GS 2025

Interdivisional Sensors Group Workshop

"Sensors and biosensors as strategic tools for health, food safety, and environmental monitoring"

15-17th December 2025

CNR, Bologna

Via Piero Gobetti, 101, Bologna

UNDER THE PATRONAGE OF

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UNIVERSITÀ DI BOLOGNA
DIPARTIMENTO
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COMMUNICATIONS

Oral communications will last 12 minutes, followed by 3 minutes of discussion.

SCIENTIFIC AWARDS

Scientific Awards will be presented during the conference:

- *“Marco Mascini” Award*
- *«Young Researcher» Award*
- *SIOF Thesis and PhD Awards*

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Monday 15th December

12:00-13:00 SIOF Annual Meeting

13:00-14:20 Registration

14:20-14:30 Opening Cerimony

14:30-15:15 “Marco Mascini” Award: Prof. A. Roda
Biosensors in the field: still a dream or reality

15:15-15:30 **O1 - Noemi Bellassai**
Non-invasive pre-implantation genetic testing of cell-free DNA for monogenic diseases using superparamagnetic particle-based plasmonic assay

15:30-15:45 **O2 - Simone Ventisette**
Epitope-Imprinted Polynorepinephrine Nanoparticles for Advanced Affinity Assays

15:45-16:00 **O3 - Blanca Cassano**
Polydopamine-based One-Pot Immobilization of PQQ-GDH on Graphite Electrodes for Reliable Glucose Sensing

16:00-16:15 **O4 - Stefano Zampolli**
Applications of MEMS-based gas sensing systems

16:00-16:30 **O5 - Tatsiana Pobat**
MicroNIR/Chemometric Platform for Rapid Trihalomethanes Screening in Water

16:30-16:50 Tea Break

16:50-17:05 **O6 - Alessio Bruttomesso**
Advanced Technology from Lens to System

17:05-17:20 **O7 - Valentina Marassi**
LOREM IPSUM as a microfluidic platform for nanozyme-based biosensors: ultra-small pyramidal Pt nanoparticles for robust and ultra-sensitive chemiluminescent assays

17:20-17:35 **O8 - Agata Checcozzo**
Development of a multiparametric electrochemical sensor for the monitoring of Nickel, Copper and Zinc in wastewater and surface water

17:35-17:50 **O9 - Erica Belforte**
Activity based (bio)sensor for the monitoring of MutyH DNA glicosilase

17:50-18:05 **O10 - Alexandru Dron**
2D Metal-Covalent Organic Framework as a versatile water-based ink for the development of electrochemical sensors

18:05-18:20 **O11 - Stefano Gianvittorio**
Electrochemical (bio)sensing platform fabrication by coupling inkjet- and 3D printing

18:20-18:35 **O12 - Luca Sartorelli**
Electrochemical sensing of glucose using a flexible fully ink-jet printed wearable platform

18:35 Cocktail party in UNIBO

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Tuesday 16th December

09:00-09:12 Aw1 - Giulia Crotti
Modelling and design of nonlinear metasurfaces for the control of light by light

09:12-09:24 Aw2 - Maria Eleonora Temperini
A new IR nanospectroscopy platform to investigate the influence of static electric fields on molecular systems

09:24-09:36 Aw3 - Gabriele Calusi
Optical Mode Level Repulsion in Hyperuniform disordered systems

09:36-09:48 Aw4 - Carlo Anelli
Development of an optical sensor based on absorption of infrared radiation for detection of urea in aqueous solutions

9:48-10:00 Aw5 - Adolfo Mazzotti
Electrical and optoelectronic properties of two-dimensional BP/MoS2 heterojunctions

10:00-10:15 **O13 - Alessandra Cutaia**
Molecularly imprinted polypyrrole-based POF dual sensor for dopamine detection exploiting plasmonic and voltammetric methods

10:15-10:30 **O14 - Enrico Cozzani**
The “ODOR-GC” Project: detection of odorous molecules by means of a compact and MEMSbased gas-chromatographic system

10:30-10:45 **O15 - Riccardo Desiderio**
Development of novel biosensing tools based on gold nanoparticle/luciferase nanotags

10:45-11:00 **O16 - Alessandro Esposito**
A Versatile and ultrasensitive SERS-Based Biosensing Platform for oligonucleotides detection in Biomedicine

11:00-11:30 Coffee Break

11:30-11:45 **O17 - Ambra Fioravanti**
Development of innovative gas sensors for H2 leak in production, storage and use sites

11:45-12:00 **O18 - Ilaria Rea**
Plasmonic–assisted biosilica nanoplatforms enable intracellular SERS sensing and in vivo label-free Raman imaging

12:00-12:15 **O19 - Simone Fortunati**
Chemically-modified gold screen-printed electrodes-based voltammetry coupled with machine learning for rapid screening of Alternaria toxins in food samples

12:15-12:30 **O20 - Giulia Elli**
Electrolyte-Gated Field-Effect Transistors-Based Sensor for Nanoplastics Detection

12:30-12:45 **O21 - Alfonso Sierra Parilla**
Biochar as a functional, sustainable nanomaterial for 2nd generation biosensor development: Lactate as a case study

12:45-13:00 **O22 - Marco Malferrari**
Micrometric Electrochemical Sensors for the Investigation of Cellular Differentiation and Photodynamic Therapy

13:00-14:30 Lunch & Poster Session

14:30-15:00 "Young Researcher" Award: Dr. A. Scroccarello
From in-solution plasmonic sensing to nanostructured sensing film-based analytical devices: the path taken

15:00-15:15 **O23 - Matteo Sensi**
Electrolyte-Gated Transistors Biosensors for Healthcare Applications

15:15-15:30 **O24 - Valentina Pifferi**
Bimodal and enantiomeric (photo)electrochemical analysis of Tryptophan by MWCNTs and BT2T4 modified electrode

15:30-15:45 **O25 - Muhammad I. H. L. Zein**
Guide RNA Design Targeting the Mitochondrial D-loop Region of Sus scrofa and Its Application in CRISPR/Cas12a Electrochemical Biosensing for Food Authentication

15:45-16:00 **O26 - M. Grazia Donato**
Sensing by Optical and Acoustic trapping

16:00-16:15 **O27 - Verdiana Marchianó**
Free-Standing Polydopamine Hydrogels as Electrodes for Edible Enzymatic Glucose Biosensors

16:00-16:30 **O28 - Chiara Vincenzi**
Design and Preliminary Evaluation of an Electrochemical Biosensor for Anticancer Drug Screening Applications

16:30-16:50 Tea Break

16:50-17:05 **O29 - Adriano Colombelli**
Real-Time Label-Free Cytokine Detection with Gold Nanoprism Arrays

17:05-17:20 **O30 - Sarassunta Ucci**
Integration of Lab-on-Tip Optical Fiber Biosensors into Microfluidic Systems

17:20-17:35 **O31 - Francesca Bruno**
Systematic Study and Optimization of Multiple Gold Electrodeposition Procedures on 3D-Printed Electrodes for Electrochemical Sensing

17:35-17:50 **O32 - Federico M. Vivaldi**
Solid state electrochemical sensor for the detection of hydrogen

17:50-18:05 **O33 - Elisabetta Primiceri**
Development of innovative MIP based sensors for liquid biopsy

18:05-18:20 **O34 - Giada D'Altri**
Electrochromic analog control based on Organic Electrochemical Transistors and driven by dopamine sensing at the gate electrode

18:20-18:35 **O35 - Lisa R. Magnaghi**
From Lab to Field: Technology Transfer of Sensor Technologies from Pavia - Smart Labels for Food Quality Monitoring

19:30 Social Dinner - A Balùs Restaurant

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Wednesday 17th December

09:00-09:15 **O36 - Giulia Siciliano**
Highly Sensitive CNTs-modified MIP-based electrochemical sensor for Selective Cyromazine Detection

09:15-09:30 **O37 - Paolo Bollella**
Allosteric Modulation Towards Sensitive Enzyme-based Amperometric Biosensors

09:30-09:45 **O38 - Francesco Baldini**
Label-free optical detection of binding protein FKBP12

09:45-10:00 **O39 - Mattia Carbone**
Colorimetric smart sensor for fish freshness evaluation

10:00-10:15 **O40 - Nicholas Kassouf**
Optimizing chemiluminescence reaction catalyzed by a two-dimensional Cu-based Metal-Organic Framework by design of experiment

10:15-10:30 **O41 - Federica Mariani**
Multisensing Electronic Platform for Real-Time Wound Healing Monitoring

10:30-10:45 **O42 - Serena Chiriacò**
Lab-on-chip technologies for extracellular vesicle enrichment and detection

10:45-11:30 Coffee break & poster session

11:30-11:45 **O43 - Gabriele Giagu**
Phage-powered electrochemiluminescence immunosensors for virus quantification

11:45-12:00 **O44 - Elena Sossich**
Peptide-Based Biosensor for Early Detection of Multiple Sclerosis via Activated VLA-4$^+$ Cells

12:00-12:15 **O45 - Dmitry S. Muratov**
Fast and flexible resistive humidity sensors on quasi-1D Zr1-xTixS3 nanoswords

12:15-12:30 **O46 - Maria Vittoria Balli**
Ruthenium complexes as electrochemiluminescent labels for advancing PCR-free nucleic acids detection

12:30-12:45 **O47 - Alessia Foscarini**
Extracellular vesicles detection through electrochemical devices: a new conservative approach to liquid biopsy

12:45-13:00 **O48 - Myriam Alfonsini**
Engineering Intrinsically Disordered Aptamers: A Combined GaussianAccelerated MD and Experimental Strategy

13:00 Closing Remarks

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Posters

P01 - Babar Ali
Self-assembled nanostructured substrates for ATR-SEIRA spectroscopy

P02 - Raffella Biesuz
From Lab to Field: Technology Transfer of Sensor Technologies from Pavia - NEMO Device: Optimization for Water Quality Monitoring

P03 - Alessandra Bonanni
2D Carbon Allotropes for Nucleic Acid Biosensing

P04 - Mattia Bosi
EGOT-based time temperature integrator for food cold-chain monitoring

P05 - Chiara Capolungo
Synthesis, characterization, and application of new luminescent biopolymer probes for micro- and nanoplastics detection

P06 - Alessandro Carvani
Detection of Microplastics in Aqueous Solutions Using Impedance Spectroscopy

P07 - Camilla Casciello
A microneedle-based platform for the detection of Amyotrophic Lateral Sclerosis (ALS) biomarker

P08 - Francesco Casnati
Fluorescent sensor in complex polymeric matrix mimicking extracellular matrix

P09 - Giulia Cazzador
Laser-Induced Graphene Cardboard Electrodes for Sustainable Histamine Detection in Food Packaging

P10 - Mattia Celant
Electrodeposition of metals onto the gate terminal of electrolyte-gated transistors for sensing applications

P11 - Francesco Chiavaioli
Simultaneous dual biomarker monitoring using

step-wise SnO2 coated lossy mode resonance fiber sensor

P12 - Adriano Colombelli
Optical Aptasensor for On-Chip Tyramine Detection: Advancing Food Safety Through Plasmonics

P13 - Luca De Stefano
Engineering Gold Nanocluster in PEGDA Hydrogel for SERS-based Food Quality Assessment

P14 - Flavio Della Pelle
CO2 laser-induced graphenic films on eco-friendly paper substrates for sensing and biosensing

P15 - Paolo Di Battista
Integrated paper/transition metal dichalcogenides colorimetric device for the nanozymatic-sensing of glutathione in saliva

P16 - Ida Valeria Di Cristoforo
Sonochemical-Assisted Formulation (SAF) of water-based conductive ink for sensors and biosensors on flexible and paper substrates

P17 - Camilla Didò
Functional evaluation of polypyrrole (PPy) after optimization of sensor Based on molecularly imprinted polymer (MIP) for PFOA detection

P18 - Luisa Stella Dolci
Design of Layered NiAl-LDH and Pyramidal Pt Nanoparticles for Sensing Applications

P19 - Dounia El Fadil
Colorimetric paper-based kit for the selective determination of melatonin

P20 - Anna Emanuele
A field-deployable, software-controlled platform for electrochemical in-flow monitoring of heavy metals in water

P21 - Luigi Falciola
UPcycling SOOT for sustainable nanocomposites-based electroanalytical sensors

P22 - Sara Ferrara
Fluorescent Probes for biosensing applications

P23 - Ambra Fioravanti
"LIVESTAQSENS": network of AI-calibrated CH4 and NH3 chemical sensors for livestock farming

P24 - Luca Fiore
Smart paper-based electrochemical sensor for real-time monitoring of carvacrol release from functionalized porous materials

P25 - Alessandro Fracassa
Stimuli-Responsive Luminophore Drives Mechanism Switch for Highly Efficient Electrochemiluminescence Immunosensing

P26 - Guglielmo Emanuele Franceschi
From Lab to Field: Technology Transfer of Sensor Technologies from Pavia - NEMO Device Optimization for Water Disinfection Monitoring

P27 - Stefano Giordani
Towards sensitive chemiluminescent cardiac stress detection: optimization of platinum nanozyme systems

P28 - Pietro Giuseppe Gucciardi
Raman Spectroscopy in optical and acoustic traps for micro- and nano-plastics detection: advancements in the SAMOTHRACE project

P29 - Diana Guadalupe Jimenez Rivas
Molecularly Imprinted polypyrrole polymers: A strategy for the determination of glyphosate in real samples.

P30 - Elisa Lazzarini
An Innovative Chemiluminescent Approach to Type III CRISPR-Cas Nucleic Acid Sensing

P31 - Giorgia Leotta
Oxygen paper-based sensor integrated into a multi-sensor array for an Organ-on-a-Chip device

P32 - Filippo Lugli
Portable electrochemical sensoristic system for the on-site measurement of cannabinoids

P33 - Maria Grazia Manera
Optimizing Plasmonic Nanocrystals for Enhanced Fluorescence: New Trends in Optical Sensing Technologies

P34 - Mariagrazia Manera
Reduced Graphene Oxide–Gold Nanoparticle Hybrid Substrate for Surface-Enhanced Raman Detection of Pesticides

P35 - Chiara Mariani
Singling Out the Electrochemiluminescence Profile in Microelectrode Arrays

P36 - Claudia Martínez Asenjo
New coreactant set to enhance electrochemiluminescence for bead-based immunoassays

P37 - Monica Elizabeth Mosquera Ortega
Pristine Bamboo-Derived Biochar for the Electrochemical Detection of Amoxicillin in Aqueous Samples

P38 - Massimiliano Negri
Development of Capillary PDMS-Based Microcolumns for Portable Chromatographic Gas Analysis Systems

P39 - Andrea Pace
Miniaturized CRP immunosensor for spaceflight health diagnostics

P40 - Davide Paolini
Integrated 3D-printed/paper electrochemical device for the direct quantitative sensing of Amitraz

P41 - Michael Douglas Pecanha De Souza
Smart Composites for Water Screening: rGO-Lysine/Chitin nanocrystals for Glyphosate Detection

P42 - Valentina Pifferi
Designing Gold-based Electrodes for the Future: Sensitivity, Stability, and Bimodality

P43 - Laura Pigani
Electrochemical Sensors for Hashish Cannabinoid Profilin

P44 - Kamila Tassone Polisel
Surface-Deacetylated Chitin Nanocrystals (CsNCs) for Biocompatible Sensing

P45 - Alessandro Puzzello
Electrochemical Immunosensor based on Microneedles Array for the Detection of Amyotrophic Lateral Sclerosis Biomarkers in Human Interstitial Skin Fluid

P46 - Laura Lupita Rodriguez Martinez
Liquid Crystal–Templated Silver Electrodeposits for the Electrochemical Detection of Haloacetic Acids

P47 - Leonardo Rossi
Core breakage analysis in Shape sensing for structural health monitoring

P48 - Leonardo Rossi
φ-OTDR applied in on-bridge vehicle detection

P49 - Lorenzo Rucco
Integration of Rolling Circle Amplification and Electrochemical Sensing for C-circles DNA Detection

P50 - Annalisa Scroccarello
CO2-laser plotter towards the development of a paper-based colorimetric analytical kit for sodium hypochlorite determination in milk

P51 - Alessandro Silvestri
In-vitro Dopamine Sensing and Enhanced iPSC-Derived Neuronal Differentiation on a CNT-Based Electroactive Cell Culturing Platform

P52 - Mauro Tomassetti
New electrochemical sensor device, based on Arduino, for measurements of residue charge of primary alkaline batteries

P53 - Sara Tombelli
Long-Period Fiber Gratings combined with advanced functional polymers for biosensing

P54 - Mengzhen Xi
Immuno-affinity electrochemiluminescence for virus detection

P55 - Chiara Zanardi
Unusual amperometric detection of ions using machine learning applied to hexacyanoferrate and graphene oxide modified electrodes

ORAL CONTRIBUTIONS

Monday, December 15th

BIOSENSORS IN THE FIELD: STILL A DREAM OR REALITY

Aldo Roda

Deparment of Chemistyry G. Ciamician, Alma Mater Studiorum, university of Bologna

50 years of personal experience in the biosensors area give me the opportunity to discuss “super partes” the tremendous growth achieved on biosensors since the first prototype in the early seventy. As a representative trend I will use part of the work that we did using chemiluminescence transduction being the analytical format and recognition principle shared by all kind of biosensors from electrochemical , optical and luminescent. From the first Clark electrode commercially used to measure glucose in the 1975 we assist to a continuous advancements fuelled by Nobel prize. for radioimmunoassay RIA in 1974 and Monoclonal antibody in 1984 and more recently for green fluorescent protein in 2008.

The first electrochemical enzymatic biosensor for glucose or other natural analyte present a limited detectability in the range of mM -uM thus limiting their use for abundant analytes particularly in serum. The real jump in sensitivity was achieved by the use of Antibody as a recognition element and a sensitive isotope as a label to develop highly sensitive radioimmunoassay allowing to detect in blood any molecules down to nM- picoM levels. Following the success of RIA in Clinical chemistry alternative non radioactive labels were used such as an enzyme, detected with high sensitive substrate including luminescent and and electroactive compounds. The real robust and sensitive immunosensors have been developed in different analytical format based on microfluids or capillarity; the main drivers were the exponential growth in material sciences and nano technology and electronics with the in simplification of the device, miniaturization in lab-on-a chip to point of care device. Moreover label free immunobiosensors in the 90 start to be commercialized including SPR and SERS which hare still exponentially growing and achieving even best analytical performance in respect to the one with a label. Using extremely selective recognition elements in addition to Ab such as Nucleic acid, PNA MIP and other allows to further enlarge applications reaching the single molecule detection. The strong competition between the diffent trasduction principle allow to further improve in sensitivity with the use of enhancer , co-reactants nano catalyst and miniaturized detectors for both electron and photon in a homogenous format . The last 10 years were particularly productive and small portable ultrasensive integrated in a smartphone format are commercialized. Wearable biosensor are on the way to enter in the marked and portable siple device such as lateral flowimnuoassy LFIA have been extensively applied for pregnancy test or much more actually for the Covid infection. The comparison between the analytical performance different biosensor principle is difficult to establish being too many actors contributing to the final results. Recently with the university Tor Vergata group a well esblished expert in electrochemistry amperometric we under taken a comparative study wth our chemiluminescent biosensor [2]. We use the same reagents for detection such as enzyme , comparable format and same recognition Ab. Therefore “is better to measure a Photon or electron for ultrasensitive detection? The results demonstrate a similar performance in term of detectability, precision and accuracy with similar kinetic response and cost.

References

[1] Roda B et al 2024 TRAC. TRENDS IN ANALYTICAL CHEMISTRY, 180, pp. 117975 – 117995
[2] Roda A et al 2020, BIOSENSORS & BIOELECTRONICS 155, pp. 1 - 16
[3] Zangheri M et al 2019 BIOSENSORS & BIOELECTRONICS129, pp. 260 - 268
[4[Lopreside, A, et al «ANALYTICAL CHEMISTRY», 2019, 91, pp. 15284 – 15292
[5] Roda A et al 2018 ANALYTICAL AND BIOANALYTICAL CHEMISTRY, 410, pp. 669 - 677

From in-solution plasmonic sensing to nanostructured sensing film-based analytical devices: the path taken

Annalisa Scroccarello

Department of Bioscience and Agro-Food and Environmental Technology, University of Teramo, Teramo, Italy

Noble metal nanoparticles (MNPs) have been the keystone of a plethora of (bio)sensing analytical strategies due to their unique physicochemical properties, making them powerful tools in the analytical arena; among others, MNPs' localized surface plasmon resonance (LSPR) provides endless analytical opportunities [1].

This presentation will overview the scale-up process from colloidal MNPs to their integration into solid substrates, and ultimately to the manufacturing of colorimetric paper-based analytical devices [1]. It will discuss optical and colorimetric sensing and biosensing strategies based on LSPR changes, depending on the sensing substrate used. Special attention will be given to MNPs-based events at the basis of the analytical signals, with a focus on sensing strategies for evaluating analytes of interest in agri-food applications.

The aim of this talk is to demonstrate that MNPs decorated/integrated substrates are now mature analytical tools, capable of overcoming the limitations of MNPs colloidal suspensions. This results in new analytical opportunities, especially the development of integrated systems, lab-on-chip or lab-on-strip devices, and flexible sensors, paving the way for a new generation of plasmonic (bio)sensors for point-of-need applications.

Acknowledgments

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References

[1] Scroccarello A. et al. 2023. Optical plasmonic sensing based on nanomaterials integrated in solid supports. A critical review. *Analytica Chimica Acta*, 1237, 340594.

Modelling and design of nonlinear metasurfaces for the control of light by light

Giulia Crotti, [1] Andrea Schirato, [1,2] Giuseppe Della Valle[1]

[1]Politecnico di Milano, Milano, Italia
[2]Rice University, Houston (Texas), USA

In the last few decades, advances in fabrication techniques have empowered the emergence of nanophotonics, enabling the manipulation of light at deep subwavelength scales. In this context, optical metasurfaces, i.e. quasi two-dimensional arrangements of tightly packed nano-resonators, have brought forward a new paradigm as ultra-compact nanophotonic platforms for generating and shaping complex wavefronts, focusing light and controlling its polarization and amplitude in ways that were previously unachievable. Applications range from imaging to sensing, polarimetry, and holography, to mention a few [1]. Among the fields significantly benefiting from metasurfaces, nonlinear photonics is particularly relevant. Specifically, metasurfaces are promising to achieve complete light-by- light control, leveraging an all-optical approach: the photo-generation, by femtosecond-laser pulses, of a population of nonequilibrium 'hot' carriers triggers a transient modulation of the material permittivity, thus a modification of the metasurface optical response. To tackle the challenge of building reconfigurable structures for diverse functionalities, modelling of the photo-physical processes taking place at the nanoscale is of paramount importance. Moreover, it is necessary to combine this description with the rational design of the metasurface architectures, to actively and dynamically mould the electromagnetic fields. Here, I will summarize the research performed in this field during my PhD. I will present the theoretical framework for the modelling and design of semiconductor metasurfaces to achieve ultrafast control of light by light. I will show how a multi-temperature description of the hot-carriers dynamics, combined with (i) a semiclassical treatment of light-matter interaction, for the modelling of the third order optical nonlinearity, and (ii) full-wave electromagnetic simulations, for the dynamic optical response, are a versatile and effective tool towards these objectives. I will illustrate how the modelling approach – which is quantitatively validated by comparison with transient absorption spectroscopy measurements – can be exploited for engineering devices to obtain various functionalities. These include ultrafast, giant modulation of dichroism and birefringence [2], and switching of light amplitude on the (picosecond) timescale of hot-carriers spatial diffusion, via transient optical symmetry breaking at the nanoscale [3].

References

[1] Arseniy I. Kuznetsov, Mark L. Brongersma et al. 2024. Roadmap for Optical Metasurfaces. ACS Photonics. 11(3):816-865.

[2] Giulia Crotti, Mert Akturk et al. 2024. Giant ultrafast dichroism and birefringence with active nonlocal metasurfaces. Light: Science & Applications. 13:204-215.

[3] Giulia Crotti et al. 2025. Ultrafast switching of a metasurface quasi-bound state in the continuum via transient optical symmetry breaking. Light: Science & Applications. 14:240-252

A new IR nanospectroscopy platform to investigate the influence of static electric fields on molecular systems

Maria Eleonora Temperini, [1,2,3] Raffaella Polito,[1,4] Tommaso Venanzi,[2] Leonetta Baldassarre,[1] Huatian Hu,[5] Cristian Ciracì, [5] Marialilia Pea,[4] Andrea Notargiacomo,[4] Francesco Mattioli,[4] Michele Ortolani,[1,2] and Valeria Giliberti[1,2]

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[3]Institute for Electronic Structure Dynamics, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany
[4]Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche, Roma, Italy
[5]Center for Biomolecular Nanotechnologies, Istituto Italiano di Tecnologia, Arnesano, Italy

Static electric fields play a crucial role in many molecular systems, such as protein channels embedded in lipid membranes. Some of these proteins also exhibit electron transport capabilities and are considered promising candidates for molecular electronics applications. Since these systems are characterized by nanometric dimensions, it is essential to apply localized static electric fields while simultaneously acquiring structural and chemical information from the specific region under investigation. Infrared (IR) nanospectroscopy based on atomic force microscopy (AFM-IR) using metal- coated probes and substrates offers an ideal configuration for both applying DC electric fields and achieving strong IR field enhancement within nanoscale detection volumes [1]. To this end, we developed a customized AFM-assisted photothermal expansion platform, enabling electrical contact between the gold-coated AFM probe and a conductive supporting substrate, and integrated an external electric circuit analogous to that used in conductive AFM [2,3].

As a calibration sample, we employed PMMA polymer to study the influence of AFM tip geometry, supported by simulations of both the IR field enhancement and the DC field distribution in the nanogap formed between the gold-coated tip and metallic surface. The Vibrational Stark effect was clearly observed in the AFM-IR difference spectra of PMMA with local electric field strengths on the order of a few MV/cm. We then investigated lipid bilayer membranes incorporating the light-sensitive transmembrane protein Bacteriorhodopsin (BR). In these proteins, ion and proton transport processes are governed by conformational changes in the protein backbone [4]. Specifically, in BR, visible light absorption initiates a sequence of structural rearrangements known as the BR photocycle. We performed IR difference nanospectroscopy on the amide-I band of individual 10-nm-thick membrane stacks composed of two overlapping bilayers, detecting conformational changes induced by locally applied electric fields and comparing them spectroscopically with those triggered by light excitation [5].

References

[1] Lu F. et al. Nature photonics 8.4 (2014).
[2] Venanzi T. et al. Applied Physics Letters 123.15 (2023).
[3] Temperini M. E. et al. Nano Letters 24.32 (2024).
[4] Kottke T. et al. The Journal of Physical Chemistry B 121.2 (2017).
[5] Giliberti V. et al. Nano letters 19.5 (2019)

Optical Mode Level Repulsion in Hyperuniform disordered systems

Gabriele Calusi[1], Nicoletta Granchi[1], Kris Stokkereit[2], Camilla Gonzini[1], Matteo Lodde[3], Andrea Fiore[3], Marian Florescu[2] and Francesca Intonti[1]

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Recently, disordered dielectric materials with structural correlations, which are halfway between random structures and perfectly ordered photonic crystals, have generated an ever-growing interest. Hyperuniform Disordered (HuD) photonic materials exhibit a high spectral and spatial density of resonant modes, characterized by extremely different spatial extensions depending on the light transport regime which can vary from diffusive to Anderson-like localization [1]. These regimes belong to modes of different spectral ranges, highlighted in the spectrum of Fig. 1a. The presence of deterministically tailored localized and diffusive transport within the same photonic platform has raised novel and exciting questions. Here, we investigate the properties of modes in different transport regimes within luminescent HuD materials, focusing on the Level Repulsion phenomenon [2, 3]. This effect causes spatially overlapping modes to exhibit a frequency level distribution with a near- zero probability of closely spaced frequencies. In contrast, when level repulsion is absent, modes are uncorrelated and may have close or degenerate frequencies. Detecting such phenomenon in a HuD photonic architecture, where both kind of regimes can be found, would definitively set a hallmark of Anderson localization in these systems. Here, we take advantage of the subwavelength spatial resolution offered by Scanning Near-field Optical Microscopy (SNOM) to present the first experimental evidence of level repulsion between optical modes in a tailored diffusive regime. To extract from the experimental spectra the level repulsion hallmark we performed a statistical analysis based on the autocorrelation technique [2]. Fig.1 reports the results of a SNOM measurement performed on the sample which consists in a dielectric slab patterned with the HuD geometry (Fig.1b); the SNOM PL maps in (1c) and (1d) are examples of typical Anderson localized modes and delocalized ones, respectively. We evaluate the autocorrelation function in the spectral windows of localized (green curve, Fig.1e) and delocalized modes (purple curve, Fig.1e). The presence of a pronounced shoulder at short spectral distances in the purple curve is a clear indication of level repulsion between delocalized modes, differently, from what is observed between localized modes. In conclusion, we experimentally demonstrated that in a HuD system there is a strong correlation between the mode spatial extension and their energetic level distribution. The findings introduced here are essential to the exploration of the energy level structure in complex disordered photonic materials.

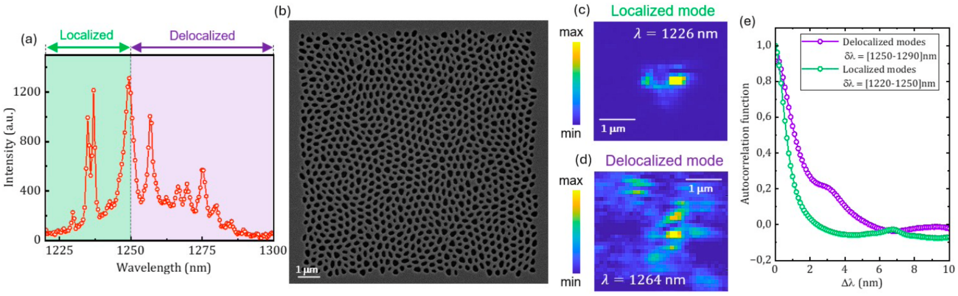

Figure 1: (a) SNOM typical spectrum. (b) SEM image of HuD sample. (c) SNOM PL map of a localized mode at 1226 nm. (d) SNOM PL map of a delocalized mode at 1264 nm. (d) Autocorrelation function of localized (green curve) and delocalized modes (purple curve). The shoulder in the purple curve indicates level repulsion.

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Development of an optical sensor based on absorption of infrared radiation for detection of urea in aqueous solutions

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Contactless and label-free detection of urea content in aqueous solutions is of great interest in chemical, biomedical, industrial, and automotive applications. This work presents a compact and low-cost instrumental configuration for label-free, reagent-free, and contactless detection of urea dissolved in water, which exploits the absorption properties of urea in the near infrared region. The intensity of the radiation transmitted through the fluid under test, contained in a rectangular hollow glass capillary with an optical pathlength of 1 mm, is detected in two spectral bands. Two low-cost, low-power LEDs with emission spectra centered at λ1 = 1450 nm and λ2 = 2350 nm are used as readout sources. The photodetector is positioned on the other side of the tubing, in front of the LEDs, as shown in Fig. 1a. The detection performances of an amplified photodiode and of a thermal optical power detector have been compared, exploiting different approaches for LED driving current modulation and photodetected signal processing. The implemented detection system has been tested on urea–water solutions with urea concentrations from 0 up to 525 mg/mL as well as on two samples of commercial diesel exhaust fluid AdBlue®. Considering the transmitted intensity in presence of the urea-water solution at λ1 and λ2, normalized to the transmitted intensity in presence of water (T1450(C) and T2350(C), respectively), it was demonstrated that their ratio is linearly related to urea concentration over a wide range and with good sensitivity [1]. Using the derived calibration line shown in Fig. 1b, the urea concentrations of two AdBlue® samples were estimated. The instrumental configuration for absorption measurements was also tested on food substances, such as solutions of urea in white wine [2] and caffeine in water.

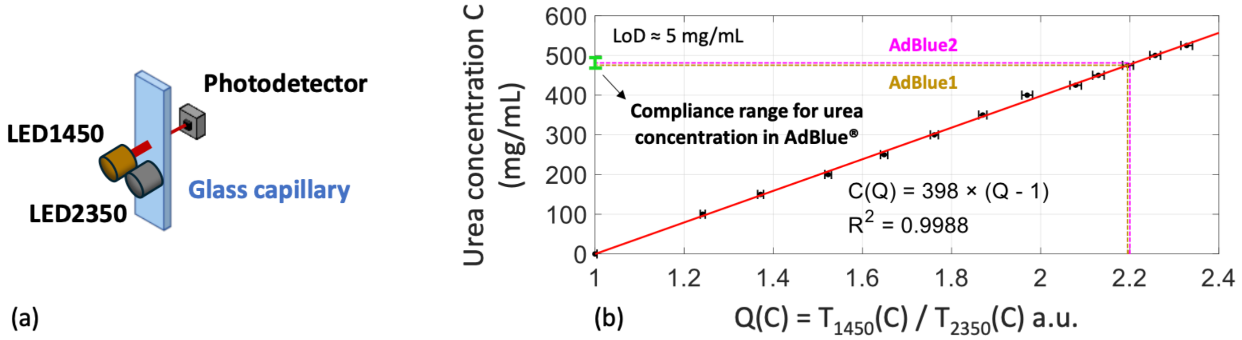

Fig. 1: (a) Instrumental configuration scheme; (b) Ratio Q(C) = T1450(C)/T2350(C) (black markers) and the corresponding calibration line (red trace) exploited to estimate the urea concentration for each AdBlue® sample; results obtained with photodiode.

Acknowledgments: The author wishes to thank his master's thesis advisor in Bioengineering, Prof. Sabina Merlo, for her guidance and support.

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Electrical and optoelectronic properties of two-dimensional BP/MoS2 heterojunctions

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Van der Waals heterostructures composed of two-dimensional (2D) materials provide versatile platforms for the realization of advanced electronic and optoelectronic devices. Among them, black phosphorus (BP) and molybdenum disulfide (MoS_2) stand out for their complementary band structures and gate-tunable properties. In this work, we investigate the electrical and optoelectronic behavior of a vertical BP/MoS_2 heterostructure fabricated on a SiO_2/Si substrate in a back-gate configuration. The optical image of the device is reported in Figure 1. Both two- and four-point probes measurements are conducted. The device exhibits gate-tunable rectifying current–voltage characteristics with a rectification ratio close to 10^3, arising from type-II band alignment between BP and MoS_2. A characteristic kink indicates a transition between different conduction mechanisms [1]. Temperature-dependent measurements reveal an interfacial energy barrier of about 68 meV at the interface between the two materials. Under illumination the device exhibits a fast and linear photoresponse, with a nearly constant spectral responsivity between 450 and 600 nm and clear photovoltaic behavior ($I_{sc} \approx 0.12$ nA, $V_{oc} \approx 75$ mV under 126 µW white light) [2]. These results emphasize the potential of BP/MoS_2 van der Waals heterostructures for low- power electronics, pressure-sensitive applications, and self-powered photodetection.

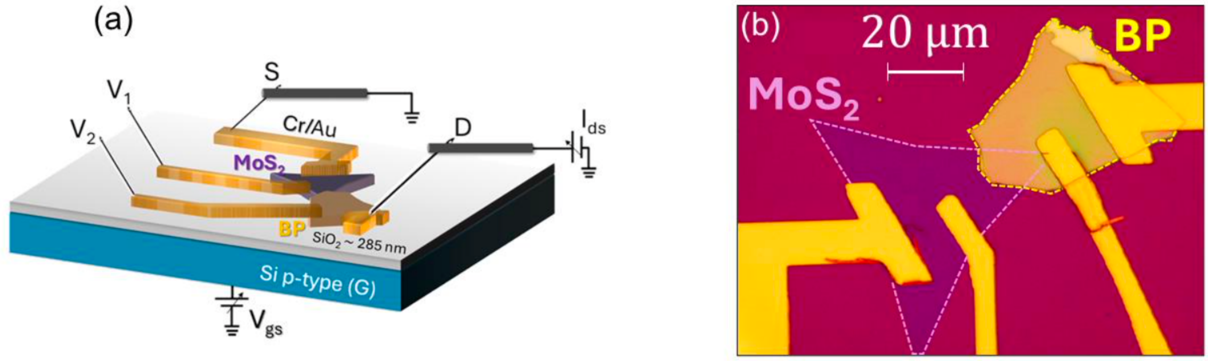

Figure 1 (a) Schematic of the studied device. The heterostructure is located over a p-Si/SiO2 substrate and two metallic contacts are fabricated over each material. (b) Optical image of the device, the purple region is the MoS2 flake while the yellow one is the BP flake.

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Non-invasive pre-implantation genetic testing of cell-free DNA for monogenic diseases using superparamagnetic particle-based plasmonic assay

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In vitro fertilization (IVF) struggles with assessing embryo quality and implantation success. Small sample volumes, low biomolecule concentrations, and contaminants hinder the accurate identification of biomarkers for embryo quality [1]. Surface plasmon resonance presents an innovative and promising approach for rapid, real-time monitoring of dynamic biomarkers in liquid biopsies [2]. A superparamagnetic particle-enhanced SPR imaging biosensor for detecting single-point mutations in non-amplified genomic DNA has been successfully proposed for cancer diagnosis and monitoring [3]. Here, we developed a non- invasive pre-implantation genetic test using superparamagnetic particle-enhanced SPR imaging biosensors to detect single-point mutations in non-amplified cell-free DNA released in spent culture medium during embryo development [4]. Magnetic beads with a biotinylated LNA sequence capture target sequences with single-nucleotide variations in the beta-globin gene related to beta-thalassemia. The assay discriminates between normal and mutant cell-free DNA using hybridization with peptide-nucleic acid probes on the plasmonic gold surface. Our assay detects hetero/homozygous mutated DNA in spiked medium and spent culture medium at sub-attomolar levels (1.5 pg µL-1, ~0.75 aM) with minimal manipulation and no dilution. Only 10 microliters of sample volume are needed for each analysis, providing a reliable detection limit (RDL) equal to 0.73 pgµL−1 within two hours. This plasmonic assay enables the rapid, non-invasive assessment of the embryo's genetic status for successful implantation.

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Epitope-Imprinted Polynorepinephrine Nanoparticles for Advanced Affinity Assays

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A rational strategy was utilized to design, synthesize, and implement bioinspired molecularly imprinted nanoparticles based on polynorepinephrine (MIPNE-NPs), tailored for the selective recognition of human immunoglobulin G1 (hIgG1). These synthetic nanoreceptors were produced using an epitope imprinting approach, relying on a peptide sequence derived from the Fc region of hIgG1 during alkali-induced polymerization. The resulting MIPNE-NPs exhibited tunable diameters (100-300 nm) and low polydispersity (PDI < 0.25), optimized using a design-of-experiments methodology.

MIPNE-NPs were integrated into Surface Plasmon Resonance (SPR) assays by employing two surface immobilization strategies: covalent binding and a non-covalent, flow-assisted adsorption process. The latter method, involving deposition on bare gold substrates, provided robust analytical performance and facile surface regeneration using NaOCl (0.1 mol L^{-1}), enabling reproducible sensor reuse across multiple cycles. The nanoparticles exhibited high molecular specificity towards both the target epitope ($\alpha = 3.5$) and full-length hIgG1 ($\alpha > 27.4$), confirming precise imprinting fidelity.

The combination of rapid, flow-based sensor fabrication, in-flow reconditioning, and high analytical performance highlights the suitability of MIPNE-NPs as reusable, cost-effective biorecognition elements. Furthermore, implementing a MIPNE-NP film as a basal layer allows application in sandwich assay formats, thereby expanding their potential utility in affinity assays. The robustness and modularity of MIPNE-NPs position them as promising synthetic antibody alternatives, with broad application prospects in diagnostics, environmental monitoring, and targeted delivery systems.

Acknowledgments

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Polydopamine-based One-Pot Immobilization of PQQ-GDH on Graphite Electrodes for Reliable Glucose Sensing

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Amperometric enzyme-based biosensors have advanced rapidly, addressing challenges in electron transfer efficiency, enzyme loading via 3D electrode architectures, and interference suppression [1]. However, reproducibility and repeatability remain underexplored, especially across immobilization strategies such as layer-by-layer (LbL) assembly, covalent linking, self- assembly, physisorption, and one-pot methods [2]. Here, we present a novel one-pot polydopamine (PDA)-assisted immobilization approach for pyrroloquinoline quinone-dependent glucose dehydrogenase (PQQ-GDH) on graphite
electrodes, designed to overcome limitations of conventional LbL assembly. The resulting (PQQ-GDH/PDA)OPA/G biosensor forms a uniform, nanostructured enzyme-polymer matrix, as confirmed by SEM and spectroscopic analysis, enhancing enzyme loading and stabilization. Electrochemical studies revealed an onset potential of +0.19 ± 0.01 V and a peak current of 0.87 ± 0.08 µA. The sensor showed a linear response from 0.4 to 1.2 mM glucose, a sensitivity of 0.47 µA mM^{-1}, and a detection limit of 26 ± 2 µM. Michaelis–Menten kinetics yielded an Imax of 1.13 ± 0.07 µA and KMapp of 3.11 ± 0.59 mM. Reproducibility was excellent, with relative standard deviations below 8% across all key metrics. The biosensor retained full performance under physiological conditions (pH 7.2, 37 °C), exhibited high selectivity against common interferents (dopamine, uric acid, ascorbic acid; <5% variation), and remained stable for over 67 days in artificial serum. This demonstrates the potential of the PDA-based one-pot strategy as a reproducible, scalable, and biocompatible platform for next-generation glucose biosensors.

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Acknowledgement

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Applications of MEMS-based gas sensing systems

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Micro-electro-mechanical-systems (MEMS) based gas sensors and gas sensing systems have been studied for several applications in the fields of environmental sensing, agrifood quality and safety, safety and security, forensics, breathomics as well as industrial applications. Nevertheless, the work and efforts necessary to promote these technologies from the lab to real-world use is often underestimated. In this presentation, some examples of MEMS-based gas sensing systems developed at the Institute of Nanostructured Materials of the Italian National Research Council (CNR-ISMN) in Bologna will be presented, with a specific focus on the high-TRL development phases.

Starting in 1996 with the development of MEMS based metal oxide semiconductor (MOX) gas sensors, CNR-ISMN in Bologna has worked on several application-driven research and development projects. To overcome one of the main issues of MOX gas sensors, namely the lack of selectivity, the R&D activities were increasingly focused on gas sensing systems combining MOX with other MEMS devices like gas-chromatographic columns (GC) [1], pre-concentration systems, zero-dead-volume injectors and additional detector technologies. The increasing complexity of multi-device gas sensing systems requires multidisciplinary development efforts, and the careful design of control electronics, embedded analysis automation capabilities as well as fluidic and micromechanical interconnection systems is mandatory.

The availability at CNR-ISMN of several MEMS-based sample pre-treatment modules for pre-concentration and GC separation [2] has become the starting point for collaborations with other R&D groups developing sensors and sensing systems, as well as with industrial partners looking for miniaturized solutions for state-of-the-art sensing applications. During the presentation, we will report on examples of MEMS-based pre-concentration and/or GC separation hyphenated with photoionization detectors [3], infrared absorption spectrometers [4], ion mobility spectrometers and other miniaturized detector technologies. The benefits of a close collaboration between R&D Institutions and companies, often fostered by technology transfer partners like Consorzio Proambiente, will be highlighted and described. Furthermore, our experience on how multidisciplinary collaboration with industrial partners can help and facilitate filling the gaps between research and the market will be reported.

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MicroNIR/Chemometric Platform for Rapid Trihalomethanes Screening in Water

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Real-time monitoring of disinfection by-products (DBPs) in drinking and recreational waters is an emerging analytical challenge. Trihalomethanes (THMs), formed by disinfectants reacting with natural organic matter and anthropogenic precursors, are among the most regulated volatile DBPs due to their toxicological significance [1, 2]. Chromatographic methods for THMs determination, although accurate, require complex sample pre-treatment and laboratory-based instrumentation, limiting their onsite applicability [3]. Miniaturized near-infrared spectroscopy (MicroNIR) coupled with chemometrics, e.g., principal component analysis (PCA), partial least squares regression (PLSR), and discriminant analysis (PLS-DA) enables contactless, non- destructive measurements and offers a sustainable alternative to conventional techniques [4, 5]. This study evaluates a MicroNIR/chemometric platform as a novel sensor-based approach for the identification and quantification of THMs. Chloroform ($CHCl_3$) and bromoform ($CHBr_3$) solutions were prepared in distilled water at 1–200 µg/L and 0.5–200 µg/L, respectively. Employed MicroNIR devices included OnSite-W (vial mode) and PAT-L (static and flow modes). PCA and PLS-DA were applied for presence/absence classification across the entire concentration range, evaluating specificity, non-error rate (NER), and root mean square error (RMSE). PLSR models were developed for quantification in two ranges: <20 µg/L to estimate the limit of detection (LOD) and limit of quantification (LOQ), and 20–200 µg/L to evaluate method linearity, accuracy, and precision. PCA and PLS-DA clearly discriminated spiked samples from blanks, achieving specificity and NER ≈100% with low RMSE. The PAT-L flow mode provided optimal quantification at low concentrations, with LOD ≈1 µg/L and LOQ <5 µg/L for both THMs. PLSR models demonstrated good linearity across the 20–200 µg/L range, with accuracy and precision sufficient for rapid THMs screening. These results confirm the potential of MicroNIR/chemometric platform as a rapid, portable, “green” analytical tool for real-time monitoring of DBPs in aquatic environments. Next steps will extend measurements to other THMs and simulated pool-water matrices and validate the platform on real samples against conventional chromatographic methods.

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Advanced Technology from Lens to System

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A path that illustrates how we can support sensor research by providing optical components, laser and tools useful for characterization up to femtosecond-laser micromachining platforms for sensor fabrication.

FFF as a microfluidic platform for nanozyme-based biosensors: ultra-small pyramidal Pt nanoparticles for robust and ultra-sensitive chemiluminescent assays

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In the latest years, disruptive advances in the biosensing diagnostic field have taken place due to the introduction of nanomaterials with intrinsic enzyme-like properties called “nanozymes”. The use of noble metal catalytic nanoparticles to replace enzyme labels in biosensing, such as horseradish peroxidase (HRP), represents a challenging yet promising strategy. In this respect, ultrasmall octahedral platinum nanoparticles (PtNPs) enable low-cost production and long-term resistance under extreme, non-physiological conditions, and have already proved excellent ability as a nanozyme, outperforming HRP and allowing for sensitive detection in different format bioassay [1]. Despite the promising applications of PtNPs, only a few methods for highly sensitive chemiluminescent (CL) bioassays have been developed so far. The CL catalytic activity of PtNPs nanoparticlesis highly dependent on their size, shape, composition, and concentration and lacks robustness. In addition, problems arise in the controlled conjugation of ultrasmall nanozymes to recognition elements such as antibody, proteins and DNA, which need to be stable in downstream applications to standardize performances of related biosensors. In this study, we introduce hollow-fiber flow field-flow fractionation (HF5) as a compact and rapid microfluidic platform for optimizing conjugation conditions—such as buffer composition and pH—and for isolating well-defined conjugated nanoenzyme probes. Ultrasmall PtNPs were conjugated with a fixed quantity of a standard protein, and the HF5 system was then employed to selectively isolate the conjugated PtNPs, which were directly used for the CL signal development. The results confirm that the HF5 approach offers a unique platform for optimizing conjugation and purifying ultrasmall nanozyme probes, enabling the removal of interfering components and yielding a purified catalytic system suitable for the development of robust CL bioassays and biosensors.

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Development of a multiparametric electrochemical sensor for the monitoring of Nickel, Copper and Zinc in wastewater and surface water

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Heavy metals (HM) pollution is an open challenge in the environmental and human safeguard since HM can bioaccumulate and are non-biodegradable. 1 Considering the law limits in wastewater for Nickel (Ni), Copper (Cu) and Zinc (Zn) (4 mg/L, 0.4 mg/L and 1 mg/L respectively)2 , the possibility to have a system that could measure in real time and fast the amount of heavy metals is an important skill for industry, also comparing to conventional methods, such as Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma Mass Spectroscopy (ICP- MS), that require a high cost and longer time to analysis. In this prospect, the electrochemical sensors are an innovative and rapid solution for real-time monitoring heavy metals in wastewater being portable, low-cost and requiring no specialized personnel. 3

Herein we used a well know and commercially available Ni-dependent enzyme, urease, to build a selective monitoring system, taking advantages from the specifically dependence of urease activity by Ni. We developed and optimized an in vitro spectrophotometric assay, following the hydrolysis of urea, typically catalysed by urease, into ammonia and carbon dioxide by the presence of an acid-base indicator, phenol red (PR). We optimized the reaction parameters, such as substrate concentration, pH, buffer and temperature and we have found that at pH 6, with a relatively low buffer strength (5mM MES), the enzyme showed a 65% increase in activity compared to pH 7, while temperature (25 or 37 degrees Celsius tested) had no pronounced effect on the system.

With the aim of measuring metals in contaminated water, we tested the effect on urease activity of free Ni, Cu, and Zn metal ions in solution. Within the same range of exogenous metal concentrations, we observed a clear concentration-dependent inhibition of urease activity: at 1 mg/L, inhibition reached 22% for Zn, 90% for Cu, and 2% for Ni under optimized conditions. Notably, for Ni this concentration is well below the legal limits. This findings led us to consider the inhibitory effect of metals on urease activity as a sensing principle itself. Finally, we tested also a mixture of metals in equal ratio, and we found an inhibitory trend comparable to that induced by Cu. We complemented these preliminary results with cyclic voltammetry (CV), aiming to establish an electrochemical protocol for detecting unhydrolyzed substrate in solution with and without the redox mediator These preliminary data show the possibility to have a selective system for HM monitoring in wastewater, looking at the inhibitory effect that metals have of urease activity, especially Cu. Furthermore, the integration with electrochemical detection of urea gives the chance to optimize the final sensor and take advantages, for examples, from sensitive and portable system that Screen Printed Electrodes (SPE) gives.

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ORAL 09

Activity based (bio)sensor for the monitoring of MutyH DNA glicosilase

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DNA is constantly exposed to mutagenic agents that can induce structural damage, posing serious risks to human health. One of the most prevalent oxidative lesions is 8-oxo-7,8-dihydroguanine (8-oxoG), which frequently leads to G:C to T:A transversion mutations. When 8-oxoG pairs with cytosine within the DNA double helix, it is identified and excised by the OGG1 glycosylase, triggering the base excision repair (BER) pathway. However, if OGG1 fails to act or if the lesion arises during replication, 8-oxoG can mispair with adenine, forming an 8-oxoG:A mismatch. This is specifically recognized by the MUTYH glycosylase, which removes the adenine to prevent mutagenesis.

Mutations in the MUTYH gene are causally linked to MUTYH-associated polyposis (MAP), a hereditary cancer syndrome that significantly increases the risk of colorectal cancer and other malignancies.

Current literature describes several molecular approaches for evaluating DNA repair activities, most of which rely on indirect detection techniques.[1] However, these methodologies often suffer from lengthy protocols, low sensitivity, and limited clinical applicability. Only a few strategies enabling direct monitoring of MUTYH activity have been reported, typically involving fluorescently labeled DNA probes.[2] Despite their potential, these systems often require complex chemical synthesis and provide limited sensitivity.

Here we propose developing a synthetic biology toolkit for real-time analysis of MUTYH activity. We design programmable nucleic acid capable of transducing glycosylase activity into downstream CRISPR-powered ultrasensitive detection. This is achieved by using a rationally designed DNA-based hybridization network based on the switching activity of a DNA probe called “DNA activator module” whose structural switch is controlled by glycosylase activity. Only when the DNA activator module populates an ON state the CRISPR/Cas12a is activated, thus generating a fluorescence signal output (Figure 1).

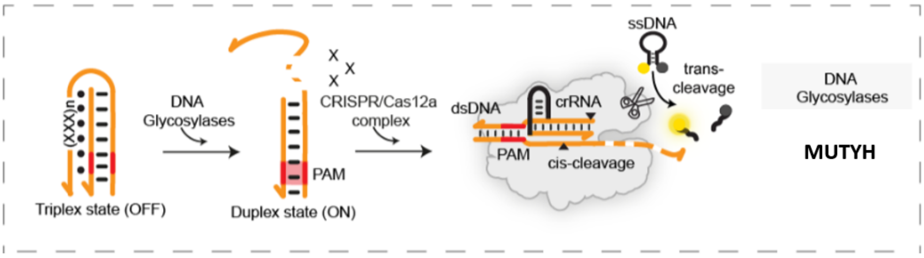

Figure 1: Description of Glycosylase-triggered CRISPR-Cas12 activity assay where the DNA activator module is identified in a DNA Triplex module.

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2D Metal-Covalent Organic Framework as a versatile water-based ink for the development of electrochemical sensors

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Covalent organic frameworks (COFs) are cross-linked nanoporous crystalline polymers achieved by the covalent self-assembly of a wide range of rigid organic molecules.[1] The chemical tunability, structure diversity and chemical stability contribute to achieving customizable nanoporous materials with a high surface area that could be functionalized with catalytic centers based on the application.[2] The main issue regarding COFs is their extremely poor processability in water and it represents a major hindrance to their application and implementation in analytical devices.

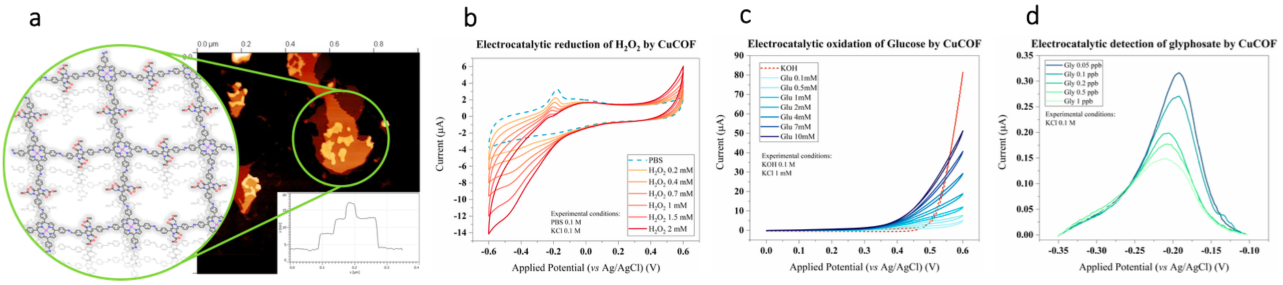

Figure 1. a) AFM micrograph of CuCOF. b) CV of the electrocatalytic reduction of H2O2. c) CV of the electrocatalytic reduction of glucose. d) LSV for the detection of glyphosate.

In this work, we report the synthesis, the characterization and the electrocatalytic properties of a 2D COFs based on derivatives of a porphyrin and a diketopyrrolopyrrole (DPP). The COFs can be easily synthesized through the chemistry of Shiff-bases to form reversible imine bonds that are fundamental to the growth of highly ordered structures. The COF is then metalated through impregnation by using non-noble metal salts (MCl2, where M= Co, Fe, Ni, Cu) to modulate the electrocatalytic performance and the eco-compatibility. The additional tunability of the DPP allows the functionalization with carboxylic groups, which increases the interlayer distance, and it enhances the exfoliability and colloidal stability in water. To prove the applicability of the COFs for healthcare- and environmental-related sensors, the COFs electrocatalytic properties are tested with hydrogen peroxide (H2O2), glucose and glyphosate. The COF itself is electroactive towards the H2O2 reduction, and the addition of a metal further improves the sensitivity. CuCOF shows good sensitivity towards both direct glucose oxidation, in the range 0.1-10mM, and it allows the glyphosate detection below the legal limit (0.1 µg/L for drinking water). These results show the potential for application in analytical devices and in the development of water-based inks and in the inkjet printing of paper based disposable sensors.

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Electrochemical (bio)sensing platform fabrication by coupling inkjet- and 3D printing

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One continuous goal of sensor development is the miniaturization of compact electrochemical sensors that are capable of working with minimum volumes of liquid samples and providing a fast and accurate quantitative and/or qualitative response. The introduction of two-dimensional ink deposition techniques (such as screen-printing or inkjet-printing) enabled the cost-effective large-scale production of compact and miniaturized thick and thin film-based electrochemical sensors. In recent years, inkjet printing as a digital mask-less deposition technique accelerated the course through critical sensor development stages, which are preliminary sensor designing, prototyping and finally commercial sensing platform production, by rapidly changing and optimizing digital printing parameters. Three-dimensional printing of polymers has enabled the rapid, flexible, and low-cost production of 3D devices that are compatible with 2D sensors in terms of the introduction and measurement of fluidic sample matrices, which includes microfluidic devices [1] as well as microtiter plates.
Herein, we shall present the fabrication of miniaturized electrochemical sensing platforms comprising inkjet-printed electrochemical sensors and 3D-printed fluidic cells. In particular, we will focus on the production of metal and metal oxide compact films as well as electrocatalyst nanoparticle coatings as electrodes using Print-Light-Synthesis (PLS) [2]. This innovative, sustainable, and low-cost technique combines highly stable metal precursor inkjet printing with simultaneous light-induced metal and metal oxide electrode material synthesis. We will demonstrate how electrode design and performance is boosted by combining electrochemical sensors with specifically designed 3D-printed microcells, which allow to carry out electrochemical measurements in real samples by using small, i.e., microliter sample volumes. It will be demonstrated how the fully printed sensing platforms can be used to monitor the acidification of cancer cell cultures (using PLS-RuO2 potentiometric sensors) [3] and to assess the bioassimilation by bacteria of molecules generated during the biodegradation of plastics (using PLS-Au amperometric electrodes) [4].

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Electrochemical sensing of glucose using a flexible fully ink-jet printed wearable platform

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The growing interest regarding research on the development of continuous glucose monitoring (CGM) devices, which employ minimally invasive technologies, underlines the necessity of comfort and handiness, besides accuracy, when it comes to the daily management of a chronic disease like diabetes [1].

In this contribution, the development of amperometric and transistor-based glucose biosensors is presented with the future scope of realizing epidermal glucose sensing [2]. The target analyte for this device is glucose in interstitial fluid, which can be accessed non- invasively by using reverse iontophoresis (RI). The devices are based on the organic semiconductor poly(3,4-ethylenedioxythiophene):polystyrene sulfonate (PEDOT:PSS), which is ink-jet printed on a thin film of parylene. The optimization of the geometry and the miniaturization process for these devices, as well as the detailed characterization of the functionalized sensing interfaces were carried out. The glucose sensing performance was evaluated, followed by the study of other chemical species as potential interferents and the effect of temperature variation on the measurements.

A single platform with a geometry that includes a pair of RI electrodes, as well as both the miniaturized amperometric and transistor-based glucose biosensors, was successfully designed and fabricated. After functionalization and characterization of the RI electrodes, the complete device was tested in a custom setup composed by a 3D-printed electrochemical cell and swine skin as support for the biosensors. This same setup has been validated employing a commercial CGM device.

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Tuesday, December 16th

ORAL 13

Molecularly imprinted polypyrrole-based POF dual sensor for dopamine detection exploiting plasmonic and voltammetric methods.

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Dopamine (DA, 3,4-dihydroxyphenethylamine) is a key catecholamine neurotransmitter involved in the regulation of central and peripheral physiological functions, including motor control, attention, blood pressure regulation, and hormone secretion. Moreover, the dysregulation of dopaminergic pathways is associated with several disorders, including Parkinson's and Huntington's diseases, schizophrenia, attention deficit, and addiction [1]. Current laboratory methods for DA quantification mainly rely on competitive immunoassays and chromatographic strategies [2]. However, although accurate, these tests are expensive, time-consuming, and unsuitable for decentralized use, underscoring the need for innovative, low-cost, and rapid biosensing approaches for point-of-care diagnostics.

Given its electroactivity, DA is typically detected via electrochemical transduction, while optical methods offer superior sensitivity and reproducibility with minimal interference [3]. To harness the benefits of both approaches, we developed a novel dual-mode dopamine sensor based on an electropolymerized molecularly imprinted polypyrrole (eMIP) integrated onto a plasmonic D-shaped plastic optical fiber (POF) platform. The gold nanofilm simultaneously acts as a plasmonic layer and a working electrode within a voltammetric cell, enabling both surface plasmon resonance (SPR) and differential pulse voltammetry (DPV) detection on the same device. The eMIP was electropolymerized using the counter and pseudo-reference electrodes of a screen-printed electrochemical cell, while shifts in the plasmonic resonance wavelength were monitored in real-time during deposition and template removal. The resulting sensor exhibited excellent analytical performance, covering a broad dynamic range from picomolar to micromolar levels, with limits of detection of 0.02 pM (SPR) and 0.8 µM (DPV). Validation with real samples demonstrated accurate DA quantification in plasma (SPR) and urine (DPV) without complex pretreatments, with results in good agreement with HPLC-fluorescence analysis. The sensor also showed remarkable selectivity against common interferents such as ascorbic and uric acids. Thanks to its portability, minimal sample volume requirements, and straightforward fabrication, this dual-mode eMIP-POF platform represents a powerful and versatile approach for point-of-care DA monitoring, potentially enabling early diagnosis.

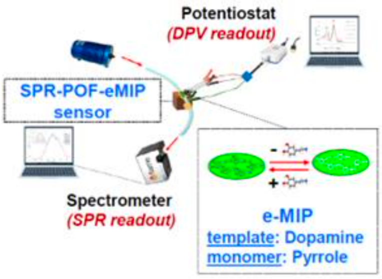

Figure 1 The hybrid experimental setup used for the optical and electrochemical determination of dopamine.

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ORAL 14

The "ODOR-GC" Project: detection of odorous molecules by means of a compact and MEMS- based gas-chromatographic system.

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Odors strongly affect people's daily life and health: although they do not represent a risk for human health, bad smells can cause both physiological symptoms (respiratory problems, nausea, headache, etc.) and psychological stress. A careful investigation of the odors issue requires odorous air measurement and analysis, by applying standardized scientific methods: instrumental approaches to the characterization of odorants are based on the evaluation of the odorous air chemical composition. At this purpose, the "ODOR-GC" Project deals with the development of a sensing system that falls in to the category of the so-called IOMS (Instrumental Odor Monitoring Systems), whose technical requirements are established by the National Regulation UNI 11761:2019. Going into detail, the system is a miniaturized gas chromatograph capable to perform continuous, real-time and in-situ measurements, in order to achieve the chemical composition of the gaseous mixture by means of the detection and quantification of the single compounds. The system architecture (see Fig. 1) is based on the general-purpose platform "Compact-GC" [1], developed at the Bologna Section of the Institute for Nanostructured Materials (ISMN) and its main feature is represented by an analytical "core" entirely based on MEMS (Micro- Electro-Mechanical-Systems) silicon components (injection system, pre-concentration unit and separation column). The measurement chain of the device is therefore capable to operate at working temperatures that can reach up to 150°C, thus allowing the detection of volatile compounds characterized by high boiling points.

Preliminary results obtained in laboratory showed that the "ODOR-GC" device (illustrated in Fig. 2), equipped with a 10.6 eV photoionization detector (PID), was capable to successfully detect more than 30 different compounds (aromatics, aldehydes, alkanes, ketones, etc.), by sampling the headspace of lab standards. Some of them were characterized by boiling points higher than 150°C, such as 1-Hexanol (B.P. 157°C) and Pinene (B.P. 166°C).

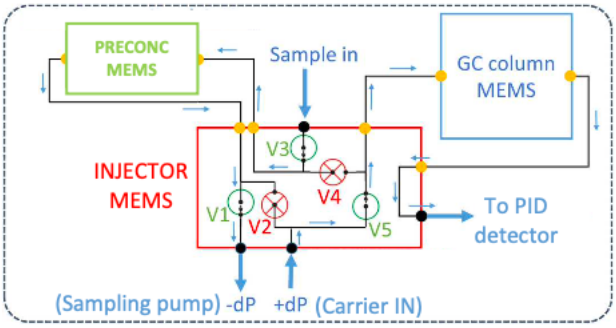

Fig. 1: "ODOR-GC" system architecture.

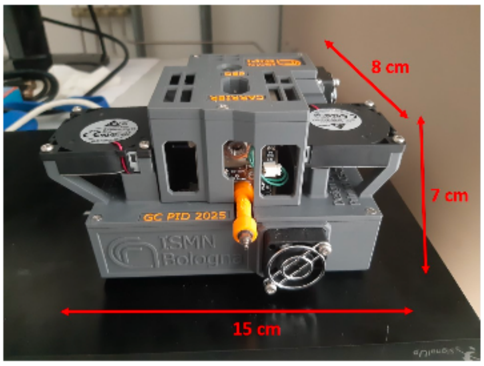

Fig. 2: "ODOR-GC" mini gas chromatograph.

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Development of novel biosensing tools based on gold nanoparticle/luciferase nanotags

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Protein-functionalized gold nanoparticles have emerged as a valuable tool in biosensing applications, offering several advantages, including high stability and enhanced signal detection capabilities. These benefits are attributed to the nanoparticles' unique properties, particularly their large surface area, which allows for the immobilization of numerous proteins, thereby improving the efficiency of target molecule binding. Furthermore, gold nanoparticles possess intrinsic fluorescence properties and can facilitate plasmon-enhanced fluorescence, leading to significant signal amplification.1

Luciferase derived from Photinus pyralis is frequently employed in biosensing due to its ability to catalyze reactions with D-luciferin, producing a bioluminescent signal with a maximum emission wavelength at 560 nm with adenosine 5'-Triphosphate (ATP) as co-factor. To improve the stability of this enzyme various nanomaterials, including metal-organic frameworks2 have been explored to protect these proteins under adverse conditions and enhance the overall stability of biosensors. 3

This study presents the development of nanotags based on gold nanoparticles functionalized with improved luciferase mutants called BgLuc, BoLuc, and BrLuc, which emit at distinct wavelengths. The immobilization of luciferases was carried out through an optimized protocol employing physical adsorption techniques, and the resulting constructs were characterized using dynamic light scattering.

The fluorescence and bioluminescence emission properties of these nanotags were evaluated to ascertain the effects of conjugation on enzyme functionality. A proof-of-concept application is reported demonstrating the suitability of these nanotags to detect ATP. Furthermore, these nanotags can be combined with biological recognition elements, such as antibodies, expanding their applicability in different fields.

Funding

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Call for tender n. 3277, A.N. 0001052

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A Versatile and ultrasensitive SERS-Based Biosensing Platform for oligonucleotides detection in Biomedicine

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Surface-Enhanced Raman Scattering (SERS) biosensors have emerged as a versatile platform for the ultrasensitive and specific detection of oligonucleotides, offering rapid, amplification- free analysis suitable for clinical and point-of-care applications. Building on our previous studies, we developed a versatile SERS sensing platform that can be operated in both label-free and reporter-assisted configurations, enabling a broad range of molecular detection applications. [1].

In the label-free configuration, we designed a thiolated peptide nucleic acid (PNA)-based SERS biosensor for direct detection of SARS-CoV-2 RNA sequences in saliva. The PNA probe, immobilized on colloidal gold nanoparticles uniformly deposited on functionalized glass, provided high hybridization selectivity and structural stability. Label-free SERS spectra captured the intrinsic vibrational fingerprints of nucleobases, while multivariate analysis (PCA–PCR) enhanced signal discrimination, achieving a detection limit of 110 pM in clinically relevant conditions. [2].

In the labeled configuration, we implemented an inverse Molecular Sentinel (iMS) SERS biosensor for microRNA-223-3p, a cancer-related biomarker, integrating electrospun nanofibers decorated with AuNPs and a Cy3-labeled DNA probe. The incorporation of the nanofiber scaffold rendered the sensor flexible and significantly enhanced the plasmonic coupling and molecular accessibility, making the device highly stable and reproducible. Upon hybridization, a conformational switch generated a distinct Raman on/off signal with a limit of detection of 19.5 ± 0.05 fM [3]. These complementary detection schemes demonstrate that the same plasmonic platform can be adapted to different analytical formats—either label-free or reporter-based—depending on the molecular target and application context. The integration of rational probe design, reproducible AuNP-based substrates, and chemometric analysis bridges molecular specificity and signal reproducibility. These advances position SERS-based oligonucleotide biosensors as promising candidates for next-generation molecular diagnostics, enabling early disease detection and real-time monitoring with high precision and minimal sample requirements.

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Development of innovative gas sensors for H_2 leak in production, storage and use sites

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Today, hydrogen (H_2) is the most promising clean fuel suitable for many applications answering to the global problems of energy consumption and environmental pollution reduction. However, hydrogen is flammable and explosive when it reaches concentrations between 4 – 75 % [1]. The prompt monitoring of concentration leak becomes fundamental for the safe use of H_2. Chemiresistive gas sensors represent a convenient way to detect H_2, due to their low cost and dimension, easy use and tunable properties. This work aims to optimize functional material to develop H_2 sensors with suitable features for applications. $(Ti,Sn)O_2$ solid solution were selected due to their enhanced sensing properties with respect to the pristine oxides [2] and Pd loading both for its role of oxidation catalyst typically in sensors for reducing gases and to improve humidity effect on sensor response [3]. SnO_2 and TiO_2 were prepared according to the procedure described in [2]. $(Ti,Sn)O_2$ with Ti:Sn molar ratio of 25:75 (TS25) was prepared by adding a diluted HNO_2 solution to a hydroalcoholic solution of Sn(II) 2–ethylexanoate and Ti(IV) n-butoxide in stoichiometric proportions. The precipitate was calcined for 2 hours at 550 °C. $(Ti,Sn,Pd)O_2$ (TSP) were obtained following the previous preparation by adding to a TS25 solution 1.5 at% Pd as $Pd(NO_3)_2$. Powders were characterized by FE-SEM microscopy and XRD analysis. Powder morphologies consisted in nanoparticles, for solid solutions of about 10 nm. All powders showed a single phase: SnO_2 cassiterite, TiO_2 anatase, and solid solutions rutile phase. Screen printing technique was used to deposit the sensing layers, which were fired at 600 °C. The electrical characterization was performed using the flow-through technique. Electrical measurements confirmed an n-type behaviour for all sensors. Comparison of responses to 100 ppm H_2 where each sensors is considered at its best working temperature decreases in the following order TSP (400 °C), TS25 (450 °C), SnO_2 (450 °C) and finally TiO_2 (550 °C) with poor sensibility. TSP and TS_{25} exhibited the ability to detect H_2 concentrations from 0 to 1000 ppm, also in a wet environment (up to 60 %). The selectivity test of TSP and TS25 toward main hydrocarbons demonstrated that the main interfering gas is CO, but H_2 continued to induce the higher responses.

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Plasmonic–assisted biosilica nanoplatforms enable intracellular SERS sensing and in vivo label-free Raman imaging

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Engineered nanoparticles (NPs) are powerful tools in nanomedicine, offering new possibilities for precise disease diagnosis and targeted therapy. Among them, inorganic NPs stand out for their tunable size and surface chemistry, high surface-to-volume ratio, chemical stability, biocompatibility, and distinctive optical, magnetic, and electrical properties.

In this work, we describe the use of porous biosilica-based NPs for biomedical applications. These nanoparticles are derived from diatomite, a sedimentary material formed from fossilized diatom skeletons. Diatomite-based nanoparticles (DNPs) are produced through an ultrasound-assisted mechanical process followed by filtration, yielding particles in the 100–400 nm size range. Their inherently porous morphology allows for efficient drug loading. Moreover, they can be made photoluminescent for imaging purposes. Biocompatibility and cellular uptake of DNPs were confirmed across several human cancer cell lines, including epidermoid, breast, cervical, and colorectal cancers. Moreover, the silica surface can be chemically modified using various functionalization strategies to enhance drug loading capacity and improve the pharmacokinetic and pharmacodynamic profiles of the encapsulated agents.

A hybrid nanosystem was developed by coating DNPs with gold nanoparticles, creating SERS-active substrates capable of simultaneous intracellular drug sensing and delivery. The multifunctional performance of this system was demonstrated through the efficient delivery of the small-molecule inhibitor galunisertib (LY) and the quantitative monitoring of its intracellular release with sub-femtogram sensitivity using surface-enhanced Raman spectroscopy (SERS). The therapeutic efficacy of the nanosystem was further validated *in vivo* in mouse models, showing significant inhibition of tumor growth. In addition, label-free Raman imaging enabled high-resolution mapping of nanoparticle distribution within tumor tissues, highlighting the platform's potential for integrated therapeutic and diagnostic (i.e., theranostics) applications.

Overall, this study underscores the multifunctional potential of plasmonic-assisted biosilica nanoparticles as SERS-active probes for intracellular sensing and Raman imaging, paving the way for advanced approaches in targeted cancer therapy and real-time tissue diagnostics.

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Chemically-modified gold screen-printed electrodes-based voltammetry coupled with machine learning for rapid screening of Alternaria toxins in food samples

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Alternaria mycotoxins have emerged as a food safety concern because they are commonly found on grains, fruits, tomatoes and tomato-based products and can cause adverse health effect [1]. Detection and quantification of the major Alternaria-related toxins such as alternariol (AOH) and alternariol monomethyl ether (AME) in tomato samples are challenging due to their low concentrations and complex matrix. This requires sensitive and selective analytical methods, often involving advanced mass spectrometry-based techniques [2]. On the other hand, there is an urgent need for on-site screening tools to manage food safety challenges that require immediate action, such as quickly identifying contaminants at various points in the food supply chain [3]. In this context, we devised an electroanalytical platform based on chemically modified electrodes (CMEs), namely two gold screen-printed electrodes differently derivatized with dodecanethiol SAMs to reliably detect AOH and AME. This modification prevents the electrode surface from fouling effects, allowing for a more accurate and sensitive measurement of the mycotoxins voltammetric response [4]. We optimized the functionalization conditions of each CME using experimental design techniques to achieve maximum sensitivity. Notably, successful detection was achieved in minimally treated tomato samples, despite the presence of other interfering polyphenolic compounds. As for the processing of the voltametric response data, different classification algorithms were tested and the results obtained by processing the entire DPV data set and the peak current and potential values were compared. The best results were obtained using an optimized Support Vector Machine (SVM) algorithm applied to the peak current and potential values. This machine learning approach was applied to the classification of three different sample classes, i.e., compliant tomato samples, samples spiked with AME, and samples spiked with AOH, achieving classification accuracies of up to 87%. Furthermore, thanks to the time- and cost-effectiveness of the entire analytical process and its integration with portable, low-power readout instrumentation, the developed methodology fulfils most of twelve principles of green analytical chemistry [5].

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ORAL 20

Electrolyte-Gated Field-Effect Transistors-Based Sensor for Nanoplastics Detection

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Nanoplastics (NPs) accumulating in the environment pose a severe environmental threat, harming both animals and humans1. This urgently calls for reliable, fast and easy to use sensing methods, as the currently used methods rely on expensive and bulky techniques1. Easy-to-use and cheap solutions such as sensors, have been recently investigated for this application2,3. In this work we investigated the use of an electrolyte-gated field-effect-transistor (EG-FET) based sensor with a carbon nanotube (CNT) semiconducting channel (EG-CNTFET) for the detection of NPs in aquatic environments4. In Figure 1a, a picture of the device is shown (glass substrate, chromium + gold electrodes and CNTs as semiconducting material). A variety of NPs models, made from different materials and with different surface modifications, are nowadays available. Here, we compared the EG-CNTFET sensitivity using two NPs models: polystyrene NPs with both non-functionalized and carboxylated surface. NPs in the range of 0.025 and 0.5 mg/ml were added to the solution, while IDS (drain-source current) was continuously monitored. The proposed sensing mechanism relied on CNTs + polystyrene NPs non-covalent interaction, as shown in Figure 1b2,4. Corrected IDS (*IDS) was measured, to take into consideration the CNTs intrinsic instability2, and the average of three devices (per test) was calculated and presented in Figure 1c. The EG-CNTFET devices presented a sensitivity of 22.6 µA*ml/mg for non-functionalized NPs, and of 20.9 µA*ml/mg for carboxylated NPs. This sensitivity is attributed to the non-covalent interaction between CNTs and the NPs, and it shows similar sensitivity towards both NPs models. Indeed, through scanning electron microscopy, NPs were observed on the CNTs network, while not on the gate electrode, as shown in Figure 1d. This study offers a starting point for future use of EG-FET-based sensors for detection of environmentally relevant NPs.

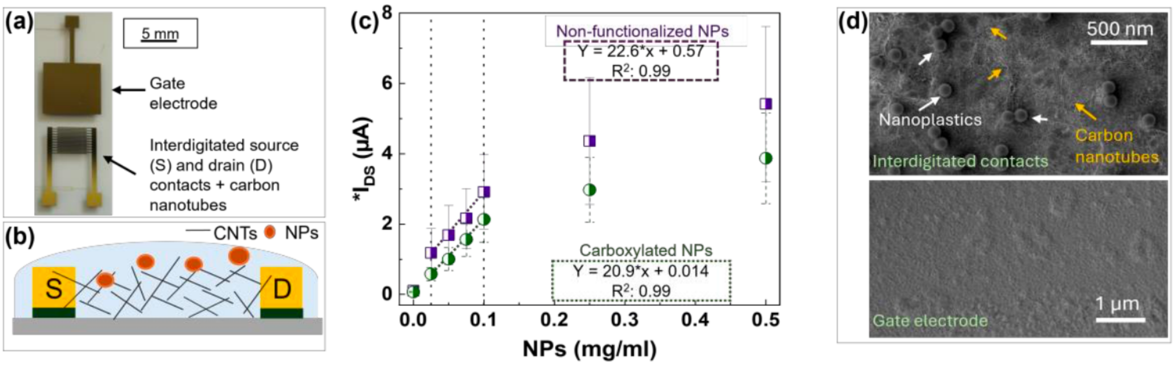

Figure 1: a) Picture of the EG-CNTFET sensor. b) Proposed sensing mechanism: CNTs and NPs interaction. c) Calibration curves (*IDS vs NPs concentration) in purple non-functionalized NPs, in green carboxylated NPs; linear fit performed (dotted lines) and equations shown in the boxes. d) Scanning electron microscopy image of interdigitated contacts (top) and gate electrode (bottom), after carboxylated NPs test.

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Biochar as a functional, sustainable nanomaterial for 2nd generation biosensor development: Lactate as a case study.

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Biochar (BH) is a sustainable carbon material typically produced through pyrolysis of waste or by-product biomasses in an oxygen-limited environment. This renewable carbon has emerged as an affordable and eco-friendly alternative to traditional nanomaterials (e.g., carbon black, carbon nanotubes, etc.) in many applications, including sensor device fabrication. In this context, the use of BH for developing biosensors is limited: fewer than forty reports are found in the literature. These studies mainly focus on modifying commercial electrodes, while assembling bio(sensors) on custom-made platforms is rarely considered [1].

In this study, a novel sensing composite was prepared by modifying an exfoliated nano- biochar (nBH) with the redox mediator prussian blue (PB) using an aqueous procedure. The renewable carbon was dispersed through a top-down exfoliation process in water, assisted by high-energy ultrasound and a natural stabilizer [2]. The colloidal water dispersions of nBH were functionalized with PB via a simple, rapid agitation method. Integrated screen-printed electrodes were produced in series using stencil printing technology over a recycled plastic substrate and modified with the nBH/PB nanocomposite through drop-casting. The manufacturing process was optimized by comparing several BH from different feedstock sources and conventional carbon nanomaterials, focusing on their electroanalytical features in H_2O_2 sensing. The various configurations were characterized morpho-chemically by SEM and Raman spectroscopy. This platform was used to assemble a second-generation lactate biosensor by immobilizing lactate oxidase enzyme. The device's specificity of the manufactured device was assessed by studying the interference from various sugars, organic acids, and inorganic salts during amperometric lactate detection. Several food samples, including yogurts, milks, and beers, were tested with the developed biosensor, which demonstrated high reliability with recovery values between 97% and 112%. The use of nano-scaled, sustainable BH in manufacturing integrated lab-made biosensors for real-world applications has been proven, presenting an affordable and renewable alternative.

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Micrometric Electrochemical Sensors for the Investigation of Cellular Differentiation and Photodynamic Therapy

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Electrochemical techniques are powerful tools for quantifying key metabolites in living cells, such as glucose, lactate, and reactive oxygen species (ROS) [1,2]. We developed and employed micrometric electrochemical biosensors to determine these metabolites under cell culture conditions [3,4]. We investigated the localized generation of hydrogen peroxide in cell cultures, that is due to the spatially controlled illumination of poly(3-hexylthiophene) (P3HT) films [5]. We used scanning electrochemical microscopy (SECM) to study ROS production at the micrometer scale and to image cell redox balance [4,6]. Currently, we are using SECM and modified microelectrodes specific for sensing of glucose and lactate to explore the effects of prolonged photostimulation protocols on the metabolic activity of human pluripotent stem cell-derived cardiomyocytes (hPSC-CMs) [7]. Furthermore, we have exploited microsensors for ROS detection to monitor photoinduced ROS generation as a strategy for spatially controlled, time-resolved killing of cancer cells via photodynamic therapy (PDT) [8]. We aim to employ SECM and modified microelectrodes to investigate liposome-based nanocarriers for the delivery of PDT effectors. These tools will enable light-activated and spatially controlled release of photosensitizers and drugs to selectively target hypoxic tumor regions, less responsive to conventional chemotherapy and classical PDT.

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Electrolyte-Gated Transistors Biosensors for Healthcare Applications

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Electrolyte-gated transistors (EGTs) are a highly promising platform for biosensing, offering high sensitivity, label-free operation, low-cost fabrication on flexible substrates, and direct compatibility with biological samples. We present recent results demonstrating the power of this technology to develop biosensors for diverse healthcare applications by optimizing the device architecture and materials. All devices share a common transistor architecture: interdigitated source and drain electrodes covered with an active material, which contacts a gold gate electrode via an electrolyte. The biorecognition event takes place at the functionalized gate/electrolyte interface, where a specific recognition moiety is immobilized. The resulting signal is significantly amplified by the active channel, thanks to the high-capacitance electrical double-layers (EDLs) formed at both the gate/electrolyte and electrolyte/channel interfaces. We demonstrate this versatility through two applications: first, EGT biosensors with different architectures were successfully used for the detection of anti-drug antibodies produced by patients on immunotherapy, achieving limits of detection (LODs) within a clinically relevant concentration range. Second, we utilized Electrolyte-Gated Organic Transistors (EGOTs) with a TIPS-Pentacene channel for the specific detection of transcription factors, employing their consensus DNA sequence as the biorecognition element. In conclusion, EGT biosensors exhibit promising performance characteristics for future Point-of-Care (PoC) applications, while also serving as powerful tools for fundamental studies of macromolecule interactions.

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Bimodal and enantiomeric (photo)electrochemical analysis of Tryptophan by MWCNTs and BT_2T_4 modified electrodes

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The ability to discriminate between two enantiomers (i.e., mirror-image molecules that are non-superimposable on each other) is of particular relevance in electroanalytical chemistry[1]. Chiral electrochemical sensors can be based on the configurations of ionophores incorporated in an ion-selective electrode membrane, in particular on the differences in the uptake of enantiomers operated by molecularly imprinted polymers (MIP), or on chiral effects related to the doping process during the electrodeposition of conducting polymers. Another important strategy in this field is the use of "inherently chiral" molecules, both as electrode surface and as media. One of the most used inherently chiral molecule is the oligo-2,2'-bis(2,2'-bithiophen-5-yl)-3,3'-bi1-benzothiophene monomer, known as BT_2T_4. Studies[2] have shown that these thiophene structures, once deposited on an electrode surface, are able to discriminate and quantify the enantiomers of chiral probes. In particular, significant peak potential differences can be observed for the enantiomers, which can be related to diastereomeric interactions between the inherently chiral surface and the chiral probe undergoing the electron transfer process. Moreover, these oligomers can show semiconductive properties, generating a photocurrent if irradiated by the appropriate light at the correct potential.
In this study, for the first time, a carbon screen printed electrode (C-SPE) was modified with a layer of Multi-Walled Carbon Nanotubes (MWCNTs), deposited by drop casting from a suitable suspension, covered with a layer consisting of a conducting and photoactive oligomer (BT_2T_4), electrodeposited via anodic oxidation from the corresponding monomer solution in ionic liquids. The modified electrodes were later characterized and used as sensors for the detection of a specific analyte: Tryptophan (Trp). By combining the good electrochemical properties and fast electron transfer kinetics of the carbon nanotubes with the less conductive but chiral and photoactive oligomer, the idea was to obtain a bimodal sensor for the detection of tryptophan with both electrochemical (EC) and photoelectrochemical (PEC) methods. By utilizing two or more sensing modes, reliability of the measurements is enhanced significantly.

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Guide RNA Design Targeting the Mitochondrial D-loop Region of Sus scrofa and Its Application in CRISPR/Cas12a Electrochemical Biosensing for Food Authentication

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Ensuring food authenticity is essential for protecting public health, regulatory compliance, and religious dietary practices. One major concern is the unintentional or fraudulent inclusion of pork in food products, which necessitates highly specific and sensitive detection methods. This study presents the design of a targeted CRISPR/CRISPR-associated (Cas) system biosensing platform for detecting wild pig mitochondrial DNA (mtDNA). The D-loop region, the most variable part of mtDNA, was selected as the target site for guide RNA (gRNA) design. Candidate gRNAs were predicted using Benchling with sequence data from GenBank and analyzed using BLAST and Jalview to evaluate homology and mismatches. Candidate 1, with an off-target score of 99.8, showed high specificity for Sus scrofa and minimal cross-reactivity with other species. An electrochemical biosensor integrating CRISPR/Cas12a was developed using an SPCE/Ceria/STV/Biotin-ssDNA-Methylene Blue (MB) modified electrode. Surface and electrochemical properties were characterized by SEM/EDX and voltammetry. Conditions were optimized through Box–Behnken design, including probe concentration and incubation parameters. The biosensor achieved a detection limit of 4 fM, a quantification limit of 71 fM, a linear range of 10 nM–100 fM, and 1.1 % RSD. It successfully detected pig mtDNA in raw and processed meat with 100.82 % recovery and 14-day stability. This integrated approach demonstrates the potential of CRISPR/Cas12a-based biosensors as rapid, ultrasensitive, and ultraspecific tools for detecting pork adulteration in food products, supporting authenticity assurance and regulatory monitoring.

Sensing by Optical and Acoustic trapping

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Optical and acoustic trapping can be used for the contactless manipulation and sensing of particles with size from the nanometer to the millimeter scale [1]. In fact, in optical trapping, the strong focusing of a laser beam with a high numerical aperture objective allows the confinement of nano and microparticles that can be used as probes of very tiny interaction forces with viruses, cells or even special surfaces such as metamaterials [2]. The coupling with a Raman spectrometer allows the chemical identification of the material, which can be extremely useful when studying, as an example, different microplastics dispersed in simple or complex media. Acoustic trapping is obtained by using sound waves in the ultrasonic range, allowing the trapping of particles from the micron to the millimeter scale [3]. In past years this technique has been confined to a few laboratories in the world due to the inherent high costs of the setup and due to potential hazards associated with its operation. Recently, the availability of low-cost commercial ultrasonic transducers has led to a large spreading of the technique.

In this talk, after a brief introduction on the fundamentals of both techniques, I will give some recent results obtained at IPCF laboratories by applying optical and acoustic trapping to the study of microplastics for environmental monitoring [4] and to the study of micrometeorites and terrestrial analogs of cometary dust particles for space applications [5,6].

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Free-Standing Polydopamine Hydrogels as Electrodes for Edible Enzymatic Glucose Biosensors

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Edible biosensors represent an innovative strategy for the real-time monitoring of physiological and biochemical markers — including glucose, enzymes, hormones, and therapeutic compounds — offering a transformative tool for remote medical diagnostics. Despite their potential, several challenges hinder their development, such as the need for FDA- and EFSA-approved edible components (e.g., redox mediators, conductive materials, and biorecognition elements) and the engineering of bioelectronic systems capable of functioning under harsh physiological conditions, including low pH, elevated body temperature, and viscous biological fluids prone to biofouling [1,2]. The design of an edible, self-supporting electrode remains particularly complex. To address this, a multifunctional hydrogel with enhanced mechanical stability was developed by incorporating polydopamine (PDA) into a chemically crosslinked sodium alginate–calcium chloride network [3–5]. The synergistic interaction between these natural biomaterials yields an innovative hydrogel structure that combines mechanical integrity, electrical conductivity, and excellent biocompatibility.
For glucose sensing applications, the system was further optimized through the incorporation of silver nanoparticles (AgNPs), which facilitate the reduction of in-situ generated hydrogen peroxide (H_2O_2) produced by glucose oxidase (GOx) activity. Electrochemical characterization was carried out to evaluate the hydrogel's performance and conductivity, including analysis of the electroactive surface area, impedance, and electron transfer kinetics. The morphology of the polydopamine-based hydrogel electrode was examined using scanning electron microscopy (SEM), while its mechanical behavior was assessed through dynamic mechanical analysis. Finally, the biocompatibility of the developed film was investigated using Caco-2 and HTB-37 intestinal cell lines via MTT assays to assess cell viability and proliferation.

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Design and Preliminary Evaluation of an Electrochemical Biosensor for Anticancer Drug Screening Applications

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Cancer remains one of the leading causes of death worldwide, particularly in industrialized countries. This high mortality is partly due to late diagnoses, but also to the lack of selective and effective treatments capable of targeting tumor cells without damaging healthy tissue [1]. Tumor cells exhibit profound metabolic reprogramming, known as the Warburg effect, characterized by enhanced lactate fermentation even under normoxic conditions [2]. This metabolic shift is driven by the overexpression of lactate dehydrogenase (LDH), which catalyzes the reduction of pyruvate to lactate with simultaneous oxidation of NADH to NAD^+. Selective inhibition of LDH could represent a promising therapeutic strategy to impair cancer cell growth and proliferation [3].

This study aims to develop an LDH-based electrochemical device for the efficient and rapid screening of potential LDH inhibitors, by monitoring the current associated with NADH oxidation as an indicator of the enzymatic reaction progress. A conventional three-electrode cell was employed, with Ag|AgCl as a reference, Pt as the counter and a glassy carbon electrode as the working. The working electrode was modified with silver nanoparticles (AgNPs) to lower the NADH oxidation overpotential, enhance current response, and reduce electrode fouling. AgNPs were synthesized, characterized by FESEM, TEM, and EDS, and deposited on the electrode surface using Nafion as a binder.

Cyclic voltammetry (CV) and linear sweep voltammetry (LSV) demonstrated a clear oxidation peak at 0.67 V corresponding to NADH oxidation, with current increasing proportionally to NADH concentration. The sensor performance was further investigated by chronoamperometry. First, measurements were carried out upon successive additions of NADH, which allowed the construction of a calibration plot to highlight a linear relationship between concentration and current response. A second chronoamperometric test was then performed in the presence of potential interferents, including pyruvate, lactate, DMSO, and model inhibitors, in order to evaluate the selectivity of the proposed biosensor. Overall, these preliminary results evaluate the suitability of the AgNP-modified electrode for sensitive and selective NADH detection. This platform provides a solid analytical basis for future integration with immobilized LDH, enabling the development of a device for rapid and efficient screening of potential anticancer inhibitors.

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Real-Time Label-Free Cytokine Detection with Gold Nanoprism Arrays

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We present a nanoplasmonic biosensor based on periodic arrays of gold nanoprisms designed for high-sensitivity, label-free detection of Interleukins (IL-6) under biologically relevant conditions. The device integrates a nanostructured sensing surface within a microfluidic platform, enabling real-time monitoring of cytokine secretion from living cells while eliminating the need for fluorescent or enzymatic labeling. The biosensor was fabricated via Nano Sphere Lithography (NSL), producing regular nanoprism arrays with sharp geometrical features that enhance localized electromagnetic fields and maximize detection sensitivity [1,2]. Morphological and optical characterizations confirmed the reproducibility and plasmonic quality of the nanostructures, exhibiting distinct resonance peaks in the visible to near-infrared range. The sensor surface was functionalized with anti-IL-6 antibodies using a commercial Mouse Uncoated ELISA Kit, and detection was achieved by monitoring the Localized Surface Plasmon Resonance (LSPR) wavelength shift upon IL-6 binding in solution. The sensor displayed a clear, dose-dependent red shift over the 2.5–250 pg/mL concentration range, with high sensitivity at low concentrations and saturation behavior at higher levels. These results demonstrate the biosensor's ability to detect IL-6 cytokines with picogram-per-milliliter sensitivity in a label-free and real-time configuration. Ongoing work is focused on optimizing surface chemistry and fluidic coupling to enable direct cytokine monitoring in complex cell media and full integration within organ-on-chip systems, paving the way for advanced biomedical studies and personalized diagnostics.

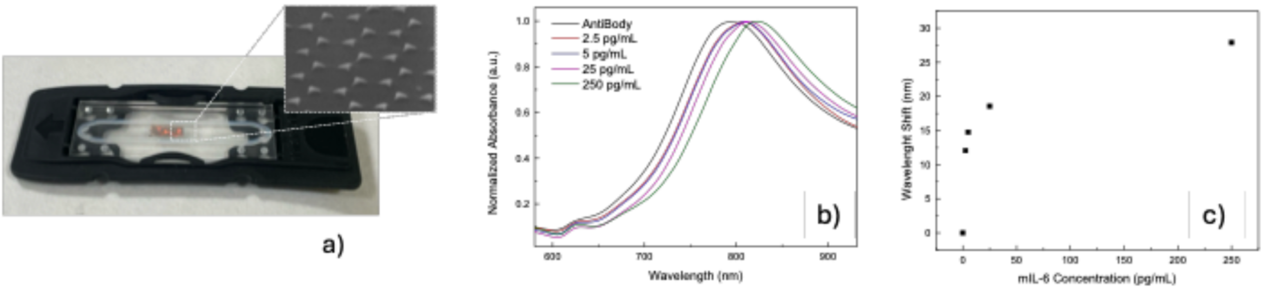

Fig. 1. (a) Photograph of the microfluidic device integrating the nanoplasmonic biosensor, with SEM inset showing the periodic gold nanoprism array fabricated by Nano Sphere Lithography (NSL). (b) Normalized absorbance spectra of the nanoprism array acquired after successive functionalization steps, confirming optical sensitivity to surface modifications. (c) LSPR spectral shifts upon exposure to increasing IL-6 cytokine concentrations, demonstrating the sensor's dose-dependent response in the pg/mL range.

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Integration of Lab-on-Tip Optical Fiber Biosensors into Microfluidic Systems

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The integration of optical fiber (OF) biosensors into microfluidic systems represents a crucial step toward the development of compact, minimally invasive and highly sensitive diagnostic platforms. This work investigates the technical aspects underlying the integration of Lab-on- Tip (LoT) optrodes within microfluidic environments—an essential step toward establishin practical guidelines for their connection with clinical tools such as needles, catheters and nanoendoscopes. As a proof of concept, we analyze the performance of a plasmonic metasurface-assisted LoT biosensor fabricated on the tip of a single-mode optical fiber [1], integrated into a T-shaped microfluidic chip for the detection of the breast cancer biomarker receptor tyrosine protein kinase (ErbB2) [2]. To evaluate the influence of the local flow conditions, the OF probe was positioned at different depths within the microfluidic channel. The functionalized biosensor, immobilized with Trastuzumab antibody, was exposed to ErbB2 solutions in the range of 1–1000 ng/mL at a flow rate of 20 µL/min. Figure 1 A and B illustrate the effect of the probe positioning in the microfluidic flow channel on the optical response to ErbB2. Collected results reveal that the biosensor response strongly depends on the probe placement: when the tip was located near the channel center, only a negligible spectral shift was observed, whereas displacing it toward the channel wall significantly enhanced the resonance shift. Numerical simulations supported these findings and confirmed an inverse correlation between local flow velocity and biosensor performance. Additional experiments further demonstrated that higher flow rates hinder effective target–bioreceptor binding due to reduced analyte–surface interaction times. Overall, this study highlights the importance of proper microfluidic design and sensor positioning for maximizing the detection performance of LoT biosensors. These insights provide practical guidelines for integrating OF-based diagnostic probes into microfluidic and clinical environments, paving the way for next- generation minimally invasive biosensing platforms.

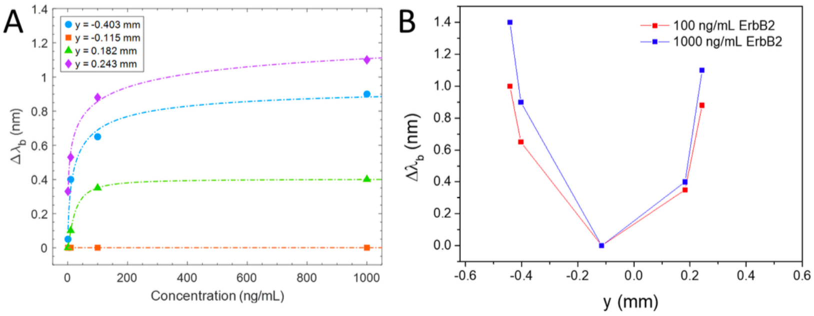

Fig. 1. Effect of the OFMT positioning in the microfluidic flow channel on the biosensor response to ErbB2

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Systematic Study and Optimization of Multiple Gold Electrodeposition Procedures on 3D-Printed Electrodes for Electrochemical Sensing

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Recent developments in 3D printing technology have transformed the manufacturing industry by enabling the efficient and cost-effective production of highly precise, customized components. One promising application of this technology is the fabrication of electrodes for diagnostic applications. Additive manufacturing enables to produce electrodes in thermoplastic filaments embedded with conductive material, creating functional structures suitable for electrochemical applications. These electrodes can be further refined through gold electrodeposition, which enhances their stability, increases electrochemical performance and provides biocompatible surfaces for protein attachment. This study focuses on the fabrication and optimization of gold-electrodeposited 3D-printed electrodes for sensing applications. The effects of different electrodeposition procedures and applied potentials on surface morphology were investigated. Scanning Electron Microscopy (SEM), Energy Dispersive X- ray Spectroscopy (EDX), and electrochemical techniques were used to characterize the electrodes. Size distribution analyses were also performed to evaluate surface uniformity. The electrode configuration that provides the best performance in terms of electrochemical response, stability, and reproducibility was integrated into an electrochemical sensing platform, demonstrating its potential for future diagnostic applications.

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ORAL 32

Solid state electrochemical sensor for the detection of hydrogen

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The shift from fossil fuels to renewable energy sources is a crucial step in mitigating climate change. Within the framework of the European Green Deal, the EU targets a 55% reduction in greenhouse gas emissions by 2030 and carbon neutrality by 2050 [1]. Hydrogen stands out as a clean energy vector with applications in transportation, industry, and power generation. Nevertheless, its adoption raises safety issues related to its high flammability, broad explosive range, and fast diffusion. Existing hydrogen sensors, such as thermal, catalytic, electrochemical, optical, and mechanical, often face challenges linked to limited operating windows and cross-sensitivity [2]. To address these drawbacks, we designed a solid-state electrochemical hydrogen sensor free of liquid components, improving both durability and stability. Figure 1A and B presents the device and its calibration curve for 0.03– 1.6% v/v H_2. The results showed a linear response between sensor output and the logarithm of hydrogen concentration, aligning with the Nernst equation. Notably, the sensitivity surpasses the theoretical Nernstian slope of 59 mV/decade, suggesting additional contributing mechanisms. The sensor was also tested in a bio H2 reactor, proving its robustness in complex atmospheres.

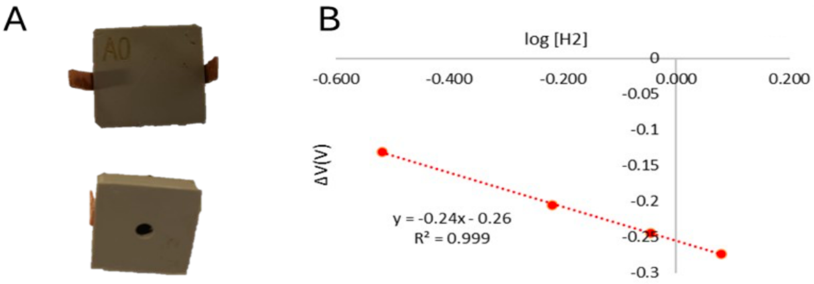

Figure 1: A) Picture of the solid-state hydrogen sensor. B) Typical calibration curve; the variation of the potential is shown as a function of the concentration of hydrogen.

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ORAL 33

Development of innovative MIP based sensors for liquid biopsy

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The development of simple and practical diagnostic methods for cancer and neurodegenerative biomarkers detection is largely driven by the growing demand for rapid, accurate, and accessible analytical tools in medical diagnostics. In this context, biochemical sensors have yielded significant advancements in biomedical analysis. In biosensor design, molecular recognition is a fundamental property of biological systems and has proven to be a powerful analytical principle, as exemplified by the antibody–antigen interaction. However, sensing systems based on natural recognition elements often suffer from inherent drawbacks, including high production cost, limited stability, and the need for controlled storage and handling conditions.

For these reasons, the development of biomimetic receptors capable of replacing natural antibodies, while offering improved stability, cost-effectiveness, and simple fabrication, has received growing attention. Among such strategies, molecularly imprinted polymers (MIPs) have emerged as synthetic receptors acting as *mimetic antibodies* for selective molecular recognition. MIPs provide tailored binding cavities complementary to their target molecules, enabling non-covalent and reversible interactions with high affinity and specificity.

In this study, we report the development of MIP-based sensors for interleukin detection as a potential tool for easy-to-use and portable platforms suitable for liquid biopsy applications. MIPs were integrated on different sensing architectures, including platinum microelectrodes, porous silicon, and nanophotonic devices supporting Bound States in the Continuum (BICs). The biomimetic layer was obtained through electropolymerization of o-phenylenediamine (o-PD) or chemical synthesis of polydopamine (p-PD) in the presence of the target molecule. The processes of MIP formation, template removal, and target rebinding were monitored using electrochemical and optical characterization techniques, as well as Atomic Force Microscopy (AFM). The resulting MIP-based sensors demonstrated high selectivity and picomolar limits of detection in both buffer and complex biological matrices, confirming their robustness and analytical precision.

Beyond cytokine detection, our recent work extended the application of MIP technology to more challenging targets, such as the neurotrophins NGF and proNGF, two structurally related proteins implicated in neurodegenerative diseases. In such cases, the lack of high-affinity and selective antibodies—largely due to the partially unfolded or intrinsically disordered nature of the proNGF pro-domain—makes conventional immunoassays unreliable. MIP-based recognition thus represents a powerful alternative, capable of discriminating between closely related isoforms and quantifying low-abundance proteins directly in biological fluids. These results highlight how synthetic molecular recognition can overcome intrinsic limitations of antibody-based assays, paving the way for robust, scalable, and selective biosensors for precision diagnostics in both oncology and neurology.

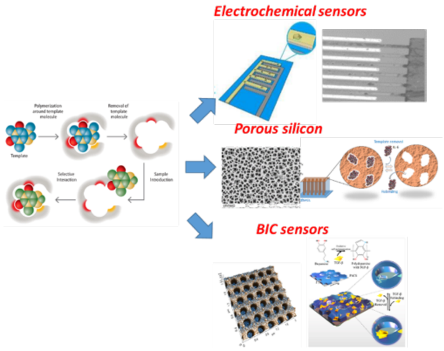

Figure 1: Graphical abstract of our activity regarding intergration of MIP on different classes of sensors.

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Electrochromic analog control based on Organic Electrochemical Transistors and driven by dopamine sensing at the gate electrode

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The growing interest in developing bio-inspired technologies aims to provide fast-responsive, wearable and smart devices that can emulate biological systems.1 However, the current devices are unable to successfully induce the chemical stimuli that characterize biological synapses, while they rely on electrical signals. To address this issue, we investigated the role of Organic Electrochemical Transistors (OECTs) in a system comprehensive of sensing, computing and actuating phases.

The analogical control system is driven by dopamine sensing, that is obtained through the analyte oxidation by applying a positive potential, above +0.2 V, at the gate electrode.2 The device functions by forcing a fixed current (Id) at the drain, thereby generating potential variations at the drain electrode, correlated to dopamine concentration. The modulation is determined by the transistor architecture, in which the channel is made of poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) in its conductive state. These devices typically operate in depletion mode, where the application of gate voltage progressively reduces the conductivity of the PEDOT:PSS channel by depleting charge carriers from the polymer matrix. Redox-active species, such as dopamine, initiate a cascade of redox processes that result in PEDOT reduction, thereby increasing its electrical resistance and modulating Vd under a fixed Id condition. Since electrochemical reactions rely on variations of the electrochemical potential, the need for a different reference arises, as in traditional OECT-based systems the source electrode operates not only as a modulated channel extremity, but also as reference. Therefore, we evaluate the actuating ability of the OECT by monitoring the drain potential against a Saturated Calomel Electrode (SCE). Vd and Ed variations were registered respectively with a sourcemeter and a potentiostat, providing a correlation with dopamine concentration. The final comparison between the two parameters report a significative enhancement in Ed modulation, while presenting also different values. In the final procedure, the device successfully responds to dopamine additions with controlled Ed variations, that can be further employed to achieve electrochemical actuation.

Thus, the previous results were exploited to induce a dopamine-driven electrochromic actuation of a ITO electrode covered by Prussian Blue (PB), connecting the drain electrode to the electrochromic PB actuator. Dopamine electrochemical oxidation triggers a potential variation across all circuit elements, resulting in PB reduction to Prussian White, as evidenced by the visual color change from blue to transparent. The system described is the first step towards analog intelligent systems, that allow both sensing and actuation in a single device.3

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From Lab to Field: Technology Transfer of Sensor Technologies from Pavia- Smart Labels for Food Quality Monitoring

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Technology transfer plays a crucial role in transforming academic research into practical solutions with tangible societal impact. At the University of Pavia, several chemical sensor platforms have been developed and optimized for real-world applications through collaborations with industrial partners. Among these, colour-changing smart labels represent a promising example of applied research in the field of food quality and safety [1].

Our research group started working on colour-changing smart labels back in 2017, developing prototypes based on different supports such as plastics, paper, and bioplastics, and targeting various foodstuffs including meat, fish, dairy products, and ready-to-eat vegetables [2-6]. All these prototypes share the same operating principle: they incorporate reactive dyes that exhibit a colorimetric response according to the chemical composition of the food headspace, which is strongly dependent on the freshness of the product.

Besides being an interesting research topic, colour-changing smart labels represent a breakthrough innovation in the food supply chain, with the potential to reduce food waste and prevent health issues. By monitoring indicators related to food spoilage, the labels provide an easy and non-invasive tool for real-time assessment of food freshness, supporting both producers and consumers toward supply-chain optimization and responsible consumption.

This research activity led to the foundation of the innovative spin-off SAFER Smart Labels, which optimized a reactive ink in terms of sensitivity, selectivity, and stability, and successfully transferred the technology to industrial-scale printing processes. The final printed labels are currently under validation through multi-technique spoilage monitoring of various foodstuffs, combining microbial analysis, TVB-N determination, and pH measurements directly on the product.

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Wednesday, December 17th

Highly Sensitive CNTs-modified MIP-based electrochemical sensor for Selective Cyromazine Detection

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The development of electrochemical sensors combining nanostructured materials with molecular imprinting offers powerful tools for the selective and sensitive detection of pesticides. In this work, a molecularly imprinted polymer (MIP) based on poly(ortho- phenylenediamine) (Po-PD) was electrosynthesized on carbon nanotubes (CNTs)-functionalized platinum microelectrodes for the specific recognition of cyromazine, a triazine pesticide of environmental and food concern. CNTs were first deposited onto the Pt microelectrode surface to increase conductivity and active area, providing a high-surface, high-conductivity scaffold that enhances polymer growth and signal transduction. The Po-PD MIP layer was then electrosynthetized by cyclic voltammetry (CV) in the presence of melamine as template, referring to a procedure previously reported [1,2]. After rinsing and drying, template removal was performed, yielding recognition sites complementary to cyromazine. A non-imprinted polymer (NIP) was synthesized in parallel without melamine.

The CNTs modification provided a substantial enhancement in sensitivity, and improved electron-transfer kinetics. Selectivity studies with atrazine, a structurally related triazine, demonstrated minimal interference, confirming molecular recognition specificity. Finally, rebinding experiments in tomato samples validated the sensor's applicability in real matrices, maintaining high response reproducibility and selectivity.

This CNTs-enhanced MIP platform demonstrates a synergistic effect between nanomaterial- driven signal amplification and template-driven molecular selectivity, establishing a promising route toward rapid, on-site electrochemical monitoring of pesticide residues in agricultural products.

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Allosteric Modulation Towards Sensitive Enzyme-based Amperometric Biosensors

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Enzymatic polypeptide proteolysis is a widespread and powerful biological control mechanism. Over the last few years, substantial progress has been made in creating artificial proteolytic systems [1], so called "chimeric" enzymes. This triggered the possibility for enzyme-based amperometric biosensors to target analytes that are not involved in ET chains.

In the last decade, the rise of synthetic biology has driven the efforts to construct artificial allosteric protein switches in order to detect such target analytes. Typically, the construction of chimeric enzymes occurs via insertion of a regulatory receptor domain into the biocatalytic reporter domain. Construction of such chimeric enzymes utilizes the recombinant DNA technology that is a core technology of protein engineering [2].

In this regard, we have investigated the bioelectrocatalytic properties of pyrroloquinoline quinone-dependent glucose dehydrogenase fusion with calmodulin (PQQ-GDH-CaM). This protein is catalytically inactive in its ground form but can be activated by the addition of calmodulin binding peptide that induces its conformational transition and activation. This system was practically utilized to realize multipurpose biosensors platforms (e.g., glucose detection, peptide detection, rapamycin etc.) [3,4].

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ORAL 38

Label-free optical detection of binding protein FKBP12

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Optical fiber long period gratings (LPGs) are being increasingly proposed as optical platforms for label-free biosensing as promising alternatives to the most traditional ones based on surface plasmon resonance or on interferometric configurations. LPGs have been demonstrated to offer comparable performance with respect to more classical optical platforms, but with the intrinsic advantages of the optical fibers, such as high compactness and potential miniaturization, as well as high compatibility with optoelectronic devices [1]. An LPG-based fiber optic sensor has been developed for the protein FBKP12, a protein that has been found to be involved in several tumor pathologies, including lung cancer. The biological recognition element is a novel molecule characterised by a chemical structure mimicking the natural FKBP12 binders such as Tacrolimus and Rapamycin [2] which is immobilised - via a self-assembled monolayer (SAM) - on the fibre surface in correspondence of the fabricated LPG (Fig.1a). The resulting optical fibre is placed in a PMMA microfluidic flow cell, equipped with a Peltier cell for thermal stabilization (Fig.1b). The measurement is performed adding increasing concentration of FKBP12, with each addition separated by washing steps. More specifically the protein FKBP12 is injected in the flow-cell at increasing concentrations in the range 1 pM - 0.1 µM (in PBS) and incubated for 15 minutes with a 3-minute washing step after each incubation. The LPG transmission spectra are acquired after each washing step in stop-flow condition by means of an optical spectrum analyser and the shift of the resonance wavelength as a function of the FKBP12 concentration is calculated by fitting the LPG transmission spectrum with a multi-order polynomial fit. The limit of detection of 60 µg/L is achieved (Fig.1c).

This work was supported by European Union - Next Generation EU, project ECS00000017 ‘Ecosistema dell’Innovazione’ Tuscany Health Ecosystem (Spoke 4: Nanotechnologies for diagnosis and therapy) and the Investment Partenariato Esteso PE8 “Conseguenze e sfide dell'invecchiamento”, Age-It project (Ageing Well in an Ageing Society)

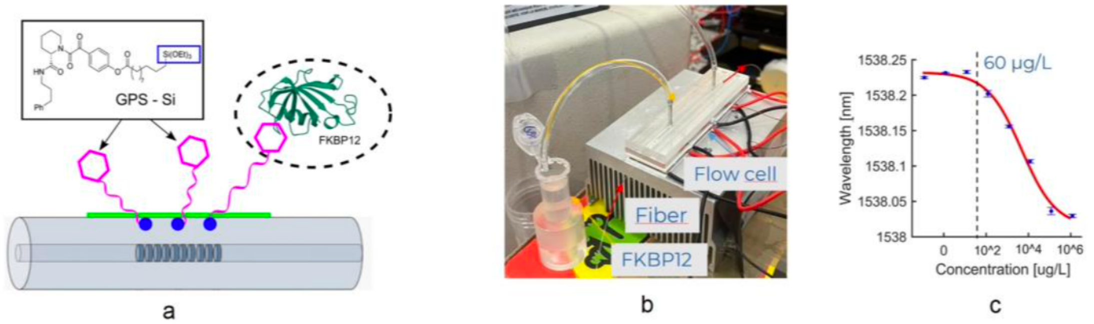

Figure 1. (a) Scheme of the immobilization of the biological recognition element GPS-Si on the optical fibre; (b) laboratory setup with the flow cell containing the sensing fibre; (c) FKBP-12 calibration curve.

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ORAL 39

Colorimetric smart sensor for fish freshness evaluation

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Fresh fish flesh is necessary for high-quality manufacturing; it is crucial for food safety. Fish handling practices, storage temperature, bleeding condition, post-processing duration, and fish species all have an impact on the complex chemical processes that start as soon as the fish die, including lipolysis and proteolysis. Fish freshness is evaluated using a variety of substances, including histamine, volatile amine, trimethyl amine, and H_2S [1]. A variety of indices and techniques have been devised to assess fish freshness; however, the majority of these are complicated and cannot be used for on-field detection.

In this study, we present a simple, low-cost sensor that detects volatile biogenic amines from fish flesh by using the colorimetric properties of the complexes formed between copper ions and amine groups. The sensor was realized by entrapping copper ions in discs of various polymeric materials and placing them into test tube caps. The sensor was then exposed to various concentrations of the analytes (ammonia, methylamine, diethylamine, triethylamine). A smartphone camera recorded the color shift from light grey to cyan blue as the sensor's quantifiable reaction to the analyte. After that, the color analysis was carried out by measuring the pixel intensity of the captured images using a smartphone photo editing app called Color Picker, which can be found on the Google Play store. The analytical signal is attributed by subtracting the value of the analyte-generated colored sensor from that of the blank obtained by analyzing a solution free of analytes.

The proposed sensor was studied and optimized in relation to different experimental parameters. Moreover, the sensor was successfully applied to track how fish samples degraded under various environmental conditions.

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Acknowledgements

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Optimizing chemiluminescence reaction catalyzed by a two-dimensional Cu-based Metal-Organic Framework by design of experiment

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In this study we present a chemiluminescent biosensing system built on a two dimensional copper Metal Organic Framework that acts as a peroxidase like catalyst for hydrogen peroxide quantification. The core of the work is a multivariate Design of Experiments strategy that structured the entire investigation from factor screening to response surface optimization with a desirability function. This plan efficiently explored the experimental space, minimized the number of trials, and revealed decisive factor interactions among pH luminol concentration SPTZ and MORP levels hydrogen peroxide dose and catalyst amount that a univariate approach would miss. For the first time the enhancers SPTZ and MORP, traditionally used in enzyme based chemiluminescence, were integrated into a MOF catalyzed luminol and hydrogen peroxide reaction, providing new insight into their behavior in a non-enzymatic context. DoE guided optimization delivered high sensitivity with a limit of detection of 1.87 micromoles per liter and strong predictive robustness. A Partial Least Squares regression model achieved R2 equal to 0.9981 in calibration and R2CV equal to 0.9971, and enabled accurate prediction of unknown samples with RMSECV below 1 micromole per liter.

Mechanistic analysis supports a radical mediated enhancement pathway involving formation of SPTZ superscript plus bullet and synergy with reactive oxygen species, while the limited contribution of MORP underscores structural differences between enzymatic and biomimetic catalysis. Overall, coupling biomimetic materials with a rigorous Design of Experiments provides a clear route to next generation chemiluminescent biosensors that are high performance reproducible and cost effective.

Multisensing Electronic Platform for Real-Time Wound Healing Monitoring

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The incorporation of electrochemical sensors into textiles and fabrics is a rapidly advancing area within the broader field of wearable device research. Smart textiles hold the potential to enable the non-invasive, continuous and real-time monitoring of key physiological information contained in various body fluids, as well as to open up new opportunities in the management of complex pathological states.

In this contribution, the design and characterization of smart textiles for the electrochemical sensing of moisture, pH and antioxidants is presented for the real-time monitoring of the body status [1,2]. Particular emphasis will be given to the latest results related to the “Wound healing real time monitoring multisensing electronics-WEAR-ME!” project, funded by the Italian Space Agency (ASI), which focuses on the development of an integrated and miniaturized wearable device comprising sensors, read-out electronics and power system for wound healing monitoring in astronauts. It is known that prolonged exposure to microgravity negatively affects the body’s natural healing mechanisms. However, while various space agencies are currently investing in novel therapeutic strategies, the design of reliable diagnostic tools remains an unmet challenge. The first prototypes of the WEAR-ME! Analytical platform integrate pH and moisture sensors, which were realized through the screen printing of a commercial ink containing a biocompatible organic semiconductor, i.e. poly(3,4- ethylenedioxythiophene):polystyrene sulfonate (PEDOT:PSS). Specific protocols for laboratory testing under real-life conditions have been developed using artificial wound exudate samples. Single and multi-sensing experiments using ex vivo wound healing models are in progress.

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Lab-on-chip technologies for extracellular vesicle enrichment and detection

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Liquid biopsy enables the use of selected biomarkers from biological fluids, greatly enhance an increasingly patient-centered approach that avoids invasive tests and tissue biopsies. Extracellular Vesicles (EVs) act as a snapshot of the cells from which they originate and as a repository of important information, facilitating the direct extracellular transfer of proteins, lipids, and miRNAs/mRNAs/DNAs. Despite EVs show great potential as powerful biomarkers, their isolation, and characterization remain challenging. Lab-on-Chip (LoC) technologies represent an innovative system to overcome the limitations of standard methods and we aim to implement these technology for EV investigation.

We design customizable LoC devices based on the experimental needs, starting from fluid dynamic simulations and using microfabrication techniques (micro-milling and 3D printing). We develop two different LoCs exploiting the microfluidic approach and electrochemical detection for EV enrichment and characterization. Large- and small-EVs were isolated by ultracentrifugation and characterized by high- resolution flow cytometry, western-blot, and transmission electron microscopy.

We developed an in-flow device using molded-plastic substrates assembled on a glass slide to create a microfluidic chamber for dynamic cell culture. Fluorescent neuroblastoma cell lines (SH-SY5Y) were seeded into the device to allow a complete replacement of the medium in the dynamic condition within 24h at controlled flow rate. We observed increased EV production and decreased EV size in dynamic versus static cell culture. Moreover, we realized a second platform for the electrochemical characterization of EVs by functionalizing a platinum electrode for the ordered deposition of antibodies of interest. Using differential pulse voltammetry, we established a calibration curve for antibodies against the most common EV membrane proteins and demonstrated sample integrity by intravesicular protein detection.

The key goals of the LoC technologies are to eliminate high-impact procedures, reduce time and cost, and preserve EV morphology. Our systems allow us to study the release of EVs under dynamic cell culture conditions that mimic the physiological scenario at the cell surface, and to identify arrays of biomarkers associated with EV subclasses. The next step is to integrate microfluidic sorting and electrochemical characterization into a benchtop device that can be customized to meet clinical needs.

ORAL 43

Phage-powered electrochemiluminescence immunosensors for virus quantification

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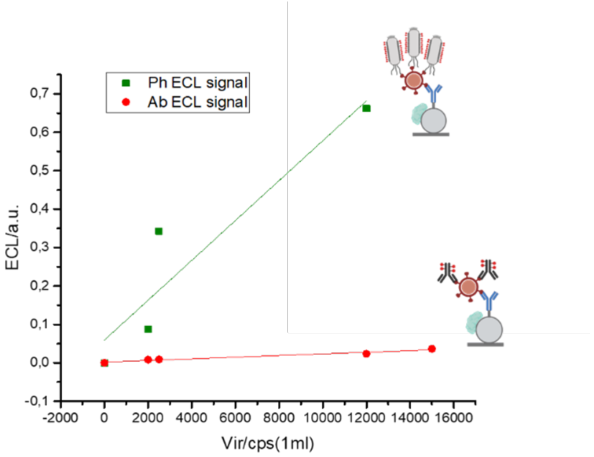
Electrochemiluminescence (ECL) is a premier transduction technique in clinical diagnostics; however, the sensitivity of current immunosensors is often restricted by the limited number of luminophores that can be attached to a standard antibody probe. To overcome this structural bottleneck, we developed an orthogonal nanoarchitectonics approach utilizing the M13 bacteriophage as ananoscaffold for highly amplified viral detection.

In this study, M13 phage were engineered to act as a "super-carrier" for signal transduction. The phage was genetically modified to display the SARS-CoV-2 specific recognition element on the pIII minor coat protein, ensuring precise antigen recognition. The core innovation of our sensor development lies in the chemical modification of the pVIII major coat protein, which constitutes the bulk of the viral capsid. By targeting the primary amines on the pVIII surface, we successfully conjugated Ruthenium(II) complex luminophores (RuS) to the phage architecture. This strategy transforms the phage into a high-density, light-emitting probe.

The ECL performance was evaluated using a magnetic bead-based sandwich assay. Our optimized phage transducer (M13_RuS) demonstrated superior signal amplification compared to traditional probes. Specifically, the phage-based sensor generated an ECL signal nearly 4-fold higher than anti-S1 antibodies derivatized with the exact same dye.

Our results demonstrate that the engineered phage transducer (M13-RuS) significantly outperforms conventional probes.

These findings establish the chemically-modified M13 phage as a powerful, high-gain transducer platform capable of significantly enhancing the performance of ECL biosensors.



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Peptide-Based Biosensor for Early Detection of Multiple Sclerosis via Activated VLA-4⁺ Cells

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Multiple sclerosis (MS) is a chronic autoimmune disorder characterized by the infiltration of immune cells into the central nervous system, where they mediate neuroinflammation and demyelination. A hallmark of this process is the expression of the α4β1 integrin, also known as Very Late Antigen-4 (VLA-4), in its activated conformation (VLA-4⁺) on the surface of T lymphocytes.[1] These VLA-4⁺ cells, absent or inactive in the cerebrospinal fluid (CSF) of healthy individuals, are significantly overexpressed in the CSF cells of MS patients, making them a promising cellular biomarker for diagnosis.[2] To exploit this specificity, we propose a peptide-based biosensor capable of selectively detecting cells expressing activated VLA-4 in CSF samples.

In this presentation, will describe a novel biosensing platform, which consists of a gold surface coated with antifouling polymer brushes and a bioreceptor, specifically designed to this end. Four polymer brushes were developed and tested, which aim at minimizing the nonspecific interactions with CSF components, thus improving selectivity and suppressing background signals.[3] The receptor consists of the peptidomimetic ligand BIO1211, a synthetic derivative of the natural VLA-4 ligand,[4] which is covalently bound to the antifouling polymer brushes via click chemistry. The formation of the antifouling layer and the successful immobilization of the peptide are monitored through ellipsometry, and X-ray Photoelectron Spectroscopy (XPS).

The biosensor's ability to selectively capture VLA-4⁺ was assessed by optical microscopy, enabling direct visualization of adhesion of Jurkat cells, known to express VLA-4⁺ (positive control), and HEK-293 cells, lacking VLA-4 expression, which will serve to evaluate potential nonspecific adhesion (negative control).[4] Finally, clinical CSF samples from healthy individuals and MS patients will be tested to assess the potential for earlier diagnosis of MS, which will allow improving patient prognosis and therapeutic outcomes.

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ORAL 45

Fast and flexible resistive humidity sensors on quasi-1D $Zr_{1-x}Ti_xS_3$ nanoswords

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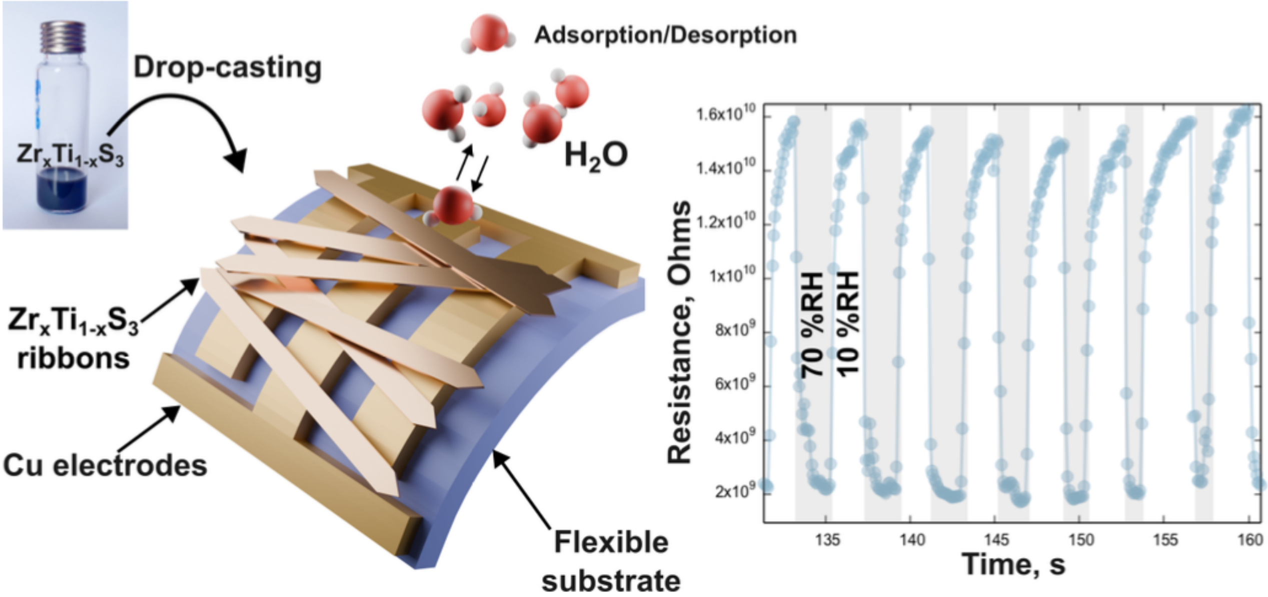
Transition metal chalcogenides (TMC) family of materials has proven to be fruitful for new applications of low-dimensional crystals and films. 1-5 While the devices based on them usually require sophisticated production procedures combined with precisely controlled environments and high-resolution lithography, we propose much simpler and more versatile approach. Here we demonstrate how $Zr_{1-x}Ti_xS_3$ solid solution crystals, produced by the chemical vapor transport (CVT) technique, could be easily used for fast, highly sensible, and robust humidity sensors in ambient without additional heating. This material has a monoclinic crystalline structure with $P2_1/m$ space group and crystallizes in high-surface-area, thin, and long sword-like or necktie ribbons6. Brief ultrasound treatment in isopropyl alcohol produces an ink, that could be used on any kind of substrate, including flexible ones by simple drop- casting. We show a sensitivity to water vapor higher than 9E8 Ohm/%RH with fast response rate of 100 ms and low restore times shorter than 1 second. The sensors produced in such a manner are stable in ambient air, work in the range of 15-85 %RH and do not require any specific storage conditions.



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ORAL 46

Ruthenium complexes as electrochemiluminescent labels for advancing PCR-free nucleic acids detection

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Accurate in vitro diagnostic tests are currently based on pathogens' nucleic acid (NA) detection by real-time PCR assays (LoD 1.15 aM), endowed with high sensitivity but lacking in simplicity and time effectiveness. Herein, we aim to present a novel electrochemiluminescence (ECL)-based biosensor (Fig. 1) for sensitive, selective, and PCR-free NA detection. ECL is a highly sensitive technique exploiting light emission from the excited state of suitable luminescent labels upon application of a proper potential. By exploiting ECL as transduction technique, we aim to obtain a faster and cost-effective process, upon optimization of a previously developed Hepatitis B Virus detection system,1 through which we had already reached PCR-comparable LoD (1.25 aM) for some pathogenic NAs. In our assay, the use of two different ECL- active ruthenium complexes2 is combined with a recognition strategy based on surface cooperative hybridization to selectively detect, e.g., SARS-CoV-2 RNA and microRNAs, without any NA amplification. The effectiveness of this strategy was further confirmed through electrochemical impedance spectroscopy analysis.2,3 Our biosensor design thus opens up the possibility to obtain point of care devices for a simple, fast and efficient detection of various infectious pathogens.

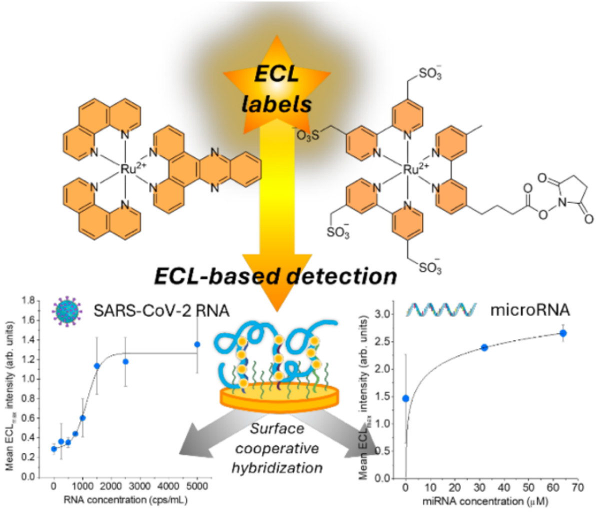

Figure 1. Schematic representation of the ECL biosensor detection approach.

Acknowledgments

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Extracellular vesicles detection through electrochemical devices: a new conservative approach to liquid biopsy

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Over the past decade, scientific evidence on extracellular vesicles (EVs) has grown exponentially, leading the scientific community to recognize their substantial importance in both medical and biological fields. The lipid bilayer of EVs encapsulates bioactive components such as proteins, nucleic acids, lipids, and metabolites which can be correlated to EVs size and function.

Our approach includes the integration into LoC biosensing devices obtained by microfabrication techniques and electrochemical detection for EVs enrichment and characterization. For comparison, Large- and Small-EVs were isolated by ultracentrifugation and characterized by nanoparticle tracking analysis, high-resolution flow cytometry, western- blot and transmission electron microscopy.

Functionalized microelectrodes were used for Differential Pulse Voltammetry measurements and we were able to build a calibration plot considering different EVs membrane proteins. Multiple assays were performed including Tetraspanin antigens (CD9, CD63 and CD81), typical from small-EVs and Flotilin and Annexin antigens, recognizing a larger category of EVs (including Large-EVs). Moreover, Alix antigen, typical from cargo was detected only after EVs lysis, confirming that our system allows non-destructive analysis of samples. An assessment of unspecific signal was also performed, related to culture medium, in order to establish if our system is able to detect EVs from non-treated samples.

With this method we were able to demonstrate both the possibility to detect very low concentrations of EVs and the preservation of sample integrity. A key point of LoC technologies is the effort of removing highly impacting procedures, reducing time and cost, and preserving EV integrity.

Funding

This work was supported by PRIN 2022 Project—financed by the European Union—Next Genera-tion EU-PNRR M4.C2.1.1. RESOLVE—an innovative platfoRm based on field-flow fractionation and sample on-chip detection to unravel extracellular vesicles heterogeneity (grant number: 202233FTW8; CUP: B53D23013360006).

Engineering Intrinsically Disordered Aptamers: A Combined Gaussian-Accelerated MD and Experimental Strategy

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EAB sensors have the potential to transform clinical practice by enabling the continuous in vivo monitoring of clinically relevant targets. These sensors rely on an aptamer which undergoes a conformational change upon binding to its target, bringing the redox label closer to the electrode surface and generating an increase in the electrochemical signal. However, the development of aptamer-based biosensors is currently limited by the lack of structural data on aptamer–target complexes, which means that lengthy and costly empirical optimisation is necessary. One effective strategy to overcome this limitation is to re-engineer aptamer sequences by introducing regions of intrinsic disorder, such as poly-T loops of variable length, which impose controlled entropic penalties and enable the modulation of binding energy [1, 2]. Nevertheless, without structural insight, it remains challenging to select splitting sites rationally and improve the success rate of designed variants.

To overcome these limitations, we propose an integrated strategy combining molecular simulations and experimental validation for the rational design of disordered aptamers. Using small-molecule-binding aptamers (doxorubicin, ATP, vancomycin) we employed Gaussian accelerated molecular dynamics (GaMD) to map aptamer–target interactions and the conformational behavior of variants carrying poly(T) linkers inserted at different positions. The in-silico predictions were confirmed by optical techniques, demonstrating that the engineered variants retain and can modulate binding activity.

This work presents a rational de novo design of aptamer variants from an atomistic perspective and proposes a generalizable computational–experimental approach to optimize sensitivity and specificity, facilitating the development of next-generation biosensors.

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Acknowledgment

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POSTERS

Poster 01

Self-assembled nanostructured substrates for ATR-SEIRA spectroscopy

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Abstract. In this study, we investigate the development of regular nanostructures composed of densely arranged gold nanodiscs (GNDs) designed to enhance the interaction between vibrational molecular modes and evanescent waves in the mid-infrared (MIR) range for Fourier-transform infrared (FTIR) spectroscopy. Through numerical simulations, we optimized the spatial distribution and geometric parameters of GNDs deposited on calcium fluoride (CaF_2) substrates in an attenuated total reflection (ATR) configuration. This design enables strong localized surface plasmon resonances (LSPRs) and intensified near-field hotspots, resulting in a simulated surface-enhanced infrared absorption (SEIRA) enhancement factor of up to 7×10^7. The GND substrates were fabricated using a low-cost, self-assembled nanosphere lithography technique. Characterization via scanning electron microscopy (SEM) and atomic force microscopy (AFM) confirmed the formation of uniform, large-area nanodisc arrays. Experimental evaluations to assess the performance of the fabricated substrates in SEIRA-based FTIR spectroscopy are currently ongoing.

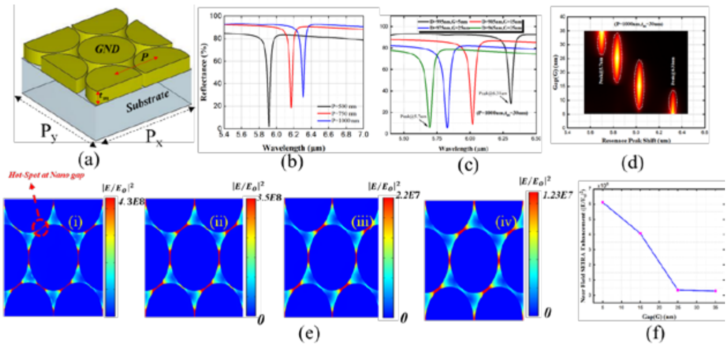
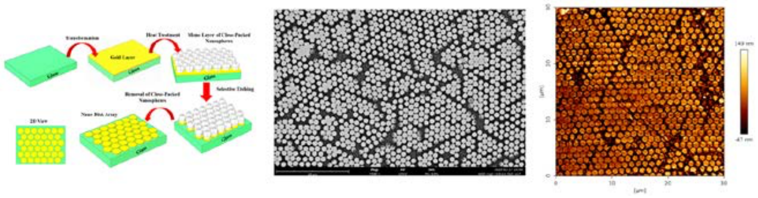


Fig. 1. (a) scheme of GNDs onto CaF2 substrate, (b) reflection spectra for various periods and constant gap, (c) reflection spectra for various gaps and constant period (d) influence of the GNDs gaps on the resonant peaks, (e) the near-field distribution (for P=995nm) at various nanogaps revealing increasing hotspots at smaller nanogaps, and (f) the near field enhancement as a function of the GND gap size.



(a) (b) (c)

Figure 2. (a) Schematic representation of the production of GNDs using self-organizing nanosphere lithography, (b) and (c) SEM and AFM images of the produced GNDs.

Poster 02

From Lab to Field: Technology Transfer of Sensor Technologies from Pavia - NEMO Device: Optimization for Water Quality Monitoring

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Bridging academic innovation with industrial implementation is essential to deliver effective environmental monitoring tools. Within this framework, the University of Pavia has established an ongoing collaboration with the company Onyax to optimize NEMO - a compact, multiparametric sensor device designed for Online Water Quality Monitoring [1].

The research focused on improving the performance of electrochemical measurements integrated into the NEMO platform by applying suitable chemometric tools, including the Design of Experiments (DoE) approach for operating parameter optimization and Multivariate Data Analysis (MDA) for data treatment and the development of qualitative and quantitative models [2]. Validation under real-world conditions is currently in progress to confirm the reliability of the system for continuous in situ measurements.

One of the pillars of this project is the use of electrical impedance spectroscopy (EIS) for both conductivity determination and “water fingerprinting” [3]. Depending on the purpose, multivariate regression tools are applied in the first case, while classification algorithms are tested in the second. The rationale behind the selection of training samples is discussed, together with the optimization of operating parameters, the definition of an effective data analysis workflow, and the results obtained.

Another part of the project involves the optimization of free chlorine determination by amperometry and ORP/redox potential assessment. In the poster session, we present the results related to this topic.

This collaboration exemplifies an effective model of technology transfer, where academic expertise in sensor chemistry meets industrial know-how in data management and IoT integration. The resulting device provides a versatile and robust tool for smart monitoring of water resources, supporting sustainability and environmental protection initiatives.

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Poster 03

2D Carbon Allotropes for Nucleic Acid Biosensing

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The global spread of viral infections such as COVID-19 pandemic has accelerated the development of rapid, reliable, and accessible diagnostic tools [1-3]. Carbon-based two-dimensional (2D) materials have emerged as powerful platforms for biosensing technologies due to their unique physicochemical properties, including high surface area, electrical conductivity, and tunable optical properties and surface functionality.

This overview presents a series of recent developments in genosensor design using advanced carbon nanomaterials for the detection of SARS-CoV-2 genetic sequences. The first approach employs graphene oxide nanocolloids (GONC) as both the platform and the electroactive label, enabling sensitive, label-free electrochemical detection based on the material's intrinsic redox properties. The second platform is based on the use of graphene quantum dots (GQDs) in a homogeneous fluorescence assay, achieving rapid detection (within 5 minutes) through selective hybridization with the viral RdRp gene. The third study focuses on graphdiyne, a novel 2D carbon allotrope, integrated into a label-free electrochemical genosensor using impedance spectroscopy, demonstrating good selectivity in the presence of mutated sequences and suitability for miniaturized, point-of-care testing.

Together, these studies illustrate the versatility of carbon-based 2D nanomaterials in designing innovative genosensors that are sensitive, selective, and adaptable to rapid and low-cost diagnostic formats. Their integration into fluorescence and electrochemical platforms positions them as promising candidates for future point-of-care and on-site viral detection systems.

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Poster 04

EGOT-BASED TIME TEMPERATURE INTEGRATOR FOR FOOD COLD-CHAIN MONITORING

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Cold chain relies on keeping perishable goods such as fresh food at a constant low temperature from the point of production to the point of consumption. Any break in the cold chain, such as temperature fluctuation, can compromise the safety and freshness of the products, leading to food spoilage and even health risks. Technologies like smart packaging(1) and temperature-monitoring devices such as time-temperature integrators(2) (TTIs) are becoming increasingly important to enhance control, reduce waste, and ensure the overall efficiency of the cold chain. Here we present an innovative TTI device based on a graphene hydrogel (3) operated as an electrolyte gated transistor (EGT). The hydrogel undergoes an irreversible dehydration in response to different environmental conditions like temperature and humidity. We study the process of mass loss (fig. 1) and propose a multiparametric description of the activated de-hydration process to quantitatively relate the loss of mass to the time, the temperature and the relative humidity. The initial mass/volume of the hydrogel is an important factor to tailor the timescale of the dehydration. Since the hydrogel is conductive, by exposing it to different conditions for a certain amount of time, it is also possible to record the effects of the temperature and humidity in time on the electrical characteristics acquired using the hydrogel as gate electrode of the EGT. Transconductance signal S_{gm} was identified as being able to discern between the various exposure conditions(4) (fig. 2).

We are also developing a predictive model to correlate dehydration kinetics with environmental exposure history, enabling precise calibration of the TTI response and quantitative assessment of cold chain integrity. We assessed this on real fresh fish samples packaged from aquaculture(5).

Fig. 1

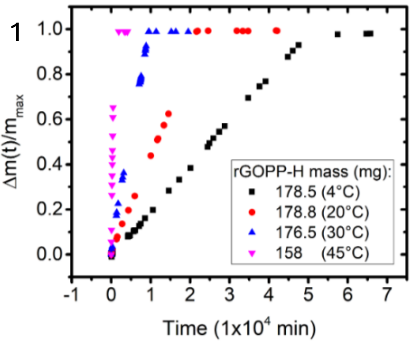
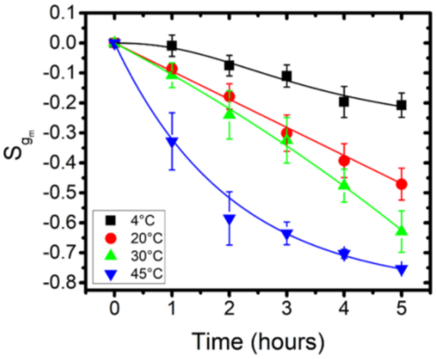


Fig. 2



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Poster 05

Synthesis, characterization, and application of new luminescent biopolymer probes for micro- and nanoplastics detection

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Plastic pollution is rising dramatically due to human activities; in particular, the plastic fragments below 5 mm – the so-called micro- and nanoplastics (MNPs) – are ubiquitous: in water, sediments, soil, and air. Their small dimensions make them more easily bioavailable and ingestible by animals, reaching humans mainly through the food chain. The detection of MNPs is a great challenge since existing protocols are unsatisfactory for microplastics and mostly absent for nanoplastics.

In this framework, fluorescence-based methods could represent a possible solution for MNPs identification and quantification, since they are fast, easy, cheap, and sensitive. Fluorescence has found application in identifying plastic debris using fluorescence microscopy after staining them with suitable dyes, such as Nile Red (NR), which has proven to be a valuable choice for staining different types of microplastics in water [1]. However, its inclination to aggregate in aqueous environment can lead to the emergence of fluorescent objects that can be mistaken for MNPs, causing "false positives" [2]. To avoid this problem, which often affects molecular lipophilic dyes used for MNPs staining, we decided to conjugate a fluorophore to a biopolymer soluble in water, such as hyaluronic acid (HA) or chitosan. Functionalizing HA or chitosan with a fluorophore, even in very small amounts, alters its colloidal behavior, solubility and photophysical features [2]. The resulting properties can be controlled by acting on the fluorophore nature and amount.

With this purpose, we synthesized and characterized in their photophysical properties HA and chitosan with derivatives of several fluorescent dyes (e.g. rhodamine B, coumarin, Nile Red). This results in fluorogenic materials, with very weak emission intensity in water, but that can recover their brightness when adsorbed onto MNPs (Fig. 1). Preliminary studies show that various fluorophore-functionalized HA or chitosan exhibit high affinity for various types of MNPs, making them luminescent and detectable by confocal microscopy. Moreover, fluorescence lifetime imaging (FLIM) can enable a discrimination of MNP nature. Finally, the fluorogenic probes can be also applied to real environmental samples to recognize plastic materials in complex matrices with several organic and inorganic interferences.

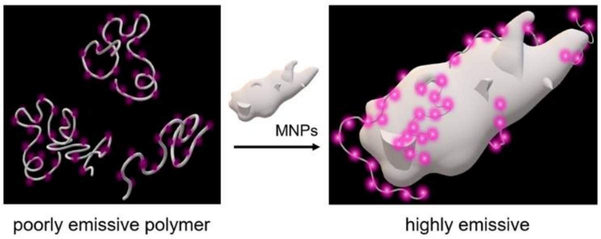

Fig. 1. Schematized interaction between fluorophore-functionalized HA/chitosan and MNPs.

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Poster 06

Detection of Microplastics in Aqueous Solutions Using Impedance Spectroscopy

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Microplastic pollution is a pressing and highly relevant issue. These particles, which originate from the breakdown and degradation of larger plastic materials, pose significant environmental threats to aquatic ecosystems and potential risks to human health. To address this problem effectively, it's important to develop rapid and cost-effective detection methods.[1,2]

This work focuses on the determination of microplastics in aqueous solutions using impedance spectroscopy.

A design of Experiments (DoE) was applied to optimize this process, evaluating multiple experimental variables.

Two types of electrochemical cells were employed: a conventional three-electrode system including a glassy carbon electrode (GCE), and a miniaturized cell based on Screen Printed Electrodes (SPEs), with a carbon paste working electrode.

Experiments were carried out using either an equimolar solution of $[Fe(CN)_6]^{3-/4-}$ in phosphate buffered saline (PBS) or tap water as the electrolyte.

These setups allowed for the evaluation of different electrical parameters following the modification of the working electrode (WE) with polystyrene microplastic solutions of varying concentrations and particle sizes (100 nm, 600 nm, and 1.1 µm).

Impedance measurements showed an increase in change transfer resistance (R_{ct}) when using $[Fe(CN)_6]^{3-}/^{4-}$ as the electrolyte solution, and a decrease in R_{ct} when using tap water.

Notably, a clear trend in R_{ct} variation was observed with different microplastic concentrations of the same size when using SPEs in the $[Fe(CN)_6]^{3-/4-}$ solution.

This study serves a stepping stone towards the development of effective, rapid, and affordable methods for the detection of microplastics in real-world samples, contributing to the monitoring and management of microplastic pollution and its associated environmental and health risks.

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Poster 07

A microneedle-based platform for the detection of Amyotrophic Lateral Sclerosis (ALS) biomarker

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ALS is a neurodegenerative disease characterised by the progressive degeneration of upper and lower motor neurons [1]. Despite intensive research efforts, there are still no validated biomarkers for early diagnosis or for monitoring disease progression [2]. Recent studies suggest that interstitial skin fluid (ISF) may provide useful information on degenerative processes, opening the possibility of monitoring the disease in a non-invasive manner. In this context, a microneedle-based device has been developed that can integrate electrochemical sensors for the rapid detection of biomarkers in ISF.

In this study, microneedles made of poly(ethylene glycol) diacrylate (PEGDA), a photopolymerisable, inert and highly biocompatible material, were fabricated using optical photolithography. This technique is notable for its simplicity, speed, and low cost, making it easily scalable and reproducible. It enabled the production of well-defined microneedle arrays with uniform and controlled geometries. The geometry of the microneedles was optimised with 300 µm base masks and heights between 650 and 700 µm, ensuring mechanical stability and skin penetration capacity. The microneedles were then metallised with chromium and gold, with optimal thicknesses selected to ensure uniformity and stable adhesion over time. Finally, to test microneedles' biocompatibility, biological analyses in terms of cell viability and morphology were performed on fibroblasts isolated from ALS patients at different stages of the disease and compared to healthy controls. Initial analyses confirm that the device maintains geometric integrity and structural stability, with controlled swelling behaviour. In vitro biocompatibility tests have shown that PEGDA patches do not induce a significant reduction in cell viability and morphological alterations after 24 and 48 hours of exposure, both in healthy cells and in cell lines derived from ALS patients. These results indicate that microneedles can effectively penetrate the skin without causing toxicity or damage to surrounding tissues, thus representing a safe and promising platform for non-invasive detection of ALS biomarkers in ISF.

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Poster 08

FLUORESCENT SENSOR IN COMPLEX POLYMERIC MATRIX MIMICKING EXTRACELLULAR MATRIX

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Drug-loaded liposomes are among the most exploited nanocarriers for drug delivery applications [1]. However, while their properties are well characterized in homogeneous aqueous media, their behaviour in complex nano- and microstructured environments such as the extracellular matrix (ECM) is still poorly understood. In this work, we developed a hybrid platform (displayed in figure 1) that mimics the ECM, consisting of an electrospun fiber mat combined with a photo-crosslinked hydrogel. This system provides tunable mechanical and diffusional properties, enabling the study of liposome behaviour within a biomimetic environment.

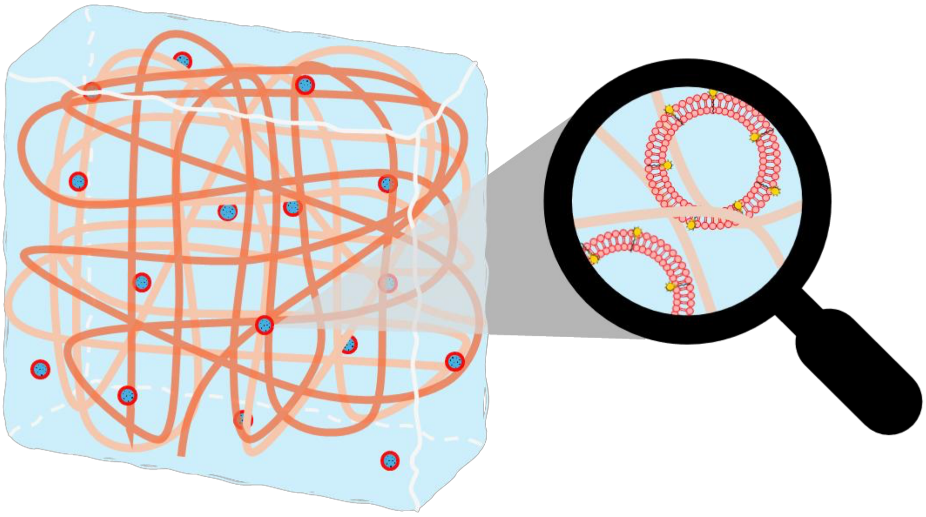

Figure 1: schematic representation of the studied system, composed of an elctrospun fibre (in orange), a photo-crosslinkable hydrogel (in light blue) and of loaded liposome (red circles) doped with the fluorescent sensor (yellow lightbulbs) inserted in their double layer.

To monitor the liposome fate and the local microenvironment, we employed a fluorescent probe (NBD-oleyl) embedded within the liposome bilayer. The probe acts as a polarity sensor providing information on both the structural integrity of the liposomes distinguishing between intact and disrupted vesicles and between different composition of the liposome double layer membrane. Steady-state and time-resolved fluorescence measurements, together with Confocal Laser Scanning Microscopy (CLSM) and Fluorescence Lifetime Imaging Microscopy (FLIM), were used to correlate fluorescence lifetime variations with liposome disassembly, diffusion, and matrix interaction.

This approach enables in situ monitoring of the nanocarrier stability and environment, paving the way for smart implantable devices for post-surgical anticancer therapy.

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Poster 09

Laser-Induced Graphene Cardboard Electrodes for Sustainable Histamine Detection in Food Packaging

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The increasing focus on environmental impact[1] and the urgent need for innovative food monitoring resulted in the development of biodegradable, low-cost electrochemical platforms[2]. These disposable sensors can be directly integrated into food packaging, which not only ensure analytical real-time analysis but also allow for easy integration into hygienically controlled systems. Among the various freshness biomarkers, histamine, a biogenic amine generated by microbial decarboxylation of histidine[3], serves as a key indicator of spoilage in protein-rich foods such as fish[4]. Elevated histamine levels are associated with food degradation and potential health risks, highlighting the importance of rapid, selective, and eco-friendly detection methods.

In this work, we report the fabrication and characterization of laser-induced graphene (LIG) electrodes obtained by CO_2 laser processing of paper-based substrates as sustainable disposable sensor platforms for histamine detection (Fig.1). The laser-based approach enables localized carbonization of cellulose without addition of any chemical reagents, ensuring precise control of electrode geometry in a solvent-free, scalable, and cost-effective process.

The electrochemical performance of the LIG electrodes was investigated using Cyclic Voltammetry (CV), Differential Pulse Voltammetry (DPV), and Electrochemical Impedance Spectroscopy (EIS). Moreover, morphological and structural characterizations were carried out.

Overall, the LIG cardboard electrodes showed good electrochemical performance, with linear range (0.1mM to 1mM) in line with the legal thresholds for histamine in fish, highlighting their suitability as sustainable, disposable and low-cost sensors for smart food packaging.

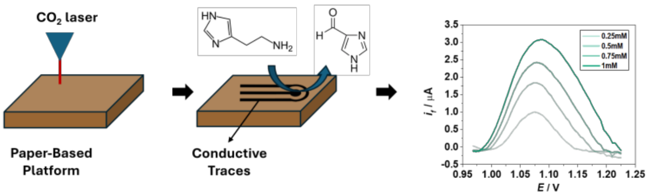

Figure 1. Schematic Representation of Cardboard Electrodes Fabrication

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Poster 10

Electrodeposition of metals onto the gate terminal of electrolyte-gated transistors for sensing applications

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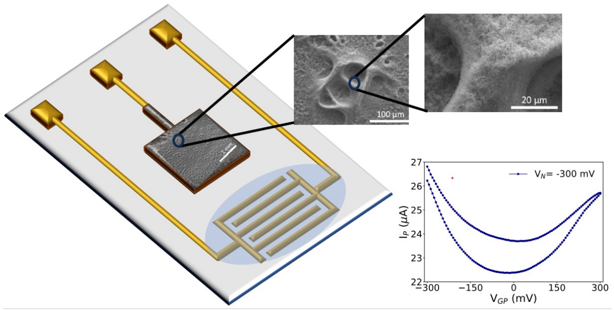

Figure 1 On the left: sketch of the electrolyte-gated transistor coated with a porous Cu coating. Top right: SEM image of the porous Cu coating. Bottom right: IV transfer characteristic of the corresponding device.

Reduced graphene oxide field-effect transistors (rGO-FETs) are sensitive and versatile sensing platforms. The partial reduction of GO provides high conductivity while retaining surface functional groups for receptor immobilization, enabling selective and real-time detection of chemical and biological species. Their low-cost, scalable fabrication and strong signal transduction make rGO-FETs promising candidates for biosensing and environmental monitoring applications [1].

Based on these premises, we fabricated electrolyte-gated transistors (EGTs) using rGO thin films deposited onto commercially available substrates featuring gold microelectrodes sputtered on polyethylene terephthalate (PET). Then, aiming at modifying the gate terminal we electrodeposited Cu, Ni and Pb compact films onto it, using standard electrochemical approaches. To elucidate the effect of the coating morphology we also produced porous Cu coatings by hydrogen bubble-templated cathodic electrodeposition [2].

When compared with devices featuring unmodified Au gates, the Cu-modified devices (see Figure 1) exhibited remarkable improvements, including a shift in the minimum gate voltage (from –50 mV to –300 mV), enhanced potentiometric sensitivity (of the order of a few millivolts), a signal-to-noise ratio (SNR) ranging between 6 and 10, and a stable signal during 1 hour in high ionic strength media (1M $NaCl_{(aq)}$) [2]. For instance, the porous Cu morphology opens the possibility of integrating specific antibodies within the gate structure for selective antigen detection by exploiting the enhanced capacitive coupling between the gate terminal and the active material.

The effects of the gate modification by electrodeposition of metals other than Cu, along with their chemical functionalization, are currently investigated to assess their potential towards the development of potentiometric sensors.

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Poster 11

Simultaneous dual biomarker monitoring using step-wise SnO_2 coated lossy mode resonance fiber sensor

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Simultaneous detection of multiple analytes, essential for disease diagnosis and monitoring treatment outcomes, remains a significant challenge. While planar sensing platforms have demonstrated this capability, optical fiber sensors still lag behind. A novel approach involving a real-time, dual lossy mode resonance (LMR) biosensor has been developed, using a side-polished single-mode fiber for quantifying clinical markers associated with inflammatory processes, such as those observed in COVID-19 infections [1]. The dual LMRs are achieved through a two-step deposition process based on DC sputtering, forming a step-wise nanostructure with distinct SnO_2 layer thicknesses over the flat surface of the polished fiber (Fig. 1a). Both theoretical predictions and experimental validations confirm the platform's feasibility, showcasing a sensitivity of about 4500 nm RIU^{-1} for each LMR. A key advancement presented in this work is the spatially-separated biofunctionalization of the different sensitive regions of the fiber, which is demonstrated through fluorescence assays that exhibit high selectivity for different immunoglobulins (Fig. 1b). This biosensor enables real-time and label-free detection of two critical inflammatory markers, C-reactive protein (CRP) and D-dimer, underpinning clinically-relevant minimum detectable concentrations below 1 μg mL^{-1} for both biomolecules (Fig. 1c). This proof-of-concept study represents a significant advancement in fiber-based biosensing, offering a compact, multifunctional analytical tool designed for effective and reliable multi-analyte detection.

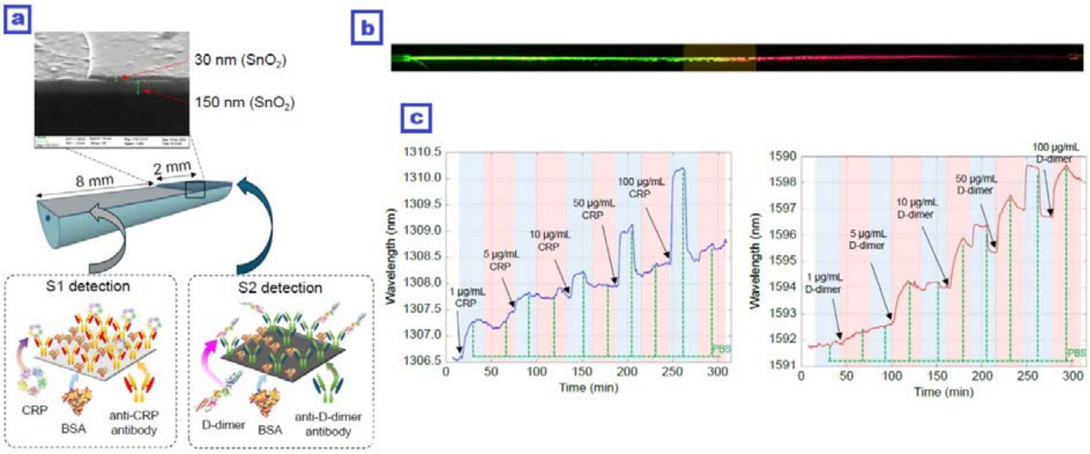

Figure 1. (**a**) Step-wise SnO_2-coated side-polished fiber sensor with spatially-modulated surface functionalization; (**b**) fluorescence IgG-based assay; (**c**) sensorgram of simultaneous CRP (left) and D-dimer (right) detection.

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Poster 12

Optical Aptasensor for On-Chip Tyramine Detection: Advancing Food Safety Through Plasmonics

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Ensuring food safety and quality requires advanced analytical methods capable of rapidly and accurately detecting contaminants and degradation markers. Among these, biogenic amines play a critical role as they are biochemical indicators of food freshness and microbial spoilage [1,2]. Tyramine, a biogenic amine formed by the decarboxylation of tyrosine, is an important marker for assessing food quality and potential health risks. In this work, we developed a plasmonic nanobiosensor for the label-free and highly sensitive detection of tyramine, combining the high refractive index sensitivity of gold nanostructures [3] with the molecular specificity of aptamer-based recognition. The nanostructured transducers were fabricated using Nanosphere Lithography (NSL), which enables low-cost production of large-area, reproducible nanostructures with tunable plasmonic properties. A thiolated aptamer specific for tyramine was immobilized on the gold surface to ensure selective binding. Detection was achieved by monitoring spectral shifts in the Localized Surface Plasmon Resonance (LSPR) peak upon aptamer–analyte interaction. The sensor exhibited a linear response in buffer conditions across a 0.25–30 ppm range, with a limit of detection of 0.2 ppm, demonstrating excellent performance compared to conventional chromatographic methods. This approach represents a rapid, label-free, and miniaturizable optical sensing platform that could be integrated into microfluidic chips for on-site food quality monitoring. Ongoing studies aim to validate the sensor using real food samples and to explore its potential for multiplex detection of other biogenic amines relevant to food safety.

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Poster 13

Engineering Gold Nanocluster in PEGDA Hydrogel for SERS-based Food Quality Assessment

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Hydrogels, due to their three-dimensional polymeric network, offer exceptional properties such as controlled swelling, biocompatibility, tuneable porosity, and optical transparency. These features make them ideal candidates for integrating plasmonic nanomaterials and advancing surface-enhanced Raman scattering (SERS) technologies, particularly in applications requiring sensitivity, flexibility, and real-world adaptability. Unlike traditional rigid SERS substrates, hydrogel-based platforms have mechanical softness and surface conformability needed for complex sample geometries, such as irregular food surfaces. However, limitations such as slow analyte diffusion and nanoparticle aggregation have sometimes hampered their performance and reproducibility.

Recent studies have explored both rigid (e.g., Klarite, silicon wafers) and flexible (e.g., paper, cellulose films) SERS substrates for pesticide detection, including dimethoate (DMT), a widely used but hazardous organophosphorus pesticide [1]. While rigid platforms have demonstrated high sensitivity, they often lack adaptability for on-site or in-situ use. On the other hand, flexible systems still rely heavily on laboratory setups or lack reproducibility. Moreover, colloidal approaches, despite their high signal enhancement, present challenges in terms of stability and practical deployment [2]. In this study, we present an innovative SERS substrate composed of gold nanoparticles (AuNPs) embedded within a poly(ethylene glycol) diacrylate (PEGDA) hydrogel matrix that already proved its efficacy in sulphites quantification in wine. This flexible plasmonic system is specifically engineered for real-time, in-situ detection of DMT on olive surfaces. Key to our approach is a novel pre-mixing strategy that significantly improves analyte diffusion within the hydrogel matrix, a challenge in most hydrogel-based sensors. This method ensures uniform distribution and aggregation control of AuNPs, enhancing signal intensity and reproducibility. The system is fabricated via a low-cost UV polymerization method, enabling direct application to food surfaces and facilitating portable field use.

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Poster 14

CO_2 laser-induced graphenic films on eco-friendly paper substrates for sensing and biosensing

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The synthesis and integration of nanostructured films into paper-based analytical devices remain significant challenges. Benchtop-scale CO_2 laser plotter-based technologies offer an exciting opportunity to produce graphenic and graphitized films.

This presentation focuses on the production of various functional nanostructured films using a CO_2 Laser plotter and their integration into fully lab-made paper sensors and biosensors. This study concerns the integration of laser-induced graphene oxide (rGO) and laser-induced graphene (LIG) into cellulosic substrates, enabling the creation of complete nanostructured paper sensors and biosensors capable of addressing various analytical requirements. To achieve this, eco-friendly cellulosic substrates were explored, including recycled papers and those derived from textile and agro-industrial wastes, and manufactured using fiber sources alternative to trees. Paper sensors were produced in batches through an accessible stencil printing process, and rGO/LIG films were seamlessly incorporated via pressure.

The paper/rGO's morphological, structural/chemical, and electrical/electrochemical features were thoroughly examined. In brief, each paper interacts with the rGO/LIG differently, resulting in a unique graphene film formation and chemical rearrangements that impact their electrochemistry and electroanalytical properties. The presentation will cover: (i) electrochemical sensors based on laser-induced rGO films integrated into eco-friendly papers capable of detecting various analytes in different samples, including food, supplements/medications, and biological fluids. For each application, a dedicated paper sensor proved to be more effective (tree-free/rGO, recycled fibers/rGO, and kiwi by-products/rGO), highlighting the role of the cellulosic substrate even in their final use. Reproducible data ($RSD \leq 7\%$; $n = 3$), with nano- to micromolar detection limits and satisfactory recoveries (91-108%), were achieved across all applications. (ii) Additionally, bamboo-derived paper was used to host LIG obtained from polyimide and to accommodate Fructose Dehydrogenase (FDH), with the ultimate goal of fabricating a third-generation enzymatic biosensor for detecting inulin, a natural fructose polymer used as an exogenous marker for glomerular filtration rate (GFR) estimation to evaluate kidney function. Bamboo paper biosensors were employed to measure inulin in real urine and serum samples at clinically relevant levels, yielding satisfactory recoveries (90–111%; $RSD \leq 7.9\%$, $n = 3$).

This presentation aims to demonstrate how CO_2-laser plotter-based technologies can create effective nanostructured sensing surfaces and transducers that are accessible and easy to interface through everyone-reach technologies on paper-based substrates, opening new opportunities for developing on-demand, sustainable analytical devices that meet specific needs.

Acknowledgments

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Poster 15

Integrated paper/transition metal dichalcogenides colorimetric device for the nanozymatic-sensing of glutathione in saliva

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Herein, a colorimetric paper-based analytical device (PAD) is proposed for the direct determination of glutathione (GSH) in saliva. The device's sensing ability is based on the GSH-induced inhibition of the peroxidase (POD)-like activity of transition metal dichalcogenide (TMD) 2D-nanoflakes integrated on paper.

TMDs (i.e., MoS_2, WS_2, $MoSe_2$, and WSe_2) were nanostructured via sonochemical exfoliation in water using sodium cholate as stabilizing agent, and, for the first time, their POD-like activity was comprehensively studied on paper towards TMB (3,3',5,5'-tetramethylbenzidine) oxidation. The nanozymatic activity of the four TMDs was carefully tested on six different papers under various TMD loading conditions. MoS_2 proved to be the most effective 2D-TMD when combined with Whatman 602H paper. The MoS_2-PAD was then used to develop a smartphone-based colorimetric method that relies on GSH-mediated inhibition of catalytic TMB oxidation, resulting in a blue colour switch-off.

The MoS_2-PAD, shown in **Figure 1**, was conceived to host a 3-point 'control calibration' and sample analysis in triplicate. Its manufacturing relies on the printing of hydrophobic barriers on paper to define the sensing spots, which also act as MoS_2 and TMB reservoirs; this was performed using a simple, portable wax printer. The MoS_2-PAD smartphone-based colorimetric assay consists of two straightforward steps, i.e., (i) saliva and H_2O_2 loading, (ii) smartphone readout after 10 min. The GSH matrix matched calibration returned a linear range enclosed between 0.5 and 10 µM ($R^2 = 0.991$) with a LOD of 0.14 µM, showing a suitable inter-batch reproducibility (RSD ≤ 4%, n = 3). The device reliability was demonstrated through GSH determination in 17 real saliva samples, obtaining accurate (recovery: 81-117%) and reproducible data (RSD ≤ 16%, n=3), correlated with the Ellman-reference method (r = 0.972).

Summing up, the proposed PAD enables GSH determination at physiologically relevant levels, requiring only 3 µL of sample, representing a step toward point-of-care devices based on nanozymatic functional materials.

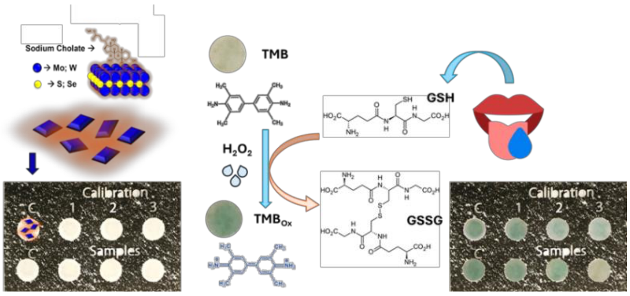

Figure 1. Picture of unreacted and reacted MoS_2-PAD, and sketch of the GSH sensing strategy.

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Poster 16

Sonochemical-Assisted Formulation (SAF) of water-based conductive ink for sensors and biosensors on flexible and paper substrates

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Herein, a new, fast, and effective method for creating versatile water-based conductive ink for developing sensors and biosensors on flexible and paper substrates is introduced. The aim is to propose a sustainable and potentially biocompatible alternative to conventional conductive carbon inks, which are formulated using toxic and pollutant solvents/components.
The proposed technique, named Sonochemical-Assisted Formulation (SAF), enables the preparation of a water-based ink composed of graphite, chitosan, and glycerol within less than 1 hour. The process relies on the high-power probe sonicator's ability to dissolve chitosan in water quickly (10 min) and then properly formulate the ink through a pulsed sonication process lasting 30 minutes. This method not only mixes the ink components but also disperses, exfoliates, and reduces the size of the graphite flakes, thereby positively affecting the final performance of the printed electronic.
Initially, the parameters of the SAF were thoroughly analyzed to produce printed tracks with low sheet resistance and sensors that offered the optimal balance between heterogeneous electron transfer rates and faradaic/capacitive current ratios. To understand the effect of the proposed formulation, the obtained inks were deeply characterized via contact angle studies, scanning electron microscopy, and Raman spectroscopy. These investigations were conducted on polyethylene terephthalate (PET) as model flexible substrate. In detail, sonication time, sonication power, and the amount of graphite were investigated. The optimal SAF-obtained ink was compared with conventional ink formation methods, including stirring, orbital, and coaxial formulations, demonstrating superior electrochemical performance.
Eventually, the optimal ink formulation was tested for sensing and biosensing purposes on various substrates, including office and recycled paper (Rismaluce office paper, Kraft, Free Tree Bamboo, Crush Cacao, Nitrocellulose), flexible plastics (PET and Polyimide Film), and ceramic foil. Specifically, the proof of the applicability of the SAF-produced inks on these substrates is being studied for creating sensors to detect food antioxidants and for developing second-generation biosensors.
Despite ongoing studies, we can confidently state that the proposed SAF ink can be applied to various substrates, resulting in a versatile and environmentally friendly alternative for the development of sustainable conductive tracks and electrochemical devices.

Acknowledgments

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Poster 17

Functional evaluation of polypyrrole (PPy) after optimization of sensor Based on molecularly imprinted polymer (MIP) for PFOA detection

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Per- and Polyfluoroalkyl Substances (PFAS) represent a complex class of synthetic chemicals, characterized by their highly stable carbon-fluorine bonds. These compounds are extremely resistant to degradation, leading to their persistence in the environment [1]. These molecules are used in industrial processes and consumer products, and specific compounds, like Perfluorooctanoic acid (PFOA), are frequently detected in drinking water, soil, and biological matrices [2, 3]. The accumulation of these persistent molecules causes a significant toxicological threat to human health, driving regulatory associations to establish stringent monitoring standards for both environmental and food safety [3].

The detection of PFAS present substantial challenges for analytical quantification. Traditional gold-standard methods, such as Liquid Chromatography Tandem Mass Spectrometry (LC-MS/MS), offer high sensitivity but time-consuming sample preparation, high operational costs, and centralized laboratory infrastructure are necessary [1, 4]. In response to these analytical issues, biosensors have emerged as a powerful device for the molecule recognition. In particular, Molecularly Imprinted Polymers (MIPs) are materials engineered to possess highly specific, high-affinity binding sites that are geometrically and chemically complementary to a target/template molecule [5].

The aim of this research was the development of a quick and simple diagnostic test for the quantification of PFOA in wastewater. Screen Printed Carbon Electrodes (SPCEs) (Metrohm, Origgio, Italy) were used, while electropolymerization process was performed with Pyrrole in ACN and PFOA. Cyclic voltammetry (CV) and differential pulse voltammetry (DPV) were performed with $[Fe(CN6)]3-/4-$ in 0.1M KCl as the redox probe using µStat-i Multi4 Multi (Bi)potenziostat, Galvanostat/Impedance (Metrohm, Origgio, Italy).

Scanning Electron Microscopy (SEM) performed on electrodes confirmed fluorine levels consistent with selective PFOA binding at the imprinted cavities: 0.33% (bare electrode), 1.04% (after electropolymerization), 0.48% (after template removal), and 1.10% (after rebinding with a synthetic PFOA sample). The developed sensor was then used to build a calibration curve (0.1-10 nM) which showed an R^2 of 0.80, while the limit of detection and quantification were of 0.1 nM. The method showed good reproducibility, with an intra-day and inter-day coefficient of variation ≤10%. The sensor was then used for the analysis of a real wastewater sample containing multiple PFAS: the method was able to quantify a PFOA concentration of ~9.0 nM, compared with 5.54 nM determined by HPLC-MS. Higher detected concentration can be attributable to matrix effects and non-specific interaction involving other PFAS that were present in the sample. In conclusion, this new sensor showed very good analytical performances for the quantification of PFOA in water matrix. Further analysis will include the detection of PFOA in biological samples.

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Poster 18

Design of Layered NiAl-LDH and Pyramidal Pt Nanoparticles for Sensing Applications

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Layered double hydroxides (LDHs) are a class of lamellar materials composed of mixed metal hydroxide layers containing divalent and trivalent cations, with a general formula $[M(II)_{1-x}M(III)_x(OH)_2]_x^+(A^{n-})_{x/n}$ - yH_2O. This structure offers high tunability in composition and functionality, making LDHs attractive for catalysis, energy storage, and sensing applications[1]. Electrochemical sensors based on LDHs benefit from their high surface area, redox activity, and interaction with electroactive species. In this study, the effect of platinum nanoparticles (PtNPs)[2,3] with controlled size and shape, combined with electrochemically synthesized NiAl-LDH (Ni:Al = 3:1) arranged in a layered configuration, was investigated as a sensor for sugars. Electrochemical analysis using a three-electrode setup assessed parameters including formal potential, peak currents, total redox charge, and electrochemically active surface area (ECSA). Cyclic voltammetry (CV) of the composite sample NiAl-PtNPs-LDH revealed distinct redox processes associated with both the NiAl-LDH (labeled I and I′) and PtNPs (system II) (Figure 1A).

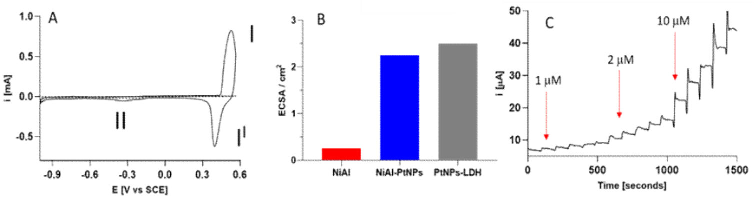

Figure 1 A: CV (scan rate = 10 mV/s) recorded in 0.1 M NaOH for NiA-PtNPs-LDH; B: ECSA values evaluated in 0.1 M NaOH of NiAl, NiAl-PtNPs-LDH and PtNPs; C: I vs time plot obtained for NiAl-PtNPs-LDH applying +0.62 V in 0.1 M NaOH

The presence of PtNPs significantly enhanced performance: while the formal potential remained unchanged, redox peak currents doubled. The concentration of electroactive Ni^{2+} sites increased more than threefold in the PtNPs-LDH composite compared to NiAl-LDH alone, confirming greater electrochemical accessibility. Additionally, the ECSA increased by an order of magnitude (Figure 1B), which can be attributed to the conductive nature and high surface area of the PtNP-modified surface. Finally, the NiAl-PtNPs-LDH composite demonstrated excellent sensing performance toward glucose (Figure1C), with a detectable response below 1 µM. Such performance highlights the synergistic effect between the LDH matrix and the PtNPs. Future studies will be aimed at exploring the influence of other noble metal nanoparticles and their use at different concentrations to further tailor the system response for specific sensing targets.

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Poster 19

Colorimetric paper-based kit for the selective determination of melatonin

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Melatonin (Mt) is the primary secretory product of the pineal gland and is commonly used in supplements for sleep regulation. However, concerns about dosage accuracy and product quality highlight the need for simple detection methods.

Here, a paper-based colorimetric kit is proposed for the determination of Mt. The kit includes the reaction cartridge, graduated sampling vessel, sample prep-holder, measuring box, and a colorimetric chart for Mt quantification; all components are paper-based and custom-molded using benchtop technologies (such as an office printer, wax printer, or CO_2 laser plotter) to make the kit user-friendly and ready for use.

The reaction cartridge contains the colorimetric assay, which is based on Mt reaction with 4-dimethylaminobenzaldehyde (Dm), producing a measurable violet color within 15 min, monitored through a smartphone camera. The assay requires only diluting the sample in a graduated sampling vessel, loading it into the reaction cartridge, and then directly comparing the resulting color with the colorimetric chart (**Figure 1**).

The calibration chart has been carefully developed to match the experimental trials (r= 0.999) and allows rapid on-site quantitative analysis of Dm without specialized equipment, enabling the determination of Mt in the range of 1-50 ppm (R^2 = 0.993) with a LOD of 0.90 ppm and acceptable inter-batch reproducibility (RSD ≤ 4%, n = 3). The method's selectivity was thoroughly evaluated against 17 potential interfering compounds, including tryptophan and other structural analogs. The kit's reliability in real-world applications was demonstrated by measuring Mt in 7 'drugs,' providing accurate (recovery: 81-117%) and reproducible data (RSD ≤ 16%, n = 3), with a relative error ranging from -7.4% to +13.5% when comparing the Mt concentration to the amounts claimed on the drugs' labels.

The proposed paper-based melatonin kit comprises all the necessary components for in situ analysis, resulting in a low-cost and user-friendly tool, making it a promising tool for routine quality control of pharmaceutical and nutraceutical products, offering a straightforward alternative to conventional, cumbersome laboratory methods.

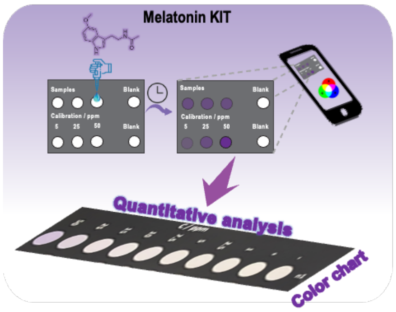

Figure 1. Graphical representation of the paper-based kit, and sketch of the melatonin sensing method

Acknowledgments

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A field-deployable, software-controlled platform for electrochemical in-flow monitoring of heavy metals in water

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The growing demand for decentralized analytical platforms to evaluate trace heavy metal contamination in environmental matrices, especially water bodies, has become increasingly pressing. In this context, electrochemical sensors represent well-established and cost-effective approaches for the development of in-field deployable monitoring solutions.

This study presents the development and implementation of a fully automated electrochemical detection platform designed for real-time, continuous on-site monitoring of heavy metals in water samples. The sensing interfaces were appropriately functionalized and integrated with an optimized protocol to ensure target analyte detection and specificity. The sample is conveyed inside an *ad-hoc* designed flow cell coupled to a stirrer by a software-controlled peristaltic pump. The developed prototype featured proprietary software able to control fluidic operations, electrochemical measurements, and data processing. The automated setup reduced manual intervention and enabled rapid results while substantially reducing sample volumes required.

Critical operational variables, including flow rates, sample volumes, and stirring steps were experimentally optimized alongside parameters for the electrochemical readout to establish optimal conditions that balanced sensitivity with analysis time. The device was applied to the multi-element quantification of heavy metals including nickel, aluminium, cadmium, lead, and copper.

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Poster 21

UPcycling SOOT for sustainable nanocomposites-based electroanalytical sensors

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Over the past 30 years, carbon-based nanomaterials have revolutionized material science and have proven to be highly effective as electroactive nanomaterials, serving as the foundation for the design of high-performance electrochemical sensors.

Among these, carbon nanoparticles (CNPs) have gained attention for their unique properties. Unlike their more structurally defined counterparts (e.g., graphene, carbon nanotubes, etc.), CNPs offer a cost-effective and scalable alternative while preserving excellent performances. Their ease of functionalization and inherent biocompatibility make them essential for next-generation sensing platforms. Traditionally, CNPs are synthesized using various methods, each offering control over particle size, surface chemistry, and graphitic ordering. However, the energy-intensive nature of these techniques and their reliance on hazardous precursors have encouraged the search for more sustainable approaches.

A promising and sustainable alternative lies in utilizing available sources, such as Carbon soot[2], a combustion-generated powder produced during the incomplete combustion of hydrocarbon fuels. To further enhance the electrochemical performance of soot-derived carbon nanoparticles, their integration with metal nanoparticles could be a promising strategy.

In this study, we aim to upcycle carbon soot particles produced through ethylene combustion and explore their potential as electroactive nanomaterials. The soot particles undergo acidic pretreatment to introduce surface functional groups that facilitate gold deposition. Au NPs are then incorporated through two distinct routes: (i) citrate-assisted reduction and (ii) spontaneous reduction. A comparative study of these two approaches is conducted to evaluate their effects on the structural and electron transfer properties using two different supports: carbon paste electrodes (CPEs) and screen-printed electrodes (SPCEs). To assess their practical electrochemical performance, the two different electrodes are applied for sensing hydrogen peroxide (H_2O_2), a key biomarker in biological processes and for detecting diclofenac (DCF), a widely used non-steroidal anti-inflammatory drug with environmental relevance.

We acknowledge financial support under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.1, Call for tender No. 104 published on 2.2.2022 by the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU– Project Title: UPcycling SOOT for sustainable nanocomposites-based wearable sensors (UP - SOOT) – CUP G53D23003000006 - Grant Assignment Decree No. 958 adopted on 30/06/2023 by MUR.

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Poster 22

Fluorescent Probes for biosensing applications

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State-of-the-art (SoA) optical fluorescent biosensors for *Escherichia coli* (*E. Coli*) detection typically outperform antibody-based methods in sensitivity and cost-effectiveness.[1] However, these biosensors normally rely on large biomolecules (*e.g*., fluorescent proteins, aptamers) and quantum dots/nanoparticles rather than small molecules (SMs) labels, which remain largely unexplored for the target application, with few recently published truly fluorescent biosensors (*i.e*., not coupled to electrochemical transducers) with best sensitivity of *ca*. 100 CFU/mL and <1 h detection times.[2] Aiming at developing bacterial biosensors, we started with the design and synthesis of several deep-red emitters to be used as fluorescent probes. In parallel, we started a preliminary investigation around the compatibility of squaraine-based dyes with biological systems. Indeed, among different fluorescent probes, squaraines are characterized by sharp and intense absorption and emission in the visible up to the near infra-red region, but in aqueous environments tend to form aggregates that lead to fluorescence quenching therefore limiting their wide applications. Despite this drawback, they are proved to turn on their fluorescence in response to a biological target, with promising application for living processes, medical diagnosis and biological imaging at molecular, cellular and organism level [3]. To this aim, we studied the interaction between two proteins (*i.e.*, Human Serum Albumin – HSA – and Porcine Gastric Mucin – PGM) and several squaraines with different substitutions in aqueous media through UV–Vis, and fluorescence spectroscopies. This will serve as basis to identify structure-activity relationships to refine the design of new fluorescent dyes.

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"LIVESTAQSENS": network of AI-calibrated CH_4 and NH_3 chemical sensors for livestock farming

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Intensive livestock farming with high animal density is widely used to meet the growing demand for meat in human diets. This practice has negative impacts on air, water, and soil quality, as well as on climate and biodiversity [1]. Ammonia (NH_3) and methane (CH_4) are the main air pollutants emitted, and farmers are adopting strategies to reduce their concentrations. This requires continuous and widespread monitoring, both inside and outside facilities, using reliable, user-friendly, and low-cost devices. However, conventional monitoring systems are often expensive and require specialized maintenance, which discourages regular use.

The aim of both this work and the LivestAQsens project [2] is to address the above-mentioned need by creating a monitoring network that employs MOX chemical sensors for measuring CH_4 and NH_3, supported by intelligent algorithms designed for self-calibration (LivestAQsens Network).

MOX sensors have been realized by using the screen-printing technology starting from the chemical wet synthesis of the functional materials [3] guarantying compact size, robustness, low cost, and ease of use and management. The array of five different thick film gas sensors, optimized to work in real and complex livestock housing environments, represents the core of the remotely controlled sensor node of the nett. The array is lodged in a small box together with a dedicated electronic circuitry for each sensor and a main electronic control unit equipped with a data transfer module using existing on the field Wi-Fi connection. Collected data from the sensor nodes, including temperature and relative humidity, and data from conventional instrument are sent to a remote dedicated server through a secure connection in real time. Collected data on the server, allow the monitoring network to be supported with calibration algorithms based on innovative machine learning techniques to ensure correct calibration and compensation of the sensors, minimizing measurement errors, and maximizing the accuracy and precision of the data collected. The optimized MOX sensors, combined with the developed algorithms that dynamically adjust calibration based on actual operating conditions, make the MOX sensor network a practical and efficient solution for reliable, real-time air quality monitoring in livestock contexts, supporting the implementation of strategies to mitigate the environmental and climate-related impacts of livestock farming.

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Poster 24

Smart paper-based electrochemical sensor for real-time monitoring of carvacrol release from functionalized porous materials

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Paper-based electrochemical (bio)sensors have established a new route in the electrochemical sensing field[1,2], because paper-based electrochemical biosensors have been not only environmentally friendly devices, but recently our group demonstrated further advantages, including the simple combination with vertical microfluidics and their use as a reservoir to deliver smart electrochemical (bio)sensors able to i) contain the reagents, ii) preconcentrate the target analyte, and iii) synthesize the nanomaterials inside the paper network. Furthermore, these devices have demonstrated their ability to overcome the limitations of the other printed electrochemical sensors in the measurement of entirely liquid samples by detecting the target analyte in the aerosol phase or solid sample, without the additional sampling system[3]. In the era of sustainability, the use of natural compounds as antimicrobial compounds is a rational selection to avoid the release of pollutants into the environment. Among natural compounds, essential oils (EOs) are characterized by reliable antimicrobial activity, and their use is estimated to grow in the future, thus their detection is an asked point. Herein, we report an electrochemical paper-based device developed to monitor the pH-dependent loading and release of carvacrol from functionalized Cu-SMINpolyDMAEMA particles. A physical entrapment strategy was employed to incorporate carvacrol EO into the porous Cu-SMINpolyDMAEMA structure and to evaluate the loading/release capability of the particles. Carvacrol loading was achieved at pH values below 6, where the polymer brushes adopt an open conformation, while the entrapment was stabilized by shifting the pH above 9 before initiating the release experiments. The working electrode was functionalized by drop-casting carbon black, leading to improved sensitivity due to the enhanced electroactive surface provided by this affordable nanomaterial. To assess sensor performance, standard solutions of carvacrol were analyzed using Differential Pulse Voltammetry (DPV) in the concentration range 2–16 ppm. The resulting calibration curve exhibited good linearity $y = (0.065 \pm 0.003)x - (0.09 \pm 0.03)$, with a detection limit of 0.2 ppm. Finally, the release of carvacrol from Cu-SMINpolyDMAEMA particles was monitored over 60 minutes, showing a gradual increase in the released concentration from 8 ppm after 1 minute to approximately 30 ppm after 60 minutes. These results demonstrate the potential of electrochemical paper-based devices as a reliable platform to monitor and validate the pH-triggered loading and release of active compounds from functionalized porous materials.

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Poster 25

Stimuli-Responsive Luminophore Drives Mechanism Switch for Highly Efficient Electrochemiluminescence Immunosensing

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Although widely used in clinical diagnostics, the sensitivity of electrochemiluminescence (ECL) bead-based immunoassays is intrinsically limited by the reaction mechanism driving the emission of $[Ru(bpy)_3]^{2+}$ on the bead surface.

Depending mostly on the coreactant oxidation, the ‘remote’ pathway (Fig. 1a) is hindered by the slow coreactant oxidation rate and the short half-lives of electrogenerated radicals. Herein, we present the synthesis a $[Ru(bpy)_3]^{2+}$ derivative featuring a stimuli-responsive disulfide bond in its linker to the bead. Electrogenerated tri-*n*-propylamine (TPrA) neutral radicals reduce disulfide moieties, electrochemically inducing the release of Ru(II) labels in solution and thereby leading to an unprecedented mechanism shift toward the more efficient “homogeneous” ECL pathway (Fig. 1b). Leveraging ICP-MS, ECL microscopy, and finite element simulations, we demonstrate rapid bond cleavage and an impressive signal enhancement of up to 613%. Using an experimental configuration designed to emulate commercial clinical analysis, we developed an ECL-based immunoassay for the rapid detection of the SARS-CoV-2 Spike (S) protein in whole virus samples from swab formulations (Fig. 1c). The immunosensor incorporating the cleavable luminophore demonstrated a 40% lower detection limit and a 2-fold increase in sensitivity, while reducing TPrA consumption by 72%. These findings establish stimuli-responsive luminophores as a groundbreaking class of ECL labels, promising substantial improvements in the sensitivity of commercial biosensors.

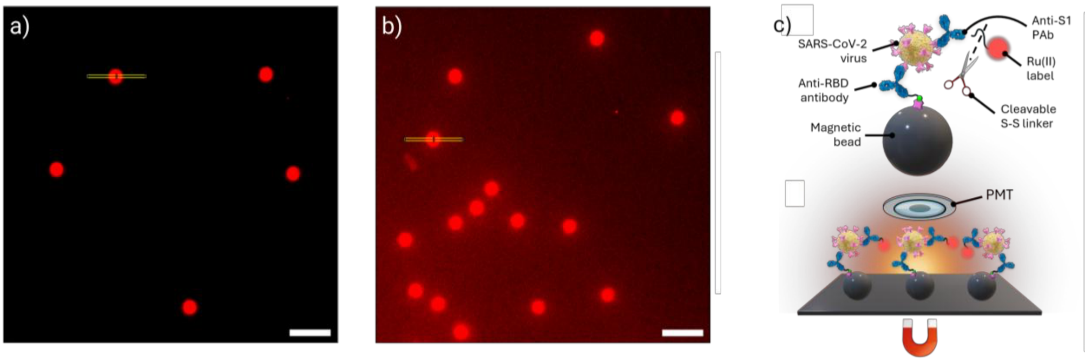

Figure 1. ECL images of (a) the conventional and (b) the stimuli-responsive bead-based systems in 0.3 M PB with 180 mM TPrA (pH 6.8). c) Immunoassay structure and experimental setup for ECL measurements.

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From Lab to Field: Technology Transfer of Sensor Technologies from Pavia - NEMO Device Optimization for Water Disinfection Monitoring

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Bridging academic innovation with industrial implementation is essential to deliver effective environmental monitoring tools. Within this framework, the University of Pavia has collaborated with the company Onyax to optimize NEMO, a compact multiparametric sensor device designed for Online Water Quality Monitoring [1].

The research focused on the development of an amperometric analytical method that enables the joint quantification of free chlorine (FAC) and RedOX potential, two key parameters for monitoring water quality and disinfection, using a standard commercial combined ORP electrode [2]. To overcome the problem of the absence of the semiperbeable membrane on the electrode, which makes it selective only to HClO, this project studies the pH dependence and the conductivity dependence of chlorine in water using multivariate techniques. Specifically, thanks to the use of Multiple Linear Regression (MLR), it has been possible to study this actual problem in a rational manner [3].

This research has therefore resulted in the development of a chemo-assisted analytical method that not only allows the miniaturisation of two measurements by a single electrode but, thanks to MLR prediction, makes the device scalable without the need for calibration at each installation point [4].

This collaboration exemplifies an effective model of technology transfer, where academic expertise in sensor chemistry meets industrial know-how in data management and IoT integration. The resulting device provides a versatile and robust tool for smart monitoring of water resources, supporting sustainability and environmental protection initiatives.

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Poster 27

Towards sensitive chemiluminescent cardiac stress detection: optimization of platinum nanozyme systems

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Platinum nanoparticles (PtNPs) are emerging as powerful nanozymes capable of catalyzing chemiluminescent (CL) reactions, representing a promising alternative to conventional enzyme-based systems such as horseradish peroxidase (HRP). Their intrinsic peroxidase-like activity, combined with exceptional stability and catalytic efficiency, can significantly enhance the sensitivity of analytical assays. Consequently, incorporating PtNPs into lateral flow immunoassay (LFIA) platforms—traditionally based on colorimetric detection—holds great potential for improving analytical performance. However, several challenges still hinder the application of PtNPs in CL detection. One of the main issues is the absence of chemiluminescent substrates specifically tailored for PtNPs. The commonly used luminol–H_2O_2 system typically produces extremely fast and intense signal bursts when catalysed by PtNPs, leading to transient light emissions that are difficult to record and quantify accurately. In addition, the CL response depends strongly on nanoparticle characteristics such as size, morphology, and surface chemistry. In particular, antibody conjugation, required for integration into LFIA platforms, can markedly influence both signal intensity and kinetics. Hence, achieving uniform PtNP batches is crucial for obtaining reproducible and stable CL responses, enabling the fine-tuning of reaction conditions to prevent flash-type kinetics. This study aims to optimize both the composition of the chemiluminescent substrate and the PtNP concentration to achieve a steady and quantifiable CL signal. Owing to their distinctive catalytic properties, PtNPs constitute a promising and innovative alternative to traditional enzymes in CL-LFIA systems. Such platforms could pave the way for sensitive, portable, and robust diagnostic devices suitable for point-of-care detection of cardiac stress biomarkers.

Acknowledgements

ASI Project - GRAVI-CUORE: Biosensore multiparametrico per il monitoraggio di marcatori salivari di danno cardiaco in corso di volo umano spaziale

Poster 28

Raman Spectroscopy in optical and acoustic traps for micro- and nano-plastics detection: advancements in the SAMOTHRACE project

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The SAMOTHRACE project (www.samothrace.eu) is the Sicilian "ecosystem for innovation" funded by the EU and MUR within the NextGenEU – PNRR framework. Research is developed around the common themes of micro and nano technologies, micro- and nanophotonics, nano-materials, systems and devices, and directed towards six main areas: energy, health, intelligent mobility, environment, cultural heritage and smart agriculture. IPCF carries out research in the Environment Pillar, with the goal of developing advanced spectroscopic technologies, nano-materials and models for pollutants detection in air and water. This contribution summarizes the major advancements of the project in the fields of instrumental techniques development based on Raman Acoustic/Optical tweezers and applications for microparticles analysis in liquid environment, as well as in electromagnetic modeling of optical trapping forces of microplastics using deep learning [1-4].

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Poster 29

Molecularly Imprinted polypyrrole polymers: A strategy for the determination of glyphosate in real samples.

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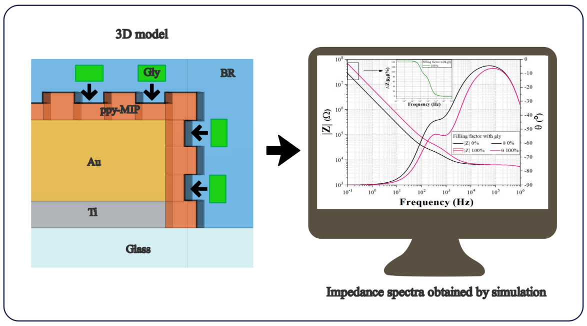
Molecularly imprinted polymers (MIPs) coupled with electrochemical transducers enable selective, low-cost, and portable detection of glyphosate in environmental and food samples. MIPs create recognition sites complementary to glyphosate's structure, ensuring high selectivity even in complex matrices. When integrated onto screen-printed or metal electrodes, they produce measurable electrochemical signals, i.e., current, potential, or impedance, upon glyphosate binding. Recent advances, including electroactive MIP films [1], surface-imprinted polypyrrole nanotubes [2], and nanomaterial-enhanced composites [3], have achieved low detection limits (ng·L^{-1} - nM), good reproducibility (RSD < 5–7%), and successful application to real water and food samples with minimal pretreatment. These systems complement chromatographic methods by providing faster, cheaper, and simpler on-site monitoring. Key challenges remain, including matrix interferences, fouling, stability, and validation against reference methods, but ongoing improvements in imprinting chemistry and device integration are driving progress toward reliable field-deployable sensors.

This study employs a polypyrrole-based molecularly imprinted polymer (MIP) as a recognition layer for glyphosate detection in real samples. The MIP was synthesized via electropolymerization followed by overoxidation and characterized using Electrochemical Impedance Spectroscopy (EIS) across different frequencies. Real sample concentrations (0, 0.41, and 0.51 ng/mL) were analyzed sequentially on the same sensor. The impedance magnitude changes with increasing glyphosate concentration, reflecting changes in the MIP's electrical properties, and confirming that the imprinted sites promote glyphosate incorporation within the polymer matrix and achieving detection of concentrations as low as 0.1 pg/mL. Graphical abstract illustrating glyphosate detection via a polypyrrole-based molecularly imprinted polymer using electrochemical impedance spectroscopy [4].



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Poster 30

An Innovative Chemiluminescent Approach to Type III CRISPR-Cas Nucleic Acid Sensing

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CRISPR-Cas systems serve as adaptive immune mechanisms in prokaryotes, enabling them to target and neutralize invading mobile genetic elements. These systems are divided into two major classes and several subtypes, among which Type III systems stand out for their RNA-targeting activity. Guided by CRISPR RNA (crRNA), Type III systems employ a multi-subunit effector complex to recognize and degrade foreign RNA molecules. This recognition event also activates the Cas10 subunit, which catalyses the synthesis of cyclic oligoadenylate (cOA) signalling molecules. The cOA molecules subsequently activate effector proteins containing sensory domains, triggering additional biochemical responses [1].

The unique signal amplification capability of Type III CRISPR-Cas systems has been harnessed for innovative nucleic acid detection methods. A well-established approach couples the cOA-activated RNase Csx1 with an RNA-targeting CRISPR complex to generate a measurable fluorescent signal [2]. However, fluorescence-based detection requires external light excitation, which complicates integration into compact, field-deployable diagnostic devices.

To overcome this limitation, a chemiluminescent (CL) detection strategy has been developed. This method uses a G-quadruplex (G4) RNA probe capable of catalysing a chemiluminescent reaction between luminol and hydrogen peroxide in the presence of hemin. Upon detection of the target RNA, the CRISPR-Cas complex activates Csx1, which cleaves the G4 probe, thereby diminishing the chemiluminescent signal. This system provides a simple, highly sensitive, and light-independent readout. The chemiluminescent detection approach thus represents a practical solution for portable and efficient nucleic acid diagnostics, making it especially suitable for on-site testing applications.

This work was supported by the Nano-ImmunoEra project that has received funding from the European Union's MSCA Staff exchange Horizon Europe programme, Grant Agreement Number 101086341.

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Poster 31

Oxygen paper-based sensor integrated into a multi-sensor array for an Organ-on-a-Chip device

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Organ-on-chip (OoC) technology has recently revolutionised biomedical research, offering more accurate models than traditional in vitro and in vivo systems. These microfluidic devices replicate human organs' structure and function by culturing living cells in 3D environments, enabling dynamic biological processes such as fluid flow and mechanical forces. Sustainability drives progress across many fields.[1] Here, we report the development of a novel paper-based electrochemical sensor for dissolved oxygen detection, to assembly in a paper-based OoC. The device was fabricated on a wax-patterned paper substrate to make an impermeable zone, where Ag/AgCl and graphite inks were sequentially printed to form the pseudo-reference, working, and counter electrodes. The working electrode was further modified with a carbon black dispersion by drop-casting, enhancing the electrode's surface conductivity and catalytic activity. The choice of carbon black as electrode modifier was inspired by its proven ability to enhance electrochemical oxygen detection[2]

The sensor operates via chronoamperometric detection, enabling continuous monitoring of dissolved oxygen in phosphate buffer media. Preliminary studies demonstrated that carbon-black modification significantly enhances signal stability, current response, and reproducibility. The RSD% for the saturated solution was 81% with the bare electrode, compared to only 9% for the modified electrode. Continuous measurements over two hours on a solution purged with N_2 for 15 minutes and then exposed to air confirmed the excellent responsiveness of the sensor. The current initially measured – 0.842 µA, increased to – 3.023 µA after 30 minutes, and reached – 3.697 µA after two hours. The minimal variation observed after the first 30 minutes (ΔI = 0.674 µA) indicates that the current had reached a stable plateau, suggesting that equilibrium conditions were achieved within this period. The proposed device represents a low-cost, sustainable, and flexible analytical platform for real-time oxygen monitoring, with potential applications in OoC systems.

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Poster 32

Portable electrochemical sensoristic system for the on-site measurement of cannabinoids

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In recent years, the EU common agricultural policy has provided subsidies for the cultivation of certain varieties of the *Cannabis sativa* L. plant for industrial uses, provided the principal psychoactive constituent, Δ^9-tetrahydrocannabinol (Δ^9-THC), does not exceed 0.3% w/w [1]. Moreover, in many countries, *C. sativa* derivatives such as oils, biscuits, and even dried parts of the plant can be freely sold. However, in freely commercialized products it is not uncommon to find Δ^9-THC concentrations exceeding the legal limit. Therefore, accurate controls to meet specific regulations are mandatory. The analysis of cannabinoids such as Δ^9-THC, cannabidiol (CBD) and their natural acidic precursors (i.e. Δ^9-THCA and CBDA), in *C. sativa* samples (female inflorescences) is usually carried out by chromatographic techniques [2-4]. However, the equipment cost, the reagent consuming sample preparation, the need for trained personnel, and long analysis times are remarkable drawbacks, preventing their use in-situ.

As promising alternatives to these techniques in allowing real-time and fast cannabinoid screening, electrochemical sensors have been receiving considerable interest, thanks to their low cost, handiness, and miniaturization possibility [5]. In fact, Δ^9-THC, CBD, Δ^9-THCA and CBDA are electroactive, due to the oxidation of the phenolic group, which makes them good candidates for electrochemical analysis. Our research group has recently demonstrated that screen printed electrodes (SPEs), modified with a carbon black (CB) coating, can be used for the fast quantification of Δ^9-THCA in recreational type *C. sativa* extracts [6] and, using a multivariate approach, for the correct classification of most *C. sativa* samples into the classes of legal and illegal samples according to total Δ^9-THC content [7]. The obtained results suggest the possibility to consider the proposed method as a starting point for the implementation of an automated device for rapid pre-screening of total Δ^9-THC content directly on site.

The design of a portable device for on-field measurements represents the final stage in the configuration of a sensor system. The ideal device should facilitate all stages of analysis, from weighing the sample to recording the relevant electrochemical signal, in order to minimise and simplify the operations required by the operator. This study describes the developed measuring system prototype and the measurement principle. It also illustrates the proposed measurement procedure and the experimental activities performed for its preliminary verification.

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Poster 33

Optimizing Plasmonic Nanocrystals for Enhanced Fluorescence: New Trends in Optical Sensing Technologies

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In recent years, nanophotonics has increasingly focused on the optical properties of metal nanostructure arrays, especially those combining plasmonic and diffractive resonances. When designed to meet periodicity conditions, such arrays enable the coupling between localized plasmonic resonances and diffractive modes, resulting in distinctive optical responses [1]. Acting as nanoscale resonant cavities, they modulate light–matter interactions and produce strong electromagnetic field enhancement, offering promising opportunities for sensing and light management [3].

This study presents a systematic investigation of ordered metal nanostructure arrays fabricated on planar substrates, aimed at advancing optical sensing technologies. A combined theoretical–experimental approach was employed to identify the structural parameters that maximize electromagnetic field localization and optical signal enhancement at the metal–dielectric interface. By tuning array geometry, the conditions for amplifying fluorescence emission from molecular monolayers in close proximity to the metallic surface were optimized, resulting in enhanced emission efficiency and reduced decay times.

Exploiting these plasmon-assisted enhancement effects, we realized proof-of-concept experiments for miRNA detection, where the strong near-field amplification provided by the nanostructured transducers enabled sensitive optical readout of specific target sequences. The results demonstrate that coupling between plasmonic and photonic modes can substantially improve biosensor performance, paving the way for new high-efficiency plasmon-based optical platforms.

Overall, the findings provide valuable insights into nanoscale light–matter coupling and contribute to the development of more sensitive and reliable biosensors [4]. The approaches outlined here could also inspire future applications in environmental monitoring and medical diagnostics, where enhanced optical transduction is crucial.

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Poster 34

Reduced Graphene Oxide–Gold Nanoparticle Hybrid Substrate for Surface-Enhanced Raman Detection of Pesticides

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Reduced graphene oxide (rGO) decorated with gold nanoparticles (AuNPs) represents an appealing strategy for developing cost-effective and reproducible substrates for surface-enhanced Raman spectroscopy (SERS). In this work, a hybrid nanocomposite was synthesized through a simple one-pot route, where AuNPs were grown in situ onto rGO functionalized with 1-aminopyrene (AP) as a non-covalent π–π linker. The hybrid material was deposited on glass by drop-casting to obtain thin, SERS-active films. Transmission electron microscopy (TEM), atomic force microscopy (AFM), and UV–Vis spectroscopy confirmed a uniform distribution of 7–8 nm AuNPs on rGO and a strong plasmonic response with the localized surface plasmon resonance (LSPR) centered at 526 nm, red-shifted to 620 nm upon film formation. The SERS activity was first tested using Rhodamine 6G (R6G) as a molecular probe, subsequently, the substrate was applied to detect the pesticide thiram, yielding clear typical Raman bands and a linear response between 10^{-2} M and 10^{-5} M, corresponding to a limit of detection of ~1×10^{-5} M (≈ 2.4 ppm). These findings highlight the reproducibility and quantitative capability of the rGO–AuNP hybrid system. The combination of plasmonic and graphene-induced chemical enhancement makes this nanostructured film a scalable, low-cost SERS platform suitable for rapid pesticide residue screening in agrifood and environmental analysis.

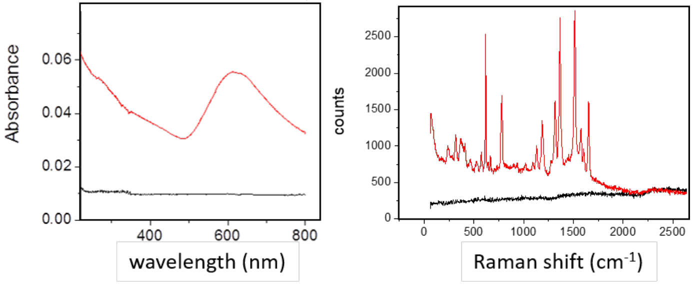

Figure 1 – (Left panel) Optical absorption spectra of rGO (black curve) and PyNH2-rGO/AuNPs (red curve) deposited on a glass substrate. (Right panel) SERS spectra of Rh6G deposited, at the same concentration, on PyNH2-rGO (black curve) and PyNH2-rGO/AuNPs (red curve).

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Poster 35

Singling Out the Electrochemiluminescence Profile in Microelectrode Arrays

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Among various electrochemical imaging techniques, Electrochemiluminescence Microscopy (ECLM) stands out for its ability to visualize electrochemical reactions by converting localized reactivity into optical signals [1-4]. This study explores the spatial distribution of ECL light emission in a confined space using microelectrode arrays (MEAs) fabricated on glassy carbon (GC) and gold (Au) substrates through thermal nanoimprint lithography (TNIL). Using the Ru(bpy)$_3^{2+}$/TPrA system, ECL imaging revealed distinct emission profiles, with Au exhibiting a broader spatial distribution compared to GC under identical geometric conditions.

To quantify these differences, we defined the thickness of the ECL emitting layer (TEL) as the distance from the centre of the microelectrode surface to the point where ECL intensity approaches zero. For the GC MEA, this distance was approximately 4 µm, while the Au MEA showed a more expansive TEL of about 7 µm, as derived from their respective ECL intensity profiles.

These differences in ECL behaviour were attributed to the interplay between electrode material and the dominant ECL mechanism.

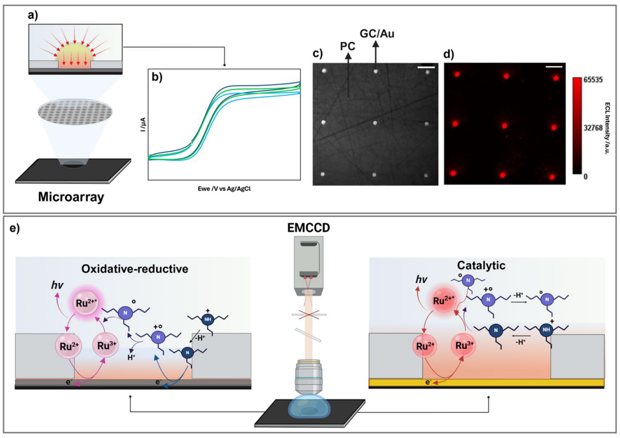

Figure 1 *(a) Schematic of hemispherical diffusion at a recessed microelectrode array. (b) Simplified cyclic voltammograms of the microelectrode array. (c) Optical image of a GC carbon microelectrode array (2.5 µm spot diameter, 30 µm spacing. (d) Corresponding ECL image.*

Reducing the Ru(bpy)$_3^{2+}$ concentration had minimal impact on the GC ECL profile, consistent with a predominant oxidative-reductive mechanism. However, a significant narrowing of the ECL profile was observed on Au, indicating a transition from a catalytic to an oxidative-reductive pathway. These findings were supported and rationalized by finite element simulations. Our results highlight the ability to fine-tune TEL and modulate ECL emission through electrode material selection and luminophore concentration. This level of control has important implications for developing highly sensitive and spatially resolved bioanalytical assays, particularly those utilizing bead-based detection methodologies.

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Poster 36

New coreactant set to enhance electrochemiluminescence for bead-based immunoassays

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Sepsis and bacterial infections are the leading causes of death in hospitals, arousing more than 30 million of deaths per year, worldwide.[1] Due to the unspecific symptoms and antibiotic administration, most bacterial pathogens are drug- or multidrug-resistant. The current methods for sepsis diagnosis based on blood culture take time and results are often obtained after 24-48 hours. The inadequate or delayed treatment increases mortality and antimicrobial resistance.[2] Innovative and highly sensitive sensors are required to accelerate pathogen identification, enabling a direct and early diagnosis. Electrochemiluminescence (ECL), a powerful bioanalytical technique due to its high signal-to-noise ratio and low detection limits, is emerging as a novel and accurate approach for fast biomarkers’ detection.[3] Bead-based immunoassay analyzers employ biotinylated and dye-functionalized antibodies to specifically recognize a target antigen, providing ECL signals proportional to its concentration.[4][5] Commercial ECL-based immunoassays typically exploit the coreactant mechanism between tris(2,2’-bipyridine)ruthenium(II) ($Ru(bpy)_3^{2+}$) and tri-n-propylamine (TPrA) as luminophore and coreactant, respectively. To produce the emitting $Ru(bpy)_3^{2+*}$, first $Ru(bpy)_3^{2+}$ is reduced by $TPrA^{\bullet}$ and then excited by the electrogenerated $TPrA^{\bullet+}$. Therefore, the ECL response is determined by the radical intermediates’ lifetimes and diffusion distances, and a mechanism insight is key to obtain higher ECL signals. In addition, TPrA is highly toxic and presents a poor solubility in non-buffered aqueous solutions, making the pursuit of safer and more hydrophilic coreactants particularly interesting.

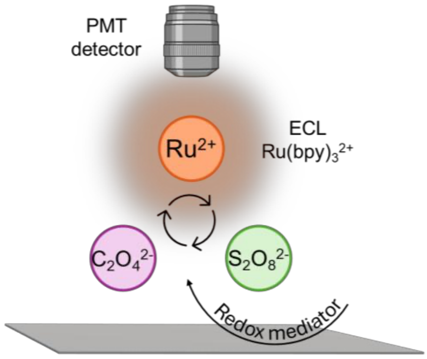

Figure 1. Scheme of the autocatalytic ECL generation.

We investigate the mechanism underlying the modulation of the ECL signal and its optimization for biosensors’ development. We analyse the reaction mechanism pursuing an enhancement of the ECL signal of $Ru(bpy)_3^{2+}$, employing a combination of ECL imaging techniques. Herein, we present an innovative approach to replace TPrA by an autocatalytic coreactant system.

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Poster 37

Pristine Bamboo-Derived Biochar for the Electrochemical Detection of Amoxicillin in Aqueous Samples

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The emergence of antibiotic-resistant genes, a significant threat to global health, is driven by the environmental release of antibiotics like amoxicillin (AMX) resulting from an incomplete metabolism in humans and animals. AMX has been detected in various aquatic systems, including effluents and the Mediterranean Sea [1]. It is essential to develop sensitive and low-cost electrochemical methods for its routine monitoring [2]. We report the electrochemical detection of AMX using bamboo-biochar (B_{800}) prepared by slow pyrolysis at 800 °C without chemical or physical activation [3]. B_{800} was dispersed by ultrasonic bath (30 min) in N,N-dimethylpyrrolidone and deposited on screen-printed electrodes (SPE) by the drop-casting technique (Fig. 1 A). The electrochemical behavior was studied using cyclic voltammetry (CV) ($K_3Fe(CN)_6$ 1 mM in KCl 100 mM) (Fig. 1 B, C). Then, differential pulse voltammetry (DPV) was employed for AMX detection in 0.1 M phosphate buffer (pH 7.0) with a 0.05 V pulse amplitude, 0.1 s pulse time, 0.04 V pulse width, and 20 mV s^{-1} scan rate (Fig. 1D). The B_{800}-modified electrode exhibited a significantly higher electrochemical response toward AMX compared to bare SPE electrodes. Moreover, the B_{800} was further modified by adding carbon nanotubes (CNT), but the B_{800}-SPE electrode still performed better than the B_{800}CNT-electrodes.

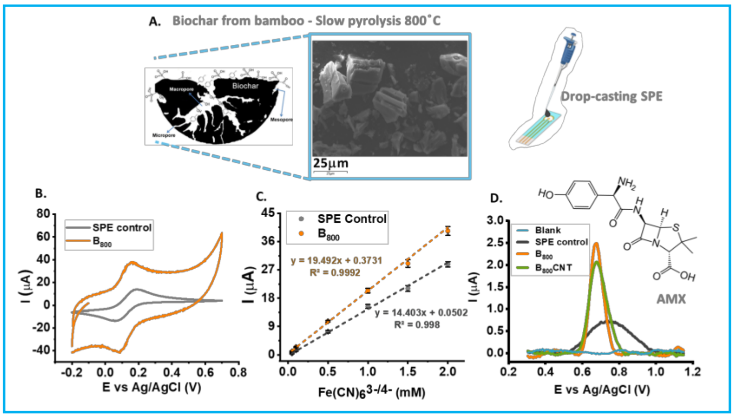

Figure 1. Experimental procedure to detect AMX using non-activated biochar. Electrochemical characterization of modified SPE electrodes by CV (B, C) and AMX detection by DPV (PBS 1mM, pH7) (D) using a SPE control, B_{800} and B_{800}-CNT.

Unlike many electrochemical sensors that rely on costly enzymes, metal oxides, or nanoparticle-based modifiers to achieve selectivity and sensitivity, the proposed method uses non-activated biochar from bamboo as a single, sustainable sensing platform (LOD 2.8 µM). This material provides abundant active sites and excellent electron transfer capability, eliminating the need for additional modifiers while maintaining high analytical performance. This simplicity reduces fabrication costs and complexity, making it a practical option for real environmental applications. These findings demonstrate that bamboo-derived biochar is a promising, sustainable, and efficient sensing material for electrochemical applications.

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Poster 38

"Development of Capillary PDMS-Based Microcolumns for Portable Chromatographic Gas Analysis Systems"

Massimiliano Negri[1,2,3], Ivan Elmi[1], Michele Morana[2], Brais Vasquez Iglesias[2], Stefano Rizzi[2], Elena Spagnoli[1], Stefano Zampolli[1]

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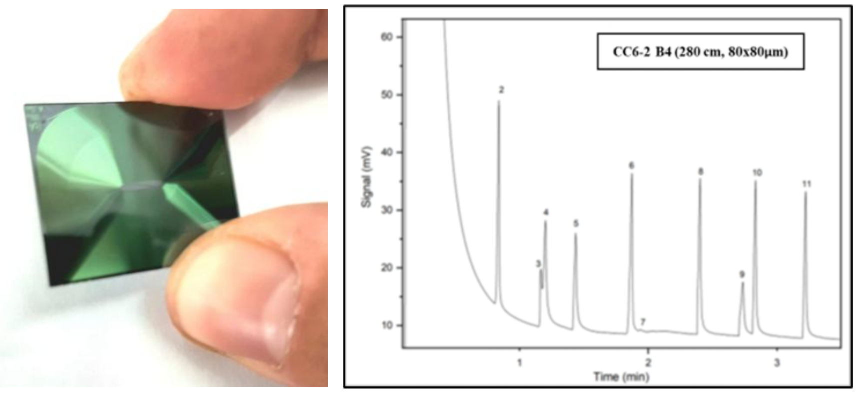
Analyzing complex gas mixtures is crucial across many areas, including environmental monitoring, industrial process control, forensic science, and medical diagnostics. These disciplines often demand highly accurate detection and measurement of volatile compounds present in very small quantities. Gas Chromatography–Mass Spectrometry (GC-MS) is considered the gold standard for such analyses; however, its bulkiness, reliance on a carrier gas, and high energy consumption make it unsuitable for on-site measurements.

In recent years, the advent of microtechnologies—particularly Micro-Electro-Mechanical Systems (MEMS)—has transformed this field. Microinjectors, micro-preconcentrators, micro-detectors and micro-columns enable the development of increasingly compact gas chromatographs, reducing power consumption and analysis times while supporting portable instruments. A commercially available example is the **Pyxis GC**, which employs a miniaturized packed column filled with Carbograph, a PID detector and a preconcentrator filled with cavitands as selective sorbents for rapid analysis of volatile aromatic compounds. This solution demonstrates the feasibility of compact systems but also highlights the limitations of packed columns, which provide less efficient separations and longer analysis times compared to capillary alternatives.

To achieve faster and more efficient GC separations, the proposed work explores innovative MEMS capillary columns coated with PDMS, selected as the stationary phase for its chemical inertness, thermal stability, and low bleeding. The main objective is to develop a process capable of properly functionalizing a MEMS column, enabling the application of this technology to create a portable, miniaturized fast-GC system capable of performing rapid quality analyses of gas mixtures minimizing the bulk and operational complexity associated with conventional laboratory-scale GC-MS instruments.

Figure 1 shows a 20 mm × 20 mm MEMS column, functionalized through the process developed in the present study, together with the chromatogram obtained from the injection of the Grob Test II mixture.



2. *Alkane;*
3. *Alcol*;
4. *Alkane;*
5. *Aromatic Alcol*
6. *Nitroaromatic*
7. *Acid*
8. *Amine*
9. *Ester*
10. *Ester*
11. *Ester*

Figure 1: MEMS capillary column (left), example of chromatogram performed with Grob test II mixture (center) and identification of the Grob test peaks (right)

Poster 39

Miniaturized CRP immunosensor for spaceflight health diagnostics

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The increasing focus on deep space exploration has brought crew health monitoring to the forefront of mission planning. Prolonged exposure to microgravity and space radiation poses serious physiological risks, including muscle atrophy, bone demineralization, and cardiovascular dysfunction [1]. To mitigate these threats and maintain peak performance, there is a growing need for preventive strategies and real-time diagnostic tools that can operate autonomously in space environments. Among the biomarkers of interest, C-reactive protein (CRP) has emerged as a critical indicator of systemic inflammation and cardiovascular risk. Elevated CRP levels have been strongly correlated with infarct severity, post-ischemic complications, and sudden cardiac death, even in asymptomatic individuals [2]. Monitoring CRP levels in astronauts could therefore provide early warning of inflammatory or cardiovascular events during long-duration missions. In this study, we present a chemiluminescent immunosensor designed for CRP detection in biological fluids, integrating a disposable microfluidic cartridge with an array of hydrogenated amorphous silicon (a-Si:H) thin-film photosensors. The cartridge features microchannels functionalized with immobilized anti-CRP antibodies. Upon sample introduction, CRP is selectively captured and detected via a biotin-labelled secondary antibody and streptavidin conjugated with horseradish peroxidase. The chemiluminescent signal, generated by a luminol/peroxide cocktail, is acquired by the photosensor array, enabling quantitative analysis. Preliminary results demonstrate a strong linear correlation between CRP concentration and chemiluminescent signal intensity, with a detection limit of 2.8 ng/mL, well within the range required for clinical relevance. The system's compact design, low power consumption, and disposable format make it a promising candidate for integration into spaceflight health monitoring platforms. Future developments will focus on enhancing the robustness of the assay, expanding its multiplexing capabilities to include additional biomarkers, and validating its performance under simulated spaceflight conditions. This work was supported by the Space It Up project, funded by the Italian Space Agency (ASI) and the Ministry of University and Research (MUR), under contract n. 2024-5-E.0 – CUP n. I53D24000060005.

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Poster 40

Integrated 3D-printed/paper electrochemical device for the direct quantitative sensing of Amitraz

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The use of amitraz to control the Varroa destructor parasite in honeybee colonies is a common practice, widely employed by both amateur and professional beekeepers. Although effective against the parasite, the use of amitraz remains controversial because its toxic metabolite, 2,4-dimethylaniline (2,4-DMA), can persist in honey and beeswax, potentially causing serious environmental and health issues. Conventional chromatographic techniques are still used to detect these residues, but they are expensive, cumbersome, and not suitable for in-field applications.

In this work, a fully lab-made 3D-printed electrochemical device for analyzing Amitraz is proposed. The device consists of a PLA functional scaffold featuring a hydrolysis rotary valve, designed to hold an interchangeable paper sensor. In brief, the 3D device's rotary valve allows for sample loading, and a disposable paper strip facilitates amitraz hydrolysis at 2,4-DMA. After opening the valve, the sample is transported to the sensor chamber, designed to hold the paper-based sensor, using a neutralization medium. The paper sensor provides the required electroanalytical performance to detect the analyte.

Initially, several standard and recycled papers were tested in combination with different types of carbon-based conductive inks to create an effective paper sensor. The combination of drawing paper and carbon paste ink (DP-CP) proved to be optimal, offering a high electroactive surface area, low charge transfer resistance, and superior sensing ability toward 2,4-DMA. The 3D-printed device equipped with the DP-CP paper-sensor demonstrated excellent analytical performance, showing a wide linear range (0.05–100 µM), a low limit of detection (LOD = 14 nM), and good reproducibility (RSD ≤ 7%). Eventually, the applicability of the integrated platform has been confirmed on real matrices, including various types of honey and beeswax, yielding quantitative recoveries (95.8%–112.2%) and good reproducibility (RSD ≤ 12%).

Summing up, a portable platform that includes all Amitraz analysis steps and provides reliable results in 10 min has been developed, combining the multifunctionality of paper with the versatility of 3D printing, enabling pretreatment-free analysis of beekeeping matrices.

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Poster 41

Smart Composites for Water Screening: rGO-Lysine/Chitin nanocrystals for Glyphosate Detection

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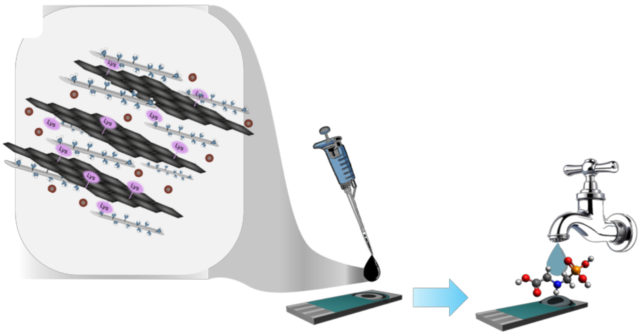
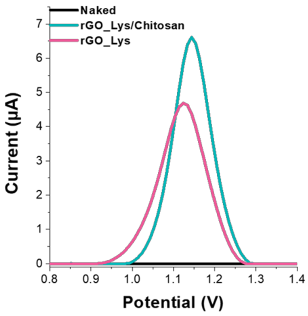
The widespread use of glyphosate (GLY), a globally prevalent herbicide, necessitates robust water quality monitoring (1). Current laboratory-based confirmatory techniques (e.g., chromatography, mass spectrometry) are highly sensitive but suffer from limitations in cost-affordability, portability, and throughput, restricting their suitability for scalable, routine water screening (2,3). There is a critical need for complementary, **on-site screening methods** that can rapidly assess contamination levels. By designing advanced composite materials, we can develop sensors that not only match the requirement for portability but also the ones of cost-affordability and scalability. In this frame, **amino acid-modified graphene oxide materials** were tested for enhancing the detection of pesticides like GLY in water matrices (4).

We report the development of a **smart composite** based on **Lysine-modified reduced Graphene Oxide (rGO-Lys), surface deacetylated chitin nanocrystals, and copper ions** for the enhanced electrochemical indirect detection of GLY in water. A design of experiments approach was implemented to precisely optimize the composite mixture, ensuring maximum stability and reproducibility. Comprehensive material characterization confirms the pronounced synergistic performance of the final composite compared to its individual components, particularly in terms of electrochemically active surface area and binding affinity.

This advanced sensing strategy achieves a detection capability in the order of ppb, successfully reaching the stringent European Union regulatory limits for GLY in drinking water (LMR= 0.1 µg/L). The developed sensor was successfully applied for the accurate and reliable determination of in **real water samples**, demonstrating its practical utility as a **cost-effective and scalable screening tool** for immediate water quality assessment.





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Poster 42

Designing Gold-based Electrodes for the Future: Sensitivity, Stability, and Bimodality

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Electrodes modified with metal nanoparticles are widely utilized in many fields, ranging from sensing to energy applications, as they combine the exceptional catalytic properties of metals with high surface area. However, traditional chemical synthesis methods often face challenges such as limited nanoparticle deposition and inconsistent reproducibility.

In this study, gold films were deposited onto FTO-coated glass slide electrodes through sputtering. Annealing of the deposited films resulted in the dewetting of the film and formation of gold nanoparticles. The prepared electrodes were investigated using SEM, UV-Vis spectroscopy and electrochemistry, revealing that the nanoparticles have narrow particle size distribution, with average size related to the initial film thickness.

The electrodes were evaluated for their stability, performing consecutive tests in $K_4[Fe(CN)_6]$, and sensitivity, detecting H_2O_2. Smaller nanoparticles, while less stable, present enhanced sensitivity compared to larger nanoparticles or even metal films, normalizing by amount of deposited material and surface area.

Finally, strategies for nanoparticle protection were tested to preserve their performance while extending the electrode's lifetime. A deposition of a porous layer of TiO_2 was used to prevent the loss of metal in solution, effectively increasing the chemical and mechanical robustness of the device.[1]

TiO2 film was deposited using wet chemistry from a TiO_2 sol, and then calcined to obtain the desired crystal structure. This also enabled the integration of new properties related to the photoactivity of the layer in the device, such as the photo-renewability under UV irradiation to prevent fouling of the surface, paving the way for application in real samples and complex matrices.

The photogenerated charge carriers were also used to oxidize species on the surface. This, in combination with other analytical techniques, was exploited to prepare a bimodal electrochemical – photoelectrochemical sensor that improves the reliability of the detection.[2]

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Poster 43

Electrochemical Sensors for Hashish Cannabinoid Profiling

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The 2024 World Drug Report by UNODC confirms that cannabis remains the most widely used drug globally [1]. Hashish, a key psychotropic product derived from cannabis, is produced from the sticky resin extracted from the female flowers of the plant, mixed with plant particles, and typically sold as a yellowish-brown paste that becomes malleable when heated. Its psychoactive effects are due to specific cannabinoids, with Δ^9-tetrahydrocannabinol (Δ^9-THC) being the most potent. Δ^9-THC interacts strongly with CB1 receptors in the central nervous system, producing its characteristic effects. Quantitative analysis of hashish seizures reveals an important variability in Δ^9-THC content, influenced by the quality of the raw material and the subsequent preparation steps. These factors lead to differences in the physical appearance, density, moisture content and flavour of the final product [2].

In this study, we employed an innovative approach using electrochemical sensors for the rapid screening and quantification of cannabinoids in various seized hashish samples. Among the different types of electrodes tested, Carbon Black modified Screen Printed Electrodes (SPEs-CB) demonstrated the best performances in terms of signal intensity, reproducibility and resolution of voltammetric peaks, confirming the results of our previous study regarding *Cannabis sativa* L. samples [1-2]. The voltammetric signals recorded were found to correlate well with the cannabinoid content of the samples in accordance with the results of the HPLC analyses. This enabled the rapid identification of the major cannabinoids. Notably, we were able to correlate the voltammetric signal with the total cannabinoid content, a key parameter for assessing the potency of hashish samples. Furthermore, the quantification of total Δ^9-THC was successfully achieved in samples particularly rich in psychoactive compounds.

This study highlights the potential of SPEs-CB as effective tools for the rapid and reliable detection of cannabinoids in cannabis-derived products. These results pave the way for the development of low-cost analytical devices suitable for field applications, forensic investigations and quality control in the cannabis industry.

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Poster 44

Surface-Deacetylated Chitin Nanocrystals (CsNCs) for Biocompatible Sensing

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Chitosan, a derivative of chitin, is a copolymer of randomly distributed N-Acetylglucosamine (GlcNAc) and glucosamine (GlcN) units, obtained via the partial removal of acetyl groups—a process called deacetylation. The degree of deacetylation is a key parameter that indicates the ratio of GlcNAc to GlcN units. In dilute acids, the protonation of chitosan's amino groups (pKa~6.3) allows it to function as a cationic polyelectrolyte, thus overcoming the solubility issues often associated with chitin [1]. As a semi-crystalline material, chitin is characterized by the presence of both crystalline and amorphous domains.

In this study, we focused on its abundant and sustainable derivative: chitin nanocrystals (ChNCs). These nanocrystals were obtained through the acid hydrolysis of shrimp chitin flakes. They were subsequently treated in an alkaline environment to produce surface-deacetylated chitin nanocrystals (CsNCs). Ultimately, these CsNCs are presented as a versatile, high-performance, and biocompatible platform for developing electrochemical sensing strategies [2].

To start, the electrochemical behavior of both chitin and its deacetylated derivatives was investigated using cyclic voltammetry and electrochemical impedance spectroscopy. We mapped how the deacetylation process influences the charge transfer kinetics, correlating the degree of deacetylation with enhanced charge transfer performance (Fig. 1). This characterization study was followed by a proof-of-concept application: CsNCs were further applied to design an indirect electrochemical sensing strategy for glyphosate.

This research holds high relevance for the growing field of portable sensors for environmental monitoring. The utilization of biocompatible and sustainable materials, such as the CsNCs investigated here, represents a crucial step towards lowering the ecological impact of these emerging devices, particularly for the analysis of water pollutants [3].

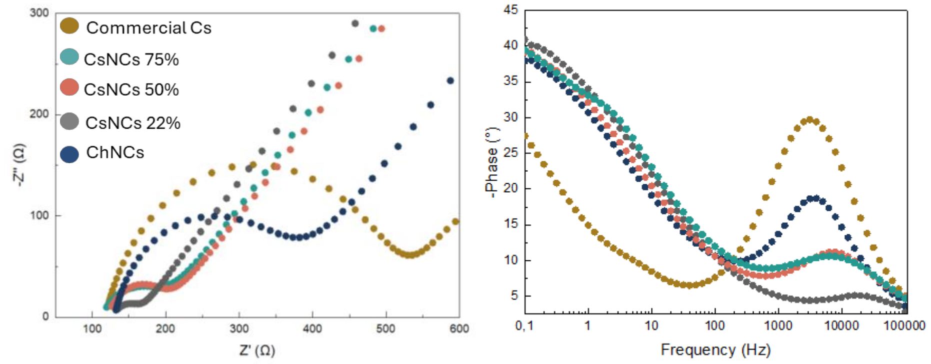

Figure 1. Nyquist plot (left) and bode phase (right) of different surface-deacetylated chitin nanocrystals and commercial chitosan in 0.5 mM of $K_3[Fe(CN)_6]/K_4[Fe(CN)_6]$ using a glassy carbon electrode.

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Poster 45

Electrochemical Immunosensor based on Microneedles Array for the Detection of Amyotrophic Lateral Sclerosis Biomarkers in Human Interstitial Skin Fluid

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Amyotrophic Lateral Sclerosis (ALS) is a progressive neurodegenerative disease that leads to severe health complications including muscle atrophy, dysarthria, dysphagia, and respiratory failure, which is the primary cause of death [1]. Early diagnosis is crucial for improving treatment efficacy and increasing patient life expectancy. However, current prognostic indicators are limited, hindering both the diagnosis as well as the definition of the disease progression. Current diagnostic procedures rely mainly on clinical assessment and neurophysiological studies, and tissue biopsies are only performed in atypical cases to exclude alternative diagnoses. Moreover, the diagnostic process remains highly dependent on specialized ALS centers and is often not easily accessible to general neurologists, leading to diagnostic delays and variability in patient management. [2, 3]

The development of a minimally invasive analytical technique would facilitate testing even with marginal evidence of the disease. As recently demonstrated, ALS progression is accompanied by an increasing concentration of specific cytokines, such as Interleukine 18 and Interleukine 6 [4, 5]. Their detection does not require invasive biopsies of the tissues, since they can be also detected from interstitial skin fluid (ISF) [6, 7], which can be analysed by wearable sensors.

Here we propose a microneedle based electrochemical biosensor for the detection of cytokines in ISF. Two different strategies are proposed, including, respectively, hollow and solid microneedles. In the first case, the microneedles serve the purpose of sampling the ISF from the skin and a modified screen-printed electrode is used for the electrochemical detection. In the latter case, the microneedles are sputtered with gold and functionalized to serve as a platform for both the sampling and the detection of the biomarker from the ISF.

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Poster 46

Liquid Crystal–Templated Silver Electrodeposits for the Electrochemical Detection of Haloacetic Acids

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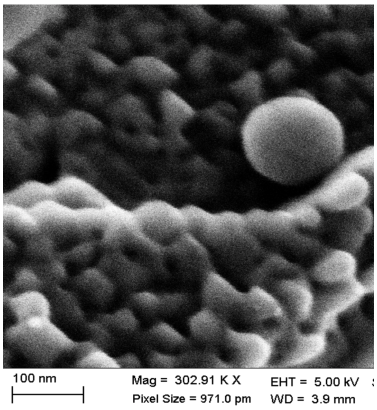
Haloacetic acids (HAAs) are ubiquitous disinfection by-products (DBPs) found in drinking and surface waters, and their routine monitoring is essential for public health protection. In recent years, electrochemical detection of HAAs has gained increasing attention as a low-cost, rapid, and potentially on-site alternative to conventional chromatographic methods [1,2].

Current research focuses on (i) the design of tailored electrode materials and nanocomposites that enhance electrocatalytic activity or adsorption toward halogenated acetic acids; (ii) biofilm- and bioreceptor-based platforms that assess HAA toxicity rather than direct concentration; and (iii) sensor arrays coupled with chemometric analysis that exploit electrochemical "fingerprints" to discriminate among HAA species in mixtures. These approaches have demonstrated excellent sensitivity and selectivity; however, key challenges persist, including matrix interferences (natural organic matter, halide background), electrode fouling, lack of standardized calibration against reference methods, and limited long-term stability and interlaboratory validation.

In this study, silver was electrodeposited on a gold electrode using liquid crystal phases composed of self-assembled non-ionic surfactant molecules [3]. The resulting Ag deposits exhibit a significantly larger electroactive surface area and enhanced catalytic activity compared with Ag nanoparticles. The modified electrodes were tested for monochloroacetic acid (MCAA), dichloroacetic acid (DCAA), and trichloroacetic acid (TCAA) detection via cyclic voltammetry. Five to six measurement sessions per electrode were conducted over the 10–1000 µM range, yielding reproducible and stable signals. In comparison with Ag nanoparticle-based systems reported in the literature, the electrodes produced consistent blank and sample responses. The figure below shows representative microstructures obtained using the electrodeposition strategy adopted in this study [3].



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Poster 47

Core breakage analysis in Shape sensing for structural health monitoring

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Shape sensing involves distributed strain measurements from cables containing multiple fiber cores or multicore optical fibers, enabling reconstruction of local curvature and bending angle for three-dimensional shape recovery via Frenet–Serret Frame reconstruction. In structural health monitoring (SHM), optical fiber bundles are employed as sensing cable due to their increased sensitivity stemming from larger radial offsets relative to the neutral axis. However, due to the stronger stresses involved in SHM, cores in fiber bundles are susceptible to breakage, compromising measurement reliability [1].

In this work, we examine the influence of sensing core breakage on the accuracy and symmetry of curvature vector estimation in fiber-bundle-based optical fiber shape sensing.

To do so, we perform Monte Carlo simulations to quantify the effect of core loss on curvature vector estimation. In particular, we simulate 5-core fibers as shown in figure, set a given curvature, and introduced Gaussian noise to analyze pristine and damaged cases (one core excluded) across 720 bending orientations (0–360°, step = 0.5°). Results indicate that intact bundles yield orientation-independent error distributions for both curvature magnitude (as shown in figure) and bending angle. In contrast, core breakage introduces anisotropic error patterns: bending angle uncertainty is maximized when the missing core lies along the neutral axis (±90° offset), while curvature magnitude uncertainty is maximized when the missing core aligns with the bending axis.

These findings highlight that loss of symmetry from core breakage introduces direction-dependent biases in curvature vector estimation, underscoring the need to account for such effects in shape sensing SHM applications to ensure robust and reliable shape sensing under operational damage scenarios.

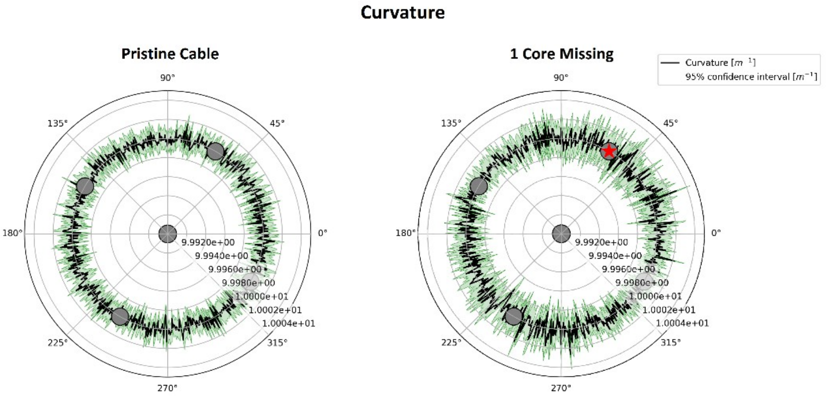

Figure: Polar plot for the curvature. The excluded core is highlighted with a red star.

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Poster 48

ϕ-OTDR applied in on-bridge vehicle detection

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Distributed optical fiber sensors enable continuous measurements of strain, temperature, and other parameters along the full length of an optical fiber using a single interrogating device. This makes them highly suitable for large-scale structural monitoring. Among these, Distributed Acoustic Sensors (DAS), typically implemented through phase-sensitive Optical Time Domain Reflectometry (ϕ-OTDR), can detect dynamic strain variations at kilohertz frequencies over fiber lengths of tens of kilometers, with spatial resolutions on the order of meters. ϕ-OTDR technique operates by sending optical pulses into a single-mode fiber, where Rayleigh scattering what is known as Rayleigh Backscattered (RBS) light. By applying phase demodulation techniques to the RBS traces, it becomes possible to track phase evolution and thereby obtain information on the change of strain at every fiber point.

This work reports on a field test of a ϕ-OTDR-based DAS system, which was previously developed in [2] for vehicle detection on a highway bridge in the Netherlands. The sensing cable, 440 meters in length, was divided into four parallel branches (10–20 m each) positioned along the slowest southbound lane. We tested multiple pulse width conditions (5–14 ns), as shown in the figure, and analysis of phase signatures for pulse widths of 10 ns and 14 ns revealed that each vehicle axle produced a distinct crest–valley pair, enabling axle counting and classification of vehicle types. For instance, four-axle trucks generated four identifiable features, while two-axle passenger cars produced two. Furthermore, vehicle velocities were estimated from the slope of the vibrational bands, with measurements yielding speeds of approximately 95 km/h, consistent across both vehicle classes. The results demonstrate the feasibility of ϕ-OTDR-based DAS for real-time traffic monitoring, providing not only vehicle detection but also quantitative characterization of axle count and velocity, thereby supporting scalable and high-resolution infrastructure monitoring.

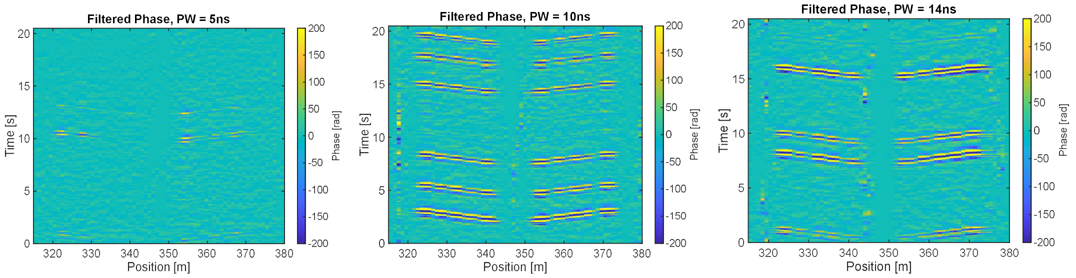

Figure: DAS measurements with passing vehicles for different pulse widths.

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Poster 49

Integration of Rolling Circle Amplification and Electrochemical Sensing for C-circles DNA Detection

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Alternative lengthening of telomeres (ALT) is a telomere length–maintenance mechanism present in 10–15% of cancers. One hallmark of ALT-positive cells is the presence, either inside cells or in extracellular vesicles, of c-circle DNA, i.e., circular telomeric DNA repeats. Because they are associated with ALT, C-circles DNA represent a potential biomarker for the early detection of cancerous cells from liquid biopsy samples, including blood. One method to detect C-circles DNA in a sample is their amplification via rolling circle amplification (RCA), an isothermal amplification technique that uses C-circles DNA sequences as templates and generates long single-stranded DNA concatemers.

This work describes the development of a device capable of coupling RCA with electrochemical detection of its amplification products. Using a redox probe such as methylene blue, which can interact with the single-stranded DNA produced by RCA, enables verification of the amplification outcome. Indeed, the change in the probe's peak current is directly correlated with the interaction of methylene blue with the amplification products. Moreover, exploiting an isothermal amplification such as RCA eliminates the need for a thermocycler, as required for conventional PCR. Electrochemical detection of successful amplification is performed using a minimal sample volume of approximately 20 µL demonstrating the potential for miniaturization and integration of amplification and detection within a single lab-on-chip platform. This approach represents an important step toward the realization of portable, point-of-care diagnostic tools for the early and sensitive detection of ALT-related cancers through liquid biopsy.

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Poster 50

CO_2-laser plotter towards the development of a paper-based colorimetric analytical kit for sodium hypochlorite determination in milk

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Nowadays, the use of the CO_2 laser to induce the formation of nanostructured films is rising, offering captivating opportunities in analytical device development, due to the possibility of directly patterning conductive graphenic and graphitic surfaces with strong sensing capabilities and on-demand geometries. However, the use of the laser to obtain optically active surfaces and paper-based colorimetric devices (cPAD) remains limited.

Herein will be presented a CO_2-laser plotter strategy to obtain optical-active nanostructured sensing surfaces integrated in cPAD. In brief, the laser enables the design, shaping, and anchoring of metal nanostructures (i.e., gold/Au, silver/Ag, platinum, copper, cerium/Ce, nickel, and aluminium) onto paper in a single stroke within a few seconds, and with the desired configuration; these nanostructures will be named Laser-Induced Metal nanoparticles (LIMs) [1].

To prove the LIMs sensing potentialities in cPADs, a treble lateral-flow device (LF^3) for the analysis of sodium hypochlorite (NaClO) in milk will be presented; the determination of this analyte will be contextualized in the framework of milk bleaching frauds. The LF^3 was conceived as an analytical 'kit', in which each component (i.e., LF^3, sample tray, and dark chamber for smartphone-based readout) was manufactured 'ad hoc' using CO_2-laser cut coupled to other benchtop technologies. The LF^3 is equipped with Ag, Au, and Ce-LIMs that act as colorimetric sensing elements with different sensitivity toward NaClO. The sensing strategy relies on the analyte-mediated LIM etching resulting in paper-substrate discoloration. The colorimetric assay consists of three steps: (i) milk auto sampling via LF^3 capillarity, (ii) fluidic sample reaction with LIMs, and (iii) colorimetric readout by smartphone. The device exploitability was tested on 9 milk samples belonging to different product categories. Despite the milk complexity, LF^3 enables NaClO reproducible determination at different contamination levels in 10 min (RSD ≤ 17%, n=3), with no matrix effects and recoveries ranging from 85 to 115%, confirming the usability of the LF^3-based kit for milk analysis.

Summing up, the herein proposed laser writing strategy turns out an innovative and sustainable nanopatterning technique, prone to generate optical sensing zones useful to develop (bio)sensing strategies and analytical kits manufacturing within everyone's reach.

Acknowledgments

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Poster 51

In-vitro Dopamine Sensing and Enhanced iPSC-Derived Neuronal Differentiation on a CNT-Based Electroactive Cell Culturing Platform

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The progressive nature of neurodegenerative diseases, like Parkinson's disease (PD), is linked to neurotransmitter dysregulation, specifically declining dopamine (DA) levels. [1] Current DA-regulating pharmaceutical therapies for PD lose efficacy over time, driving an urgent need for new drug discovery approaches. This necessitates high-throughput, non-invasive screening platforms for real-time monitoring of complex neuronal systems.

In this work, we introduce a novel electroactive cell cultivation platform utilizing carbon nanotubes (CNTs) for the non-invasive, electrochemical quantification of DA from living dopaminergic neurons. The CNTs perform a triple function: enhancing the sensor's electroactive area, catalyzing DA oxidation,[2] and promoting neuronal growth and synaptic interconnection.[3] Furthermore, the CNT substrate significantly improves the differentiation of induced pluripotent stem cells (iPSCs) into specific neuronal phenotypes, evidenced by enhanced expression of neurotransmitter-specific genes. We generated both dopaminergic (DA-producing) and glutamatergic (glutamate-producing) cultures for platform validation.

The system successfully quantified secreted DA with a linear range from 66 nM to 10 µM. Using these cultures, the platform demonstrated the ability to distinguish among dopaminergic and glutamatergic neurons and quantify the effect of drugs (e.g., benztropine) on extracellular DA concentration in real-time. This validates the CNT-based platform as a powerful tool for accelerating drug discovery for neurodegenerative diseases.

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Poster 52

NEW ELECTROCHEMICAL SENSOR DEVICE, BASED ON ARDUINO, FOR MEASUREMENTS OF RESIDUE CHARGE OF PRIMARY ALKALINE BATTERIES.

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As is well known, although so-called secondary batteries, i.e., chemical-physical devices that can be returned to a 'charged' state by appropriate charging methods, are readily available on the market; but, given their low cost, **the most widely used and widespread batteries on the market are the so-called "disposable", or non-rechargeable batteries, or alkaline batteries, or, more properly, "primary alkaline batteries"**. Of the various primary batteries that have gradually appeared on the market, alkaline Zn-Mn dioxide batteries are the most commonly used for portable equipment. These latter devices, as is well known, convert chemical energy produced by internal (irreversible) redox reactions into a flow of electrons in the external circuit. In fact, when an alkaline battery of this type discharges, the electrolytic water decomposes into H^+ and OH^- ions. The H^+ ion reacts with the contained MnO_2, forming an interstitial compound, simultaneously transferring an electron. In fact, in the reduction process: $MnO_2 + xH^+ + xe^- <=> H_xMnO_2$ (being x = 2). In this reduction process, manganese goes from an oxidation number of +4 to +2. At the same time, the hydroxyl ion OH^- oxidizes the metal zinc, which changes to zinc hydroxide, $Zn(OH)_2$, that is, the metallic zinc loses two electrons (2 e^-),i.e.,: $Zn + 2OH^- <=> Zn(OH)_2 + 2e^-$ (Zn passes from Oxide Number = 0, to O.N.= +2). At the beginning of the discharge, when less than 40% has reacted (x < 0.4), the intermediate component H_xMnO_2 has the same structure (ramsdellite) as MnO_2. As the discharge continues, a new compound appears, MnOOH (groutite) (where the O.N. of manganese is +3). This new compound has a very different structure and cannot be transformed back into ramsdellite, even by changing the pH, i.e., by removing H^+ from the solution. This is why, during the discharge (i.e., when becomes x < 0.5, **the reaction is no longer reversible**), **i.e., the battery cannot be recharged**. For this purpose at least two main possible formats are reported in the literature). Unfortunately both of these formats, however, are rather expensive and complicated. So our research group is studying a simple and inexpensive circuit based on the Arduino UNO R3, Atmel based; **however, given the above, it is first necessary to measure the residual charge of an alkaline battery**. **This is precisely the topic of this paper**. On the other hand, accurately measuring the residual charge is a complex task. **The aim of this work is to build a simple hand-made instrument, based on Arduino [1], that estimates the state of charge of an alkaline battery**, such as AA/LR06, in three steps. The first step involves measuring the voltage with a high-impedance voltmeter (Atmel stated > 100 Mohm) with 10 steps of 1 sec, simulating no load. The second step involves a relay connecting the battery to a 100 Ohm resistive load simulate a low discharge. The third step includes a 10-second relaxation period, to allow the battery to regenerate, open a relay and the voltage is measured again with 10 steps of 1 sec with no load. So far, with our device, up to this point, we have measured the values of residual charge of 158 disposable primary batteries, obtained using the last point of the discharge each curve: from which we can conclude that 48% of the measured batteries show a residual voltage between 1.2 and 1.6 V. Once this first part of the research is complete, our study will continue by developing a inexpensive device for recharging primary batteries, again using Arduino.

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Poster 53

Long-Period Fiber Gratings combined with advanced functional polymers for biosensing

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Long-period fiber gratings (LPFGs) have emerged as powerful tools in biosensing due to their exceptional sensitivity to variations in the surrounding refractive index. However, achieving the necessary levels of sensitivity and selectivity for detecting biomolecules in complex biological samples remains a considerable challenge. To overcome this, LPFGs have been functionalized with a range of natural and biomimetic biological recognition elements (BREs). A key aspect of this approach involves engineering a selective biolayer on the fiber surface, composed of BREs specifically designed to interact with the target analyte.

Imprinted biopolymers, created through the spontaneous polymerization of endogenous neurotransmitters, like dopamine, in the presence of molecular templates, represent a promising alternative to traditional molecularly imprinted polymers. These materials can effectively mimic antibodies and offer high specificity. In this work, LPFG-based sensors were employed to monitor the polymerization dynamics and growth behaviour of a serotonin-derived imprintable biopolymer, both with and without the presence of a molecular template.

In parallel, to fabricate functional layers suitable for BRE immobilization, LPFGs were coupled with various polymers and hydrogels. The photopolymerization of acrylamide into polyacrylamide hydrogels was thoroughly investigated, revealing their potential as porous matrices for anchoring antibodies and aptamers designed to capture bacterial targets and assess their antibiotic resistance profiles.

The integration of LPFG sensors with thermally stabilized, custom-built microfluidic platforms enabled the synergistic utilization of the unique properties of the studied polymers and hydrogels. This approach leverages the inherent advantages of LPFGs—such as their adaptability, cost-effectiveness, and portability—making them highly suitable for advanced biosensing applications.

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-Call for tender No. 1409 published on 14.9.2022 by the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU– Project Title P20227PWE5.PE4 PRIN2022PNRR Discovering the SEcret woRld of pOlyseroTONin for green molecular ImprINting and its application in bioanalytics – CUP B53D23025260001.

Poster 54

Immuno-affinity electrochemiluminescence for virus detection

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The outbreak of coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has had a profound and unprecedented impact on public health, social behavior, global economy, and individual life [1]. Therefore, in view of the possible occurrence of new challenges, it is highly desirable to develop rapid, accurate and ultrasensitive detection methods for the diagnosis of viruses.

Electrochemiluminescence (ECL) has become a promising analytical technique in immunoassay applications, owing to its superior sensitivity, negligible background signal and easy miniaturization [2]. ECL immunosensors typically utilize luminescent molecule-labeled monoclonal or polyclonal antibody as luminescence probes. However, the limited number of labelable groups and the decrease in binding activity induced by excessive labeling have constrained further improvements in the sensitivity of ECL immunosensors. It is imperative to explore novel antibody molecules that provide more available sites for labeling.

The phage-displayed antibody, as a promising recognition molecule for immunoassay, demonstrates enormous potential in diagnostic applications [3]. Compared with traditional monoclonal or polyclonal antibody, phage-displayed antibody exhibits distinct advantages, including low molecular weight, high quantum yield, remarkable target specificity, strong binding affinity, and excellent stability. Taking advantage of this structural feature to design signal probes for immunoassay enables effective signal amplification, thereby improving the detection sensitivity of the target molecule.

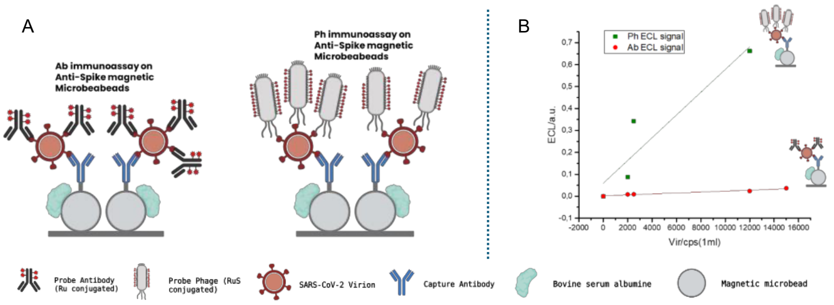

Figure 1: (A) Schematic representation of two different immunoassay assemblies. (B) Comparison of linear relationships between two different immunoassays.

Based on the above research strategy, we constructed an innovative ECL immunosensor for the detection of SARS-CoV-2 by employing phage-displayed antibody as the target recognition element and the specific luminescence probe. The massive viral capsid of phage, which encapsulates the affinity fragment, shows enhanced signal amplification and superior detection sensitivity compared with the double antibody sandwich structure (Figure 1). We remain optimistic about the amplification effect of phage-displayed technology in immunoassay applications.

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Poster 55

Unusual amperometric detection of ions using machine learning applied to hexacyanoferrate and graphene oxide modified electrodes

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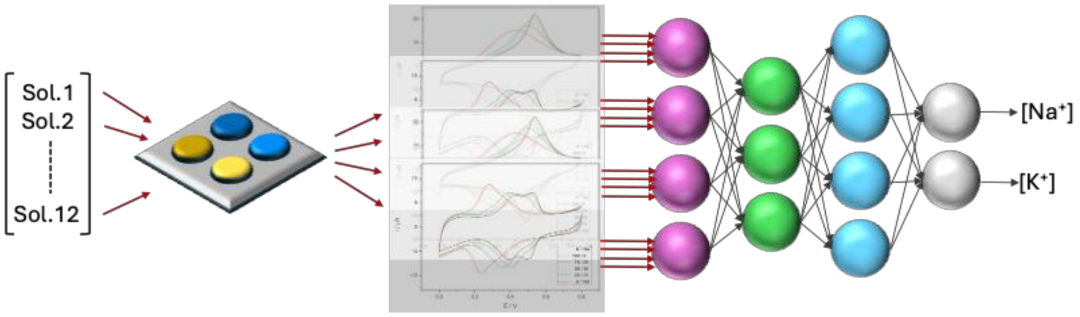
The quantification of electrolytes (e.g. Na^+ and K^+) in biological fluids leads to important physiological information connected to the hydration state and to the occurrence of severe pathologies. For this reason, many devices have been developed so far for the monitoring of ions in serum, saliva and sweat. These ions are normally detected and quantified by ion selective electrodes (ISE), exploiting the high selectivity of a tailored membrane. Despite effective, these sensors suffer from matrix effects which limit their accuracy. In addition, their sensitivity is limited, due thermodynamic reasons, to 59 mV/decade.

As an alternative approach for the quantification of Na^+ and K^+, we have recently proposed the use of a multi-sensor platform consisting of four poorly selective amperometric sensors (Fig. 1)[1]. The recognition elements consisted, in this case, by poorly selective iron and nickel hexacyanoferrates (Fe-HCF and Ni-HCF), coated with a thin layer of reduced graphene oxide (RGO). The sensing strategy is based on the different capability of ions to intercale within both RGO[2,3] and HCF[4,5], giving rise to in distinct voltammetric signals depending on the composition of the solution.

The voltammetric signals obtained by various replicates of the 4-sensors platform were used to train an artificial neural network (ANN) capable of analyzing such complex inputs to finally determine the concentrations of Na^+ and K^+ ions in solutions at different ionic strengths and even containing NH_4^+ as an interferent.

Aiming at quantifying ions possessing different ionic radius and permeability throughout the coatings, the number of electrodes in the platform was increased to also include copper and cobalt hexacyanoferrates as sensing elements, either coated or not with an external layer of RGO. The resulting multi-electrode platform was tested in more complex solutions containing variable concentration of Na^+, K^+, NH_4^+, and Ca^{2+}.



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