene)/gold nanoparticle (NH_2-rGO/PProDOT/Au) nanocomposite. Systematically characterised the nanocomposite using Fourier transform infrared spectroscopy (FTIR), X-ray photoelectron spectroscopy (XPS) and FESEM. To create the sensing interface, the sequential drop-casting method was used to apply the hybrid composite onto the SPCE surface. A thin Nafion (Naf) overlayer was coated as an antifouling agent. The interfacial electron-transfer properties of the bare and modified electrodes were assessed using cyclic voltammetry (CV) in the presence of a 2 mM ferri/ferrocyanide ($[Fe(CN)_6]^{3-/4-}$) redox probe. The improved electrochemical performance of the modified electrode is due to the larger electroactive surface area and the combined effects of the NH_2-rGO/PProDOT/Au hybrid nanocomposite.[1] This allows for a quick response time of about 1 second. The electrochemical detection of carbendazim was conducted using square-wave voltammetry (SWV). Then, optimised key experimental conditions, such as the supporting electrolyte, pH, frequency, amplitude, and equilibration time. Also studied the electrochemical oxidation behaviour of carbendazim using cyclic voltammetry. With optimised conditions, the sensor showed a linear response for concentrations between 0.1 and 1 µM, achieving a limit of detection of 8 nM. The sensor displayed good selectivity for carbendazim in the presence of possible interfering substances, excellent repeatability (RSD < 3.5%), and long-term stability lasting over 35 days. Additionally, the practicality of the sensor was confirmed by detecting carbendazim in real environmental samples, such as water, fruit extracts, and vegetable extracts, which demonstrated satisfactory recovery values. These findings emphasise the potential of the NH_2-rGO/PProDOT/Au-modified SPCE as a fast, reliable, and affordable tool for monitoring carbendazim residues in the environment.



Schematic illustration of the facile fabrication of the nanohybrid sensor and its application in the voltammetric detection of carbendazim.

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Green biochar-based electrochemical platform for direct antibiotic sensing in biomedical and environmental applications

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While the discovery of antibiotics consisted a breakthrough in medicine, the downside lies in the emergence of the antimicrobial resistance (AMR) which pose significant threats to the public health, also due to the transmission through trophic chain [1]. Robust and rapid methods are necessary to address this issue and electrochemical approaches are increasingly implied as powerful tools to tackle the limitations of the traditional methods used for antibiotics assessment. These techniques stand out for their ease-of-use, fast response, higher sensitivity, feasibility for miniaturization and the stability [2]. Biochar (BCK) is a carbon-abundant material, obtained *via* pyrolysis of biomass which stands out for its availability and lower costs associated, compared to other carbon-based nanomaterials [3]. Thus, the scope of this study is to harness the ecological, electrocatalytic and adsorptive features of BCK as a surface modifier for the direct detection of AMP in complex matrices. Spent coffee-derived BCK was produced *via* pyrolysis at 850°C under an anaerobic atmosphere. The electrocatalytic effect of two types of BCK were evaluated: unactivated BCK, and KOH-activated BCK denoted as BCK-KOH. Two polymer-based embedding methods of material on the surface of the working electrode were evaluated: electropolymerization of cysteine (cys) monomer and incorporating BCK into a polyethyleneimine (PEI) containing composite. The most efficient one was assessed using microscopic and electrochemical methods. Consecutively, immobilization parameters such as number of layers, polymer and BCK concentration were evaluated *via* cyclic voltammetry (CV). The fingerprint of the target was obtained by the direct detection *via* differential pulse voltammetry (DPV) using solutions of various concentrations and different scan rate and pH values of the electrolytic media and a good limit of detection was obtained. The selectivity study focused on other antibiotics classes and common biological interferents and milk-derived compounds and the green sensor was successfully validated in commercial serum and milk samples. Thus, the developed biochar-based electrochemical sensor could form the basis for developing a decentralized platform with applications in diagnostics, environmental monitoring, and food safety.

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Biomass-Derived Luffa Sponge-Templated Amorphous Carbon/CuO Composites for Chemiresistive Sensing of Triethylamine

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The sustainable utilization of renewable biomass for the development of functional materials has recognised as a promising strategy toward green chemistry and circular material design [1]. Among various biomass resources, plant-derived natural bio-templates offer unique hierarchical architectures that can be employed to fabricate porous nanostructured materials [1,2]. Following this approach, a luffa sponge, an abundant and renewable biomass resource derived from the fruit of *Luffa cylindrica*, was utilized as a bio-template for the synthesis of CuO and amorphous carbon (a-C)/CuO composites for Triethylamine (TEA) gas sensing studies. A porous network of the luffa sponge supported as a natural platform for metal salt infiltration, followed by controlled calcination to obtain semiconducting oxides with distinct surface characteristics. In particular, tuning the calcination temperature resulted in two distinct CuO-based materials: an a-C contained CuO composite at 420 °C, resulting from carbon retention from the luffa-template, and a pure phase crystalline CuO at 550 °C. Structural and elemental analyses corroborated the formation of monoclinic CuO and the presence of luffa-derived a-C, indicating that the calcination temperature controls the crystallinity of CuO while allowing carbon species to remain in the composites. When applied as gas sensing materials, both the CuO-based sensors demonstrated selectivity toward TEA. In particular, the a-C/CuO composite sensor exhibited higher TEA response than the CuO sensor, showing an enhanced response of ~300% to 71 ppm and a low detection limit of 1.5 ppm with complete recovery characteristics. The observed TEA sensing of the a-C/CuO sensor was mainly credited to the synergistic combination of a-C, which enhanced electrical conductivity and provided abundant surface-active sites, and the mesoporous CuO framework, which enabled efficient charge transport, rapid TEA diffusion, and stronger adsorption at oxygen vacancy-rich surfaces. Overall, this research demonstrates the sustainable conversion of renewable biomass into functional nanomaterials, highlighting the potential of bio-templating approaches for the development of high-performance gas sensing materials.

