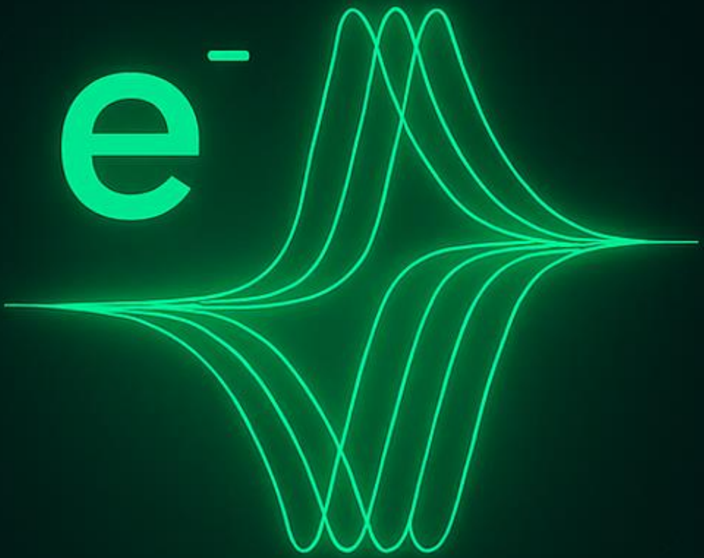
BOOK OF ABSTRACTS



XXVI Meeting of the Portuguese Electrochemical Society

November 19–21, 2025 | Porto, Portugal

Book of Abstracts
XXVI Meeting of the Portuguese Electrochemical Society
November 19-21, 2025 - Porto, Portugal
Edited by Henri Nouws
REQUIMTE/LAQV - Instituto Superior de Engenharia do Porto, Porto, Portugal

Welcome

A warm welcome to Porto and the **Instituto Superior de Engenharia do Porto** (**ISEP**), **Polytechnic University of Porto** (**P.Porto**), for the **XXVI Meeting of the Portuguese Electrochemical Society**.

As in previous editions, this meeting aims to provide a dynamic and stimulating forum for discussion on recent developments, scientific achievements and future prospects across all areas of electrochemistry. The event brings together researchers, students and professionals who contribute to the advancement of fundamental and applied electrochemistry.

Organized within the scope of the activities of the **Portuguese Electrochemical Society** (SPE) - an institution with a long-standing tradition in promoting scientific exchange and collaboration - this meeting seeks to reinforce and expand partnerships and networks between academia, research laboratories, technology transfer centres and industry. By encouraging dialogue and cooperation, this meeting highlights the key role of electrochemistry in driving innovation and supporting sustainable technological progress.

I trust that this meeting will prove fruitful and inspiring for all participants.

Cristina Delerue-Matos
Meeting Chairperson
Full Professor at ISEP / P.Porto
Vice-president for research of P.Porto
Coordinator of the REQUIMTE/LAQV-ISEP research team
(Grupo de Reação e Análises Químicas)

© Divisão de Cooperação e Comunicação - Gabinete de Design e Imagem - ISEP

Committees

Scientific Committee

- Ana Cristina Ribeiro, Departamento de Química, Universidade de Coimbra, Portugal
- Ana Viana, Faculdade de Ciências, Universidade de Lisboa, Portugal
- Annabel Fernandes, Faculdade de Ciências, Universidade da Beira Interior, Portugal
- Armando Pombeiro, Instituto Superior Técnico, Universidade de Lisboa, Portugal
- Artur Valente, Departamento de Química, Universidade de Coimbra, Portugal
- Cristina Delerue-Matos, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto, Portugal
- Cristina Freire, Faculdade de Ciências, Universidade do Porto, Portugal
- Diana Fernandes, Faculdade de Ciências, Universidade do Porto, Portugal
- Elisabete Alegria, Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Portugal
- Fátima Guedes da Silva, Instituto Superior Técnico, Universidade de Lisboa, Portugal
- Helena Braga, Faculdade de Engenharia, Universidade do Porto, Portugal
- Victor Lobo, Universidade de Coimbra, Portugal