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Poster Abstracts: Thursday

Single Solid-State Ion Channels as Potentiometric Nanosensors

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Single solid-state nanopores are powerful tools for resistive pulse sensing, but fabricating nanopores to selectively detect the smallest analytes, such as inorganic ions, remains challenging. We tackled this problem by introducing chemically functionalized single gold nanopores (GNPs) as solid-state ion channels with potentiometric transduction [1]. The "selectivity filter" is established by modifying the interior of nanometer-wide pores with a mixed self-assembled monolayer containing a thiol-bearing perfluoroalkane, ion exchanger, and ionophore. The hydrophobic nanopore interior excludes bulk electrolytes and "routes" ion transport to the functionalized inner surface, which provides ion selectivity. The combination of low resistivity and suppression of active component loss overcomes key barriers to the extreme miniaturization of conventional ionophore-based ion-selective electrodes. Here, we present a proof-of-concept for selective silver ion sensing using functionalized nanopores with a radius of only 10 nm. The new "selectivity filter" provided Ag^+ selectivities exceeding those of biological ion channels (up to 6 orders of magnitude), enabling robust ion measurements with unprecedented miniaturization, without the need for subnanometer pore-size control. The versatility of gold nanopore functionalization paves the way for fabricating single GNPs tailored to sensing and transporting other ions, while also advancing the mechanistic understanding of selective ion transport in functional nanoporous materials.

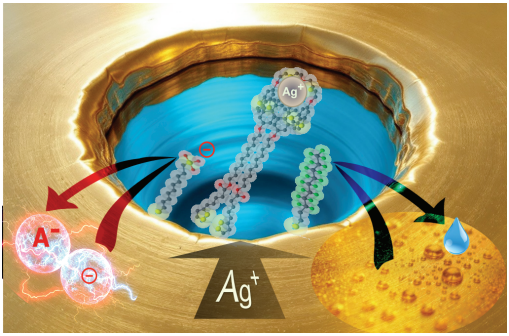

Figure 1. Concept of Ag^+-selective single solid-state ion channels.

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Electrochemical Imaging of Ion Transfer Using Charged Nanomaterials on Membranes for Dynamic Ion Behavior Analysis

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Ion transfer is a fundamental process in many systems, and its visualization is crucial for accurately understanding the underlying mechanisms of ion migration and the associated material transport dynamics. To achieve this, an electrochemical imaging system, previously developed by our group [1], integrates a voltammetric setup with a microscope. This system enables the visualization of ion transfer concentrations through a thin ion-selective membrane, presenting the data as chemical maps and corresponding graphs. It demonstrates the potential to optically observe material properties that is closely linked to ion transfer processes.

In this study, charged nanomaterials were applied to the membrane to evaluate the sensitivity and precision of ion transfer observations. Electrically charged nanomaterials locally alter the ion distribution in the immediate vicinity of their surface owing to the diffuse layer. Since these ion gradients are highly confined and stationary, it allows one to more easily assess the spatial resolution of this novel imaging technique than with freely diffusing ions.

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Development of smart sensing film with non-biofouling properties for potentiometric detection of local pH changes caused by bacterial infections

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Orthopedic surgery of the total hip and total knee arthroplasty are surgeries with the primary purpose of restoring joint function of persons affected by osteoarthritis. The increasing life expectancy of the human population also increases the number of patients in need of such surgery, which can significantly improve one's quality of life. [1] Unfortunately, orthopedic implants are highly susceptible to peri-implant sterile inflammation or microbial infections (prosthetic joint infections, PJI). The sources of bacterial infection might be the operating room and surgical equipment, bacteria from the patient's skin, and bacteria that already reside in the patient's body. According to the surveillance European Centre for Disease Prevention and Control report from 2017, the most common microorganisms identified in surgical site infections were Gram-positive cocci (Staphylococcus aureus, enterococci, and streptococci) and Gram-negative bacilli (Escherichia coli, Proteus, and Enterobacter species). [2]. After bacterial infestation and bacterial attachment to protein-coated surfaces, the biofilm-formation process starts. Changes in pH are associated with bacterial infection, as shown in several studies; for example, synovial fluid pH decreases from 7.5 under aseptic conditions to 6.7-7.0 for infections. While the intracellular pH of bacteria is close to neutral and remains almost constant to preserve metabolic capacity and cellular integrity, the extracellular pH changes. Chronic wound pH ranges from 7.15 to 8.9, while the pH of acute infection is significantly lower. The pH measurements of the individual pathogenic bacteria or pathogenic yeast revealed that *E. coli* decreased the pH by 1.24 units, *S. aureus* decreased the pH by 1.33 units, and the resistant *Methyciline resistant S. aureus* bacteria decreased the pH from 7.2 to 5.6 during 10 h, followed by a subsequent increase to 6.4. The results were statistically significant ($\alpha = 0.01$). *P. aeruginosa* was not shown to change pH levels. On the other hand, the pathogenic yeast had the lowest recorded pH, which decreased from 5.8 to 4.8. This difference in pH could be used to identify the nature of the infection. The developed electrodes have a pH response between pH 5 and 8, with a Nernstian slope of -59.6/pH, which perfectly fits the relevant pH value window. The developed electrode can contribute to the next generation of biosensors [3, 4].

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Novel 3D-Printed Sensor for Real-Time Sweat Rate and Sweat Loss Monitoring

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Sweat-based sensing has become a non-invasive tool for health status monitoring and performance assessment during sport activities [1]. To acquire reliable data on sweat biomarkers concentrations, it is crucial to precisely monitor the sweat rate, as sweat composition varies dynamically with the secretion flow rate. Although numerous sweat rate monitoring devices have been proposed to date, they suffer from critical limitations: they either operate quasi-real-time being independent of sweat conductivity or require conductivity-specific correction to enable real-time sensing.

Herein, we propose a fully 3D-printed wearable sensor for real-time sweat rate monitoring that is inherently independent of ionic concentration. Aligning with the emerging "click-and-run" manufacturing paradigm [2], multimaterial 3D printing allows the single-step, fully automated fabrication of the epidermal device. Uniquely, the high electrical resistance of 3D-printable conductive filaments, which is typically a limitation, acts as an advantage in this design, rendering the device insensitive to fluctuating sweat composition. A model to mathematically predict the sensor response has also been developed (calibration slope deviations <4%). Benchtop tests confirmed the independence of the sensor response from sweat concentration. Finally, on-body tests during localized sweat induction and dynamic cycling exercise proved the practical utility of the sensor.

Overall, the outcomes demonstrate the suitability of Fused Filament Fabrication (FFF) for creating robust, ready-to-use wearable devices for real-time sweat rate and sweat loss monitoring.

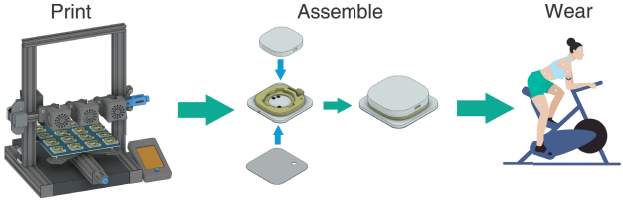

Figure 1. Schematic workflow of the 3DP-RT-SR device, illustrating the high-throughput multimaterial 3D printing process and subsequent assembly to produce a ready-to-use sensor.

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Precisely deposited carbon materials by spark discharge for solid contact ion-selective electrodes

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A spark-assisted deposition approach is introduced as a new strategy for modifying electrode surfaces with conductive carbon nanomaterials. The spark discharge approach originally introduced by the group of Prodromidis uses short electrical discharges between two conductive bodies to generate localized high-energy events that eject material and modify the electrode surface. This technique has been used for surface activation to improve voltammetric sensing [1]. This process is driven by a capacitive discharge approach and is therefore not very carefully controlled, resulting in non-specific deposition patterns and limited spatial precision. The deposition system is here integrated with a computer numerical control (CNC) platform to enable precise three-dimensional (3D) positioning of the spark electrode. The X and Y axes control the electrode movement along the flat surface of the substrate, while the Z-axis maintains a fixed spark-to-electrode distance of 0.5 mm. Localized CNF deposition was achieved at a travel speed of 1000 mm min^{-1} with a spark contact duration of 3000 ms on a screen-printed carbon electrode (SPCE, 3.5 mm diameter). The CNC-guided spark process enabled reproducible, well-defined, and spatially controlled deposition patterns on the electrode surface. This work explores the feasibility of applying this spark-based deposition technique for the fabrication of solid-contact layers in SC-ISE from carbon materials including carbon nanofibers (CNF). Green CNF is prepared from nata de coco through freeze-drying followed by pyrolysis, producing a highly porous and fibrous network [2]. The spark-deposited CNF structures are expected to provide a capacitive and hydrophobic interface suitable for supporting ion-selective membranes while improving interfacial charge-transfer characteristics. By combining renewable biosource-derived hydrophobic carbon with a rapid and spatially controllable spark-modification technique, this approach presents a promising route for developing new solid-contact architectures for electrochemical ion sensors.

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A Potentiometric Sensor for Sugar Sweetness Using Boronic-Acid-Modified Lipid/Polymer Membranes

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Electronic tongues are used as one of the methods for taste evaluation. One type developed by Toko mimics human gustatory perception, selectively responding to the five basic taste qualities—sweet, salty, sour, bitter, and umami—using lipid/polymer membranes as receptor elements. Its fundamental principle, known as global selectivity, is based on the common physicochemical properties of taste substances, whereby taste is detected through membrane potential changes induced by electrostatic and hydrophobic interactions between the lipid/polymer membrane and the analytes [1]. However, carbohydrate-based sweeteners remain difficult to measure because they are typically non-ionic and weakly hydrophobic. On the other hand, boronic acids are known to form cyclic esters with diol groups of sugars through covalent bonding, making them promising receptor materials for saccharide recognition. If complex formation between boronic acids and sugars induces changes in membrane potential, such a phenomenon could be exploited for potentiometric sensing. In this study, we aimed to develop a potentiometric sensor for non-charged sugars by incorporating phenylboronic acid derivatives into lipid/polymer membranes.

A taste sensing system, SA402B (Intelligent Sensor Technology Inc., Japan), was used in this study. The sensor membrane consisted of lipids tetradodecylammonium bromide (TDAB) and phosphoric acid di-n-decyl ester (PADE), a plasticizer dioctyl phenylphosphonate (DOPP), a supporting polymer polyvinyl chloride (PVC), and 3-nitrophenylboronic acid (3-NPBA). These components were mixed in tetrahydrofuran (THF), poured into a Petri dish, and dried for three days to form the membrane. The membrane was fixed onto the surface of the working electrode, and the membrane potential between the working electrode and the reference electrode was measured. For measurements, the membrane potential in a reference solution (30 mM KCl), denoted as V_r, was first recorded. Subsequently, the membrane potential in the sample solution (prepared with the same reference solution base), denoted as V_s, was measured. The response value (relative value) was defined as the difference between these potentials, $V_s - V_r$.

As a result, a potentiometric sensor was successfully developed using a lipid/polymer membrane containing 3-NPBA. Although boronic acids are generally known to interact with sugars under alkaline conditions, the proposed sensor exhibited positive potential responses to various sugars even under mildly acidic conditions (pH 5.8), demonstrating its applicability to practical beverage samples. The sensor membrane showed strong concentration-dependent responses to monosaccharides, disaccharides, sugar alcohols, and stevioside with good sensitivity and reproducibility. In addition, the measurements of commercial coffee samples confirmed its ability to distinguish sweetness levels in real beverages. These results indicate that the proposed boronic-acid-based potentiometric sensor can be used to quantify sweetness and has promising potential for the quantitative evaluation of sweetness in commercially available beverages.

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A One-Step Printed Wearable Sweat Rate Sensor for Hydration Monitoring: Validation via Iontophoresis and Cycling Trials

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Sweat rate (SR) is a parameter for assessing thermoregulation and hydration status. Monitoring SR may also enable the normalization of biomarker concentrations and the prevention of dehydration-induced performance decline. Current state-of-the-art wearable SR sensors primarily utilize absorbent patches or microfluidic-based systems.[1,2] While absorbent patches are cost-effective, however, they accumulate perspiration over prolonged durations instead of offering time-sensitive data. Conversely, microfluidic systems offer better temporal resolution but typically require multi-step fabrication, electrode alignment, and manual bonding of layers. These limitations somehow reduce device reproducibility and make it difficult to mass-produce sensors.

We present a sensing methodology based on a one-step, 3D-printed device for sweat rate measurement. This new approach eliminates manual post-assembly by a single manufacturing process. The sensor features a multilayered construction using conductive and non-conductive polylactic acid (PLA) filaments. Another innovation is the integration of "floating electrodes," which advantageously modify the overall impedance of the device during sweat flow measurements and increase sensing frequency while reducing the number of wires and external connections required.[3] To examine the mechanism, configurations ranging from two to eight electrodes were tested. In off-body validation, the system demonstrated a calibration range of 1–10 µL/min, a total capacity of 37 µL, and a correlation coefficient ($r = 0.927$) against timer-based measurements. Then, the sensor performance was further evaluated through on-body trials involving two protocols: pilocarpine iontophoresis for chemically stimulated sweat and stationary cycling. Results indicated variations of 0–15% and a strong correlation ($r = 0.79–0.93$) compared to the cotton patch gravimetric method. These findings show that the floating-electrode concept is feasible for personalized hydration monitoring.

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Self-Calibrating Ion Sensing Based on Electrochemically Internal Standard Addition

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Chloride ion (Cl^-) is an essential indicator for drinking water safety and a crucial factor influencing the quality of processed beverages [1]. In matrices ranging from tap water to chemically complex carbonated drinks, Cl^- levels directly impact consumer health and product flavor profile [1]. Currently, Ion Chromatography (IC) and Ion-Selective Electrodes (ISEs) are one of the primary methods for Cl^- detection. However, IC is often constrained by bulky instrumentation and high maintenance costs, while ISEs suffer from potential drift and a heavy reliance on external calibration in complex samples.

Recently, chronopotentiometric sensors based on polymeric ion-selective membranes (ISMs) in a three-electrode system have been introduced as a robust methodology for in situ analysis [2]. The principle relies on imposing a defined ion flux across the membrane via a constant current, where the transition time triggered by the depletion of analyte species at the electrode interface is used for quantitative analysis [2]. The methodology was successfully applied to determine total alkalinity, acidity, and calcium speciation [2, 3].

In this work, we developed a new three-electrode chronopotentiometric approach for ion detection, with chloride as an initial example, where the three electrodes are all simple Ag/AgCl elements. Unlike the depletion sensing mode mentioned above, our approach operates by inducing a controlled time-dependent accumulation of local Cl^- concentration at the electrode/sample interface under a constant applied current. By monitoring the potential response over time, which is influenced by the initial sample concentration, precise quantification of Cl^- is achieved. Besides investigating the influence of applied current density, temperature, and supporting electrolyte concentration, the method is validated by ion chromatography.

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Membrane Integrated Electronic Transistor for Glial Fibrillary Acidic Protein Detection

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Glial fibrillary acidic protein (GFAP) has recently emerged as a potential marker associated with brain injury [1]. GFAP can be released from the central nervous system into the peripheral blood [2], allowing a less invasive and simpler sample collection. In this work, we develop a membrane-integrated platform for the detection of GFAP. Custom-engineered nanobody receptors are immobilized onto a functional nanoporous membrane that is interfaced with a transducing amplifier [3,4], the organic electrochemical transistor (OECT). Target binding within the membrane modulates the flow and distribution of electrolyte ions at the membrane-OECT interface, altering the performance characteristics of the OECT. We systemically characterize the membrane-OECT interface and explore device configuration to enhance sensing performance. Our approach preserves the gate electrode and OECT channel from the surface modification steps typically required to immobilize the biorecognition units, which would otherwise render these expensive components single-use parts. This functional membrane integrated platform represents a significant step towards developing less invasive, lower-power, and cost-effective devices for the diagnosis of brain injury and dementia-like neurological disorders.

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Combination of xanthine dehydrogenase with a light-sensitive semiconductor electrode

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Semiconductor nanostructures are a valuable tool in the development of analytical detection systems since they allow the read-out of a sensing surface by spatially resolved illumination. One promising approach within this field are represented by nanowires which can directly be prepared on a chip electrode. InGaN nanowires have been shown not only to be valuable in evaluating photoluminescence properties [1] but also to allow defined photelectrochemical reactions. One example is the detection of NADH as a cofactor of many enzyme reactions [2].

Such semiconductor-based electrodes can also be combined with enzymes in order to introduce more specificity in the detection. Although there are different approaches in establishing enzyme – semiconductor contacts, direct electron transfer reactions possess the inherent advantage of avoiding any additional redox components. This research directions is however, still in its infancy.

The enzyme xanthine dehydrogenase from *Rhodobacter capsulatus* (XDH) can oxidise degradation products of the purine metabolism such as hypoxanthine and xanthine. We have studied whether the natural cofactor NAD+ can be replaced by ÍnGaN nanowires. Here we have used the approach of enzyme adsorption. Chopped light voltammetry was applied in order to evaluate the reaction when different concentrations of hypoxanthine are applied in solution. The anodic photocurrent can be amplified in the presence of the enzyme substrate. Since this is not the case without the enzyme attached to the surface, it can be concluded, that XDH can exchange electrons directly with the InGaN nanowires. Thus, a signal chain from hypoxanthine via the enzyme towards the nanostructured electrode can be verified. This may provide a good basis for the further development of photoelectrochemical sensing systems for the enzyme substrate.

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Electrochemical Monitoring of Cancer Biomarkers via Simultaneous Multiplexing with Gold-Coated Magnetic Nanoparticles

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Dispersible electrode biosensors based on Au@MNPs functionalized with methylene blue–labelled DNA probes were used for ultrasensitive nucleic acid detection [1]. We systematically investigated the interfacial chemistry of Au@MNPs and demonstrated that incorporation of 6-mercapto-1-hexanol (MCH) is critical for probe orientation and target accessibility, significantly enhancing the sensitivity for miRNA-155 detection in clinical plasma samples. Building on these findings, this project advances toward multiplexed and simultaneous detection of cancer biomarkers, including microRNAs (Figure 1a). Optimized Au@MNP surface modification and established calibration lines for multiple miRNA targets enable reproducible multi-biomarker measurements (Figure 1b). Integration into a 96-well electrochemical platform is underway to support high-throughput cancer monitoring (Figure 1c). By combining interface function and electrochemical assay design, this platform aims to deliver a versatile liquid biopsy tool capable of tracking disease progression and treatment response in real time.

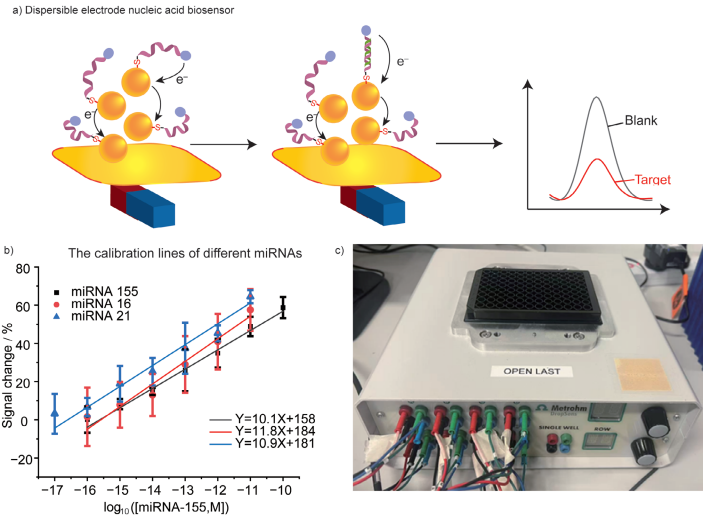

Fig. 1: a): The disposable electrode strategy; b): The calibration lines for different miRNAs detection; c) The whole 96 well platform system for the multiple miRNAS monitoring.

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Bioinspired Chitosan-Stabilized CuO Nanozymes Exhibiting Laccase-Like Activity for Highly Selective Electrochemical Serotonin Biosensing

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Enzymes, which naturally occur as protein catalysts in plants, microbes, and animals, have historically been utilized for biosensor development owing to its high selectivity and catalytic efficacy. However, high costs of synthesis, instability, and environmental sensitivity became a bottle neck towards their application towards a diverse analytes and for long term continuous usage. To address these issues, artificial enzyme mimics known as nanozymes have emerged, exhibiting high catalytic activity and stability while functioning under mild conditions. Nano-enzymes often referred as 'Nanozymes' are novel inorganic nanomaterials with customized enzymatic activity have gained attention as a direct alternative for natural enzymes[1]. The use of nanozymes in electrochemical biosensors is particularly important to achieve low cost and stable biosensors for prognostics, diagnostics, and therapeutic monitoring of various diseases. High surface area and high-density capture sites of the nanozymes could allow better loading of the electroactive species at their surfaces, resulting in improved electrochemical responses. Among the different classes of enzymes, oxidoreductases have been profoundly used in sensor development. Laccase is a multi-copper oxidase enzyme catalyzing the oxidation of amino and phenolic compounds. This catalytic activity is utilized in the biosensor development for neurotransmitters especially the monoamine ones, 'serotonin'. Detection and monitoring of serotonin gained relevance as it is involved in synaptic signaling, and the imbalances of the same results in chronic mental and physiological disorders. Here in this work, we are developing a novel Chitosan capped Copper oxide as the nanozyme platform for serotonin detection by mimicking the multicopper reaction site and the amino acid environment by the more versatile chitosan. Chitosan helps in efficient metal ion coordination, increased hydrophilicity and biocompatibility of the sensing module. The synthesized material is well characterized by advanced techniques like XPS, HRTEM. Selective and sensitive sensing of serotonin was obtained within the therapeutic range using the developed sensor. Real time-monitoring ability was confirmed by conducting analysis in artificial ISF. The new 'nanozymatic' sensor platform holds considerable promise toward real-time continuous monitoring of the important neurotransmitter in presence of structurally similar moieties.

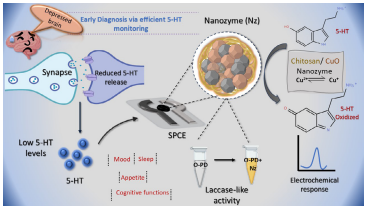

Figure 1: Schematic representation of electrochemical detection of Serotonin by Nanozyme-sensor.

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Fe_3O_4@Pt@Pd Nanozymes as Multifunctional Platforms for Application in Bioanalysis

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Hybrid (multi-component) nanoparticles enable the combination of multiple desirable properties and functionalities within a single structure [1,2]. Such nanoparticles are widely used in bioanalytics and combined anticancer therapies. This presentation will focus on the development of modern multifunctional nanoplatforms utilizing superparamagnetic cores and will present the characterization of these particles and their applications. Due to the employment of two noble metals for the decoration of magnetic cores, such nanoparticles exhibit useful catalytic activity in both oxidation and reduction reactions. Such reactions (generated products) can serve as a source of analytical signals for various biotests and biosensors.

In the framework of this presentation, various approaches to synthesizing Fe_3O_4@Pt@Pd nanoparticles will be shown. Their structure and composition will be confronted with their catalytic properties, with particular emphasis on the generation of precipitating products [3]. After modification with selected bioreceptors, these nanoparticles can be used for various bioassays, and the determination of inflammatory biomarkers using bioconjugates of these nanoparticles will be presented to highlight the potential of this nanozymes platform for sensitive protein detection and future point-of-care diagnostic technologies.

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Advanced Chemical Sensors for Biodetection

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Bioaerosols are a significant challenge for public health and environmental monitoring due to their low concentration in the air, complex composition, and strong dependence on environmental conditions. Current detection technologies frequently show significant limitations in sensitivity, specificity, interference from background particles and environmental conditions, digital integration, and real-world validation.[1] In this PhD, the handheld CRIM-TRACK colourimetric detection system, able to detect the vapours of illicit substances,[2] is adapted with the research focused on the detection of harmful chemicals in aerosol and bioaerosol samples with parts of billion sensitivity. The method integrates a multi-dye colourimetric microarray with sample exposure and imaging and enables real-time, non-invasive, and cost-effective bioaerosol detection. Microbial volatile organic compounds (MVOCs), produced as metabolic by-products of microorganisms, are included in the research as a promising chemical fingerprint for bioaerosol identification.[3] Current work focuses on the fabrication of the colourimetric sensor using a GESIM nano plotter and evaluation of its response to chemical aerosols produced in laboratory conditions. This PhD research contributes to the Future Biodetection Technologies Research Hub activities funded through the UKRI Expanding Excellence in England (E3) Scheme.

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Application of the acoustic QCM-D method for detection of bacterial lipopolysaccharides using DNA aptamers and Concanavalin A

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Detection of the lipopolysaccharides (LPS) that are incorporated into the outer membrane of bacteria or are present as a remaining lysate can be considered for indication of serious contamination in food samples [1]. As one of the most notorious foodborne pathogens of all bacteria species, *Salmonella enterica* serotype typhimurium causes serious outbreaks of typhoid fever. While typhoid fever is not so widespread as it used to be, it is still present in developing countries and common antibiotics have lost its effectiveness due to its acquired antibacterial resistance. In this work we extracted LPS lysate from *Salmonella* to study its interaction with concanavalin A (ConA) or DNA aptamer layers at the gold surface using quartz crystal microbalance with dissipation monitoring (QCM-D). For this purpose, the ConA or DNA aptamers specific to *Salmonella* LPS have been covalently attached to the monolayers of 11-mercaptoundecanoic acid (MUA) [2]. Using QCM-D we monitored the formation of ConA or aptamer layers. We have shown that optimal concentration of Con A for formation of the sensing layer was 0.3 mg/mL and for DNA aptamers it was 1 μM. We compared interaction of LPS lysate and even with lysate from different bacteria with these sensing surfaces. While ConA proved to be sensitive for detecting any LPS lysate, it lacked specificity. Aptamer layer was able to distinguish between LPS from different bacteria even at concentrations as low as 3 ng/mL. We also tested detection capabilities in the spiked milk samples. While milk protein adsorption caused signal changes of the resonant frequency and dissipation, we could clearly record the effect of LPS adsorption in diluted milk. We also monitored formation of model bacteria membranes containing LPS on the surface of biosensor and their consequent degradation at presence of antibacterial peptide polymyxin B [3].

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Revealing Nanocluster Charges by Titrimetric Permselectivity Change

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Our group introduced in 2010 a potentiometric titration method to assess the purity of lipophilic electrolyte salts in organic phase [1,2]. The method is based on a permselectivity change by a volumetric titration of the organic salt with a lipophilic counter ion. The change is monitored with two electrodes immersed in the organic phase with an aqueous internal solution. The recorded potential is given by:

$$\Delta E = \frac{RT}{z_i F} \ln \frac{a_i(aq1)}{a_i\,(aq2)} \qquad (1)$$

where a_i corresponds to the activity of the common ion present in the organic solution and aqueous internal solution. Once the endpoint is reached, the titrating salt of opposite sign will start acting as the new ion exchanger and change the permselectivity of the organic phase, and an abrupt potential change will result. The final potential will still be given by Eq. 1 but since the valency is of opposite sign, a large potential change is observed at the endpoint.

Nanoclusters characterization is essential to predict their stability and interactions with biological systems. It is currently mostly estimated by electrophoretic and spectroscopic methods [3], but the approaches are not satisfactory since they do not directly measure surface charge. The few potentiometric methods reported are mainly based on pH titration of oxide metals by determining the point of zero charge [4]. We here apply and improve the method described above to quantify the total charge of atomically precise $[Cu_{14}(C_3H_5S)_{12}(PPh_3)_6H][BF_4]$ nanoclusters by displacing their more hydrophilic BF_4^- counter ion with the much more lipophilic tetrakis(4-chlorophenyl)borate ion. This simple and precise technique should allow for direct assessment of nanomaterial charge without requiring expensive spectroscopic methods if the original counter ion can be displaced.

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Applications of electrochemical analysis in the development of new drug delivery systems

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Cancer is among the leading causes of mortality worldwide, prompting the development of novel techniques for its treatment. Targeted drug delivery systems (DDSs) have gained attention for their ability to reduce systemic side effects of chemotherapy while improving treatment efficiency. However, DDSs development is complex, requiring numerous optimization steps to ensure appropriate drug loading and release. To this scope, electrochemical methods can be employed, due to their quick response times, simplicity and use of low sample volumes.

The present work proposes two platforms based on in-lab printed electrodes for the detection of carboplatin (i) [1] and doxorubicin [2] (ii) from proof-of-concept liposomal DDSs. In both cases, the drugs were loaded into commercial nanosomes and release studies were performed *in vitro*. The amount of drugs loaded and released was determined using UV-Vis spectrophotometry as reference method and the developed electrochemical platforms. The platforms were printed in-lab, using conductive carbon and silver inks. The detection of each chemotherapeutic was based on their oxidation signal on the surface of carbon electrodes (i) or carbon electrodes modified with gold nanoparticles (AuNPs) (ii).

For carboplatin, a limit of detection (LOD) of 1.6 µg/mL was estimated for the optimized differential pulse voltammetry (DPV) method. The results obtained from release studies using the optimized method and UV-Vis spectrophotometry revealed no significant differences (ANOVA, Bland-Altman plots), indicating the good agreement of the two techniques.

For doxorubicin detection, AuNPs were deposited on the electrode surface, and the platform was characterized by using electrochemical and microscopic methods. The LOD was estimated at 0.3 µg/mL for the optimized DPV method. The results obtained for doxorubicin loading and release were compared to those obtained using UV-Vis spectrophotometry and good correlations were obtained. This demonstrates the potential of electrochemical methods as alternative strategies for quality control in the development of pharmaceutical formulations.

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Highly Sensitive Hydrogel-Protected Molecularly Imprinted Sensor on a Laser Induced Graphene Electrode for Label-Free Electrochemical Detection of Methotrexate

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Methotrexate (MTX) is a widely used chemotherapeutic and immunosuppressive drug whose narrow therapeutic index and environmental persistence require reliable monitoring strategie[1]. In this work, a highly sensitive biomimetic electrochemical sensor for MTX detection was developed using a laser induced graphene (LIG) electrode platform. The electrode was first modified with gold nanoparticles (AuNPs) to enhance the electroactive surface area and improve electron transfer[2] A Prussian Blue (PB) layer was subsequently deposited as a stable internal redox probe operating at low potential, reducing electrode fouling associated with direct MTX oxidation. For selective recognition, a molecularly imprinted polymer (MIP) was electropolymerized using o phenylenediamine as the functional monomer and MTX as the template molecule. A hydrogel protective coating was applied after MIP fabrication to preserve the integrity of the PB layer during sensing. Binding of MTX to the imprinted cavities restricts electron transfer, producing a measurable decrease in PB current. The sensor exhibited a linear detection range of 10 nM to 10 µM with excellent selectivity and reproducibility.

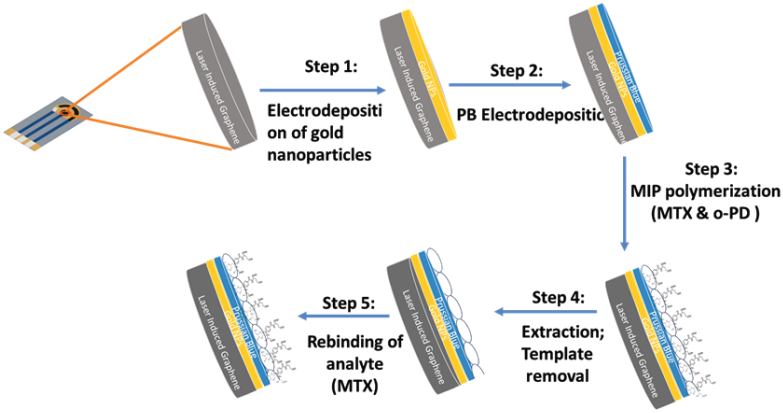

FIGURE: Schematic representation of the MTX - MIP sensor.

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Electrocatalytic Oxidation of Protein Amino Acids and Short-Chain Peptides by Prussian Blue and its Analogues

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Apart from being the building blocks of proteins, many amino acids are indispensable for certain vital functions or have specific functions of their own [1]. Manipulation of free amino acid levels by dietary or topical supplementation may support and modulate these specific functions. In addition to free amino acids, short-chain bioactive peptides represent an excellent source for drug design and are widely used in the pharmaceutical, nutraceutical, and cosmetic sectors. Electroanalytical methods seem to be the promising ones to detect and study free amino acids and short-chain peptides [2]. The specific oxidation, both direct and electrocatalytic, of nearly all protein amino acids (except for Glu) was demonstrated at potentials below 1 V by cyclic voltammetry (CV) and amperometric flow-injection analysis (FIA) on bare carbon screen printed electrodes (SPE) and electrodes modified with Prussian blue (PB, $Fe_4[Fe(CN)_6]_3$) in phosphate buffer, pH 6.0 [3]. For 20 out of 21 amino acids tested, the electrogenerated Berlin Green ($Fe[Fe(CN)_6]$) has been reduced back to PB forming a catalytic cycle thus resulting in an increase of oxidation current [3]. Moreover, it has been shown that protein and peptide molecules are oxidized via "non-electroactive" amino acid residues on unmodified and PB modified carbon SPE [3, 4]. As a continuation, a comparative study of the electrocatalytic oxidation of protein amino acids with transition metal hexacyanoferrates(II) (MHCF, where M is Fe(III), Co(II), Ni(II) or Cu(II)) was carried out. A significant effect of pH on stability of MHCF and on analytical signals of amino acids was revealed by CV and amperometric FIA. The CuHCF was stable only under strong acidic environments (pH ~ 1–3). The PB was stable only under acidic medium (pH ≤ 6.5). CoHCF and NiHCF were stable under broad pH range (pH 1–9). In most cases, CoHCF was superior to NiHCF in its ability to catalyze the oxidation reactions of amino acids under neutral and alkaline pH. The greatest catalytic effect, a 20–fold increase in current, was observed for 1 mM Arg, Lys, Asn, and Ser with CoHCF by amperometric FIA under pH 8.0. As possible practical application, several dipeptides have been tested with MHCF modified electrodes.

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High Throughput Measurement Platform for Continuous Electrochemical Sensors

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By shifting from reactive to proactive care, healthcare systems can become more effective and financially sustainable through predictive, preventive, personalized, and participatory ("P4") medicine [1]. This approach relies on rich longitudinal, multi-parameter data, for which electrochemical biosensors are particularly well suited due to their compactness, multiplexing capability, and cost efficiency [2]. Large-scale data generation is essential to validate sufficient sensor sensitivity, selectivity, stability, and reproducibility for widespread healthcare adoption [3].

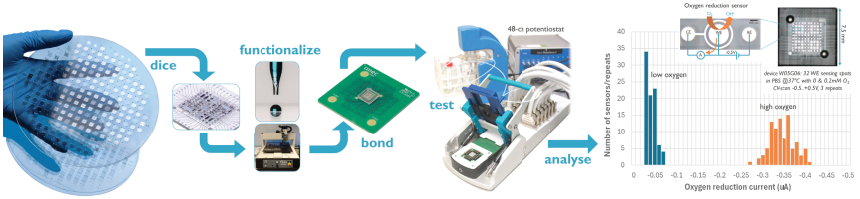

Figure 1. High-throughput measurement platform and exemplary data from a single multi-electrode sensor chip

To enable large-scale data generation for continuous electrochemical sensors, we developed a high-throughput measurement platform. It is based on wafer-scale fabricated multi-electrode chips with 100 individually addressable micro-electrodes, supporting up to 48 working, counter, and reference electrode sets on just 7.5x7.5 mm^2. Dry-film resist microwells facilitate functionalization, after which the chips are bonded to an interconnection PCB and inserted into the measurement setup. The system performs parallel measurements using a 48-channel potentiostat while applying pre-programmed fluidic test conditions, automatically mixed from 10 reservoirs. All data are stored in a cloud database for detailed analysis [4].

We have demonstrated our high-throughput platform for oxygen, glucose and conductivity sensing. Currently we are extending the range of parameters to include flowrate and hydrogen peroxide, as well as pH, sodium, potassium, and calcium using ionophores, as well as L-lactate sensing using enzymes.

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Ultra-stable biosensor transducer based on transition metal hexacyanoferrates

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Continuous monitoring has a crucial importance for medical diagnostics. Minimally invasive implantable biosensors for monitoring glucose levels have been developed to control diabetes [1]. The next step is supposed to be noninvasive diagnostics as it helps avoid injuries and infections. Still, there are only two glucose biosensing principles for continuous monitoring: hydrogen peroxide oxidation on platinum electrodes (used in all clinical analyzers and implantable devices from Dexcom and Medtronic) and osmium complexes for low potential oxidation of glucose (used in minimally invasive monitors from Abbott). However, due to much higher sensitivity towards reductants the false-positive signals on platinum-based sensors in blood can reach 100%, while low-potential glucose oxidation is based on glucose dehydrogenase, which has broader selectivity than glucose oxidase. Prussian blue (PB) was introduced as a selective electrocatalyst for H_2O_2 low-potential reduction in 1994. Prussian blue is 1000 times more active and 1000 times more selective than platinum, which allows the detection of hydrogen peroxide by its reduction in the presence of oxygen [2]. The only drawback of Prussian blue is its solubilization by hydroxyl ions, which are a product of the reduction of H_2O_2. The most promising stabilizers seem to be isostructured hexacyanoferrates (HCF) of iron triade-mates (Co and Ni) [3].

Herewith we report on different strategies for simultaneous interfacial deposition of iron and nickel hexacyanoferrates. Resulting H_2O_2 transducers are displaying operational stability peculiar to thick NiHCF film with activity close to pure Prussian blue. Reliable calibration-free H_2O_2 monitoring with the resulting composite PB-NiHCF electrode is up to 5 times longer than in case of the electrodes stabilized through layer-by-layer assembly and up to 100 times – than with pure PB. The corresponding biosensor is completely stable for 3 days of continuous glucose monitoring (at its physiological concentration of 5 mM). The reported ultra-stable and highly sensitive transducer for oxidase-based biosensors would provide reliable continuous monitoring of low-molecular weight metabolites in a variety of biological liquids.

Acknowledgements:

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Electrochemically Driven Acidification Using 3D PANI Mesh Arrays: A Reagent-Free Approach for Sustainable pH Control

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Precise pH regulation is fundamental to chemical sensing, as it dictates analyte speciation, mitigates interferences, and ensures the reliability of detection in complex matrices. Conventional pH adjustment relies on the manual or automated addition of liquid reagents, which limits miniaturization, increases the risk of contamination, and poses challenges for in-situ or decentralized monitoring. [1] While electrochemical acidification via water electrolysis or metal oxidation offers an alternative, these methods often require high overpotentials that trigger unwanted side reactions. [2]

This work introduces a sustainable, reagent-free electrochemical platform for bulk-sample acidification utilizing a novel 3D polyaniline-coated stainless steel (PANI-SS) mesh array. By exploiting the low-potential (0.4 V vs. Ag/AgCl) redox-driven proton release of PANI, we have developed a 3D-printed electrochemical cell capable of processing aqueous volumes up to 40 mL. The 3D mesh architecture significantly enhances the electroactive surface area compared to traditional thin-film electrodes, enabling scalable and rapid proton delivery.

Experimental results demonstrate that a single PANI-SS mesh releases approximately 3 µmol of protons, reducing the pH of a 40 mL solution by 1 unit within 200 seconds. By employing a parallel configuration of four meshes, the system can tune the final pH down to 3.4. The robustness of the approach was validated in challenging environmental matrices, including brackish water and sediment-seawater bioreactor samples, achieving target pH levels (pH 3.8–5.0) essential for metal recovery and bioremediation. Furthermore, we demonstrate a circular regeneration path for the PANI meshes using acidic mining leachates, enhancing the system's sustainability. This scalable, low-power acidification strategy provides a versatile tool for integrated chemical sensors and autonomous environmental monitoring platforms requiring precise, on-demand pH control.

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