Organizing Committee

REQUIMTE/LAQV-ISEP, Porto, Portugal

- Cristina Delerue-Matos (Meeting Chairperson)
- Álvaro Torrinha
- Cristina Soares
- Fátima Barroso
- Henri Nouws
- João Pacheco
- Maria Freitas
- Patrícia Rebelo
- Simone Morais

Vasco da Gama CoLAB - Energy Storage, Porto, Portugal

- Ana Rita Veloso

Sponsors

Program

November 19, 2025

14:00	**Check-in**	
	Auditorium	**Sala de Eventos**
14:30	**Opening Session** **Armando Pombeiro | Cristina Delerue-Matos**	--
14:45	**IL01 Alexandre Bastos** Electrochemical aspects of the application of ZnAl layered double hydroxides (LDH) to corrosion protection	
	Moderator Victor Lobo	**Henri Nouws Moderator**
15:15	**OC01 Katherine Bettencourt** Designing flexible organic cathodes for stable ion batteries	**Carla Eiras OC04** Biodegradable electrochemical sensor for the analysis of quercetin and rutin in grape extracts
15:35	**OC02 María Rosário de la Cruz** Ni (Ce,Zr)O_2 nanofibers with Ni exsolution as an advanced hydrogen electrode for high-temperature SOFCs	**João Barbosa OC05** Electrochemical lactate sensing via molecularly imprinted polymers for advanced fetal monitoring
15:55	**OC03 Noelia Corrochano** Tailored 3D-printed photopolymer-derived carbon materials for advanced electrocatalytic systems	**Diana Carneiro OC06** Conductive bio-inspired copolymers as versatile platforms for biosensing: insights into the electropolymerisation mechanism
16:15	**Refreshments**	
16:45	**Moderator Annabel Fernandes**	**Fátima Barroso Moderator**
	OC07 Ismael González-González Sustainable bifunctional electrodes from waste-derived hydrochar for electro-Fenton applications	**José Pedro Silva OC09** Electrochemical procedures coupled to CYP450 metabolism for control and environment risk analysis of transdermal patches
17:05	**OC08 Carlos Sousa** Phosphorus recovery from cheese whey wastewater through electroless struvite precipitation using magnesium anodes	**Lurdes Gonçalves OC10** Advancing covalent organic polymer-based sensors for saxitoxin detection
17:25	--	**Marcus Monteiro OC11** Electropolymerized hydrogel-MIP biosensor for myoglobin detection
17:45	**Poster Session 1**	
19:00	**End of Day 1**	

Program (*cont.*)

November 20,2025

09:00	**Check-in**	
	Auditorium	**Sala de Eventos**
	Moderator Victor Lobo	
09:30	**SC01 Miguel Esteso** The electrochemical system: looking at the solution	--
10:00	**IL02 Teresa Fernández-Abedul** Strategies for decentralizing clinical, food and environmental (bio)electroanalysis	
	Moderator Teresa Fernández-Abedul	**Daniel Martin-Yerga Moderator**
10:30	**OC12 Henri Nouws** Electrochemical (bio)assays for food safety and quality evaluation	**Diana Fernandes OC17** Turning endogenous resources into power: *Juniperus brevifolia* biomass for efficient (electro)catalysts
10:50	**Refreshments**	
11:20	**OC13 João Pacheco** Electrochemical molecularly imprinted polymer devices for analytical applications	**Julia Isidro OC18** Advances in PEM fuel cell sustainability: performance impact of eco-binders
11:40	**OC14 Maria Freitas** Magnetic hybrid nanoplatform-modified screen-printed electrodes for enhanced electrochemical immunosensing	**Kostadin Petrov OC19** Optimizing current collector and flow-field geometry for enhanced gas removal in PEM electrolyzers
12:00	**OC15 Miguel Tavares** A copper-based metal-organic framework sensor for rapid and reliable detection of the diabetes drug metformin	**Ángela Moratalla OC20** Advances in the development and characterization of solid oxide fuel cells and electrolysis cells
12:20	**OC16 Stephanie Morais** DNA-based electrochemical biosensors for authenticating the botanical origin of honey	**Hanane Boumeriame OC21** Performance of SO_2 depolarized electrolysis in the presence of N_2 and CO_2 gases for green hydrogen generation
12:40	**Lunch**	
14:00	**Moderator Maria Freitas**	--
	IL03 Daniel Martin-Yerga High-throughput and local probing of electrochemical interfaces	
14:30	**IL04 Felipe Conzuelo** Integrating biomolecules with electrodes: from electrochemical analysis to proof-of-concept biotechnological applications	
	Moderator Felipe Conzuelo	**Diana Fernandes Moderator**
15:00	**OC22 Miqueias Portugal** Thin-film poly(azo-BBY)–AgNP impedimetric platform for miRNA-122	**Ewelina Rudnicka OC24** Next-generation dual-doped Prussian blue analogue as a high-capacity cathode for sodium-ion batteries
15:20	**OC23 Rui Campos** Amplification-free photoelectrochemical biosensor for the detection of FLT3 mutations in acute myeloid leukaemia	**Galin Borisov OC25** Zero gap water electrolyze – metal-based electrodes, diaphragm / separator electrode assembly and possibility for stack regime
15:40	**Poster Session 2 & Refreshments**	
17:00	**General Assembly of the Portuguese Electrochemical Society (Auditorium)** (only for SPE members)	
20:00	**Conference Dinner (Casa da Música)**	
22:00	**End of Day 2**	

Program *(cont.)*

November 21, 2025

09:00	**Check-in**	
	Auditorium	**Sala de Eventos**
	Moderator **Fátima Guedes da Silva**	--
09:30	SC02 **Daniela Lopes** Electrochemical route to green steel: challenges, insights and future perspectives	
10:00	IL05 **Rui Pereira** Natural resources as core components of sustainable energy technologies	
	Moderator **Simone Morais**	**Fátima Guedes da Silva** Moderator
10:30	OC26 **Inês Marques** From shrimp shell waste to dual catalysts for energy and biomass valorisation	**Hasna Aziam** OC31 Investigating novel high-entropy NASICON-type material as positive electrode for next-generation sodium-ion batteries
10:50	**Refreshments**	
11:20	OC27 **Liliana Truta** Beyond conventional lithium-ion battery anodes	**Guillermo Díaz-Sainz** OC32 Electrochemical CO_2 reduction to formate using biomass-derived gas diffusion electrodes
11:40	OC28 **Reneta Boukoureshtlieva** Comparative study of gas-diffusion electrodes based on non-platinum catalyst for advanced fuel cells and metal-air systems	**Ana Sofia Fajardo** OC33 Electrocoagulation treatment of coffee capsule recycling wastewater with compressed recovered aluminium electrodes
12:00	OC29 **Hasna Aziam** Novel NaSICon-type as negative electrode materials for post-lithium batteries	**Bárbara Saraiva** OC34 Treatment of natural dyeing wastewaters by electrochemical oxidation
12:20	OC30 **Nouredine Oueldna** Novel inorganic filler for composite solid electrolytes in all-solid-state lithium-metal batteries	**Sandra Maldonado** OC35 Circular economy through algae: a novel pathway for CO_2 valorisation
12:30	Closing Session **Armando Pombeiro | Henri Nouws**	--
13:00	**Lunch**	
14:00	Workshops **(Laboratories Building G)**	
16:00	**End of the Meeting**	

© Jaime Neto

Program (*cont.*)

Poster sessions

November 19, 2025 | Session 1 - 17:45 - 19:00

PP01 **Álvaro Torrinha**
A paper-like self-powered biosensor for detection of lactate

PP02 **Álvaro Torrinha**
Electrochemical detection of venlafaxine in fish

PP03 **Briyitte Torres**
Analytical strategy based on enzymatic biosensors for the quantification of urea in milk samples

PP04 **Carla Eiras**
Innovative electrochemical methods for monitoring the therapeutic levels of paroxetine and escitalopram oxalate

PP05 **Carmen Ioana Fort**
Mesoporous carbon aerogel matrix for meldola blue as sensing platform for H_2O_2 electroanalytical detection

PP06 **Dmitrij Gritsok**
Considerations in the electrochemical detection of viral proteins using molecularly imprinted polymers: monkeypox A29 case study

PP07 **Fátima Barroso**
Construction of electrochemical genosensors for the identification of the polymorphism (c.100C>T, rs1065852) located in the CYP2D6*10 gene

PP08 **Fátima Barroso**
Low-cost paper-based electrochemical genosensors for the polymorphism's detection

PP09 **Graziella Liana Turdean**
A new electrochemical sensor based on chitosan-diazonium functionalized MWCNTs matrix for the detection of heavy metals

PP10 **Henri Nouws**
Simultaneous electrochemical analysis of fish and crustacean allergens

PP11 **Isabel Seguro**
Design of paper-based electrochemical sensors with molecularly imprinted polymers for selective omeprazole detection in water

PP12 **João Pacheco**
Inkjet-printed paper-based electrode modified with molecularly imprinted polymer for voltammetric detection of venlafaxine

PP13 **Maria Célia Tavares**
Development of a potentiometric sensor to monitor urease as a biomarker of *Helicobacter pylori*

PP14 **Maria Freitas**
Electrochemical biosensing approach for cystatin C: towards improved chronic kidney disease diagnostics

PP15 **Michelle Castanheira**
A novel electrochemical genosensor platform for early detection of *Candida albicans*

PP16 **Michelle Castanheira**
Paper-based electrochemical genosensors: a new approach for *Candida* spp. detection

PP17 **Miguel Tavares**
An electrochemical sensor for gemfibrozil based on electrodeposited iron metal-organic framework

PP18 **Stephanie Morais**
CYTED Network – GenoPsySEn: Development of genosensors for pharmacogenomic targets in the central nervous system

PP19 **Vitória Dibo**
Carbon fibre paper sensor with and without functionalization with zeolitic-imidazole framework for detection of bisphenol A in fish sample

PP20 **Vitória Dibo**
Inkjet-printed paper electrode modified with a covalent organic framework for the detection of pharmaceutical pollutants

PP21 **Khadija Bahend**
Electrochemical detection of melatonin in biological and pharmaceutical samples

PP22 **Carlos Almeida**
New insights into the conductivity and microstructure of EHPO and YHPO proton electrolytes

PP23 **Reneta Boukoureshtlieva**
MnO_2 - Ecological electrode material for recycling and reuse

Program (*cont.*)

Poster sessions (*cont.*)

November 20, 2025 | Session 2 - 15:40 - 17:00

PP24 **Diana Fernandes**
Turning tides: converting invasive water milfoil into green energy electrocatalysts

PP25 **Francesca Rizzo**
Electrochemical characterizations of the W-dependent formate dehydrogenase FdhAB from *Desulfovibrio vulgaris* Hildenborough

PP26 **Guillermo Díaz-Sainz**
Coupling glycerol oxidation on Au-In foam anodes with gas-phase CO_2 electroreduction for continuous co-valorisation

PP27 **Inês Marques**
Sustainable amines from biomass: biochars driving electrochemical reductive amination

PP28 **Julia Isidro**
Impact of catalyst deposition method on PEM fuel cell performance

PP29 **Sandra Maldonado**
Towards integrated carbon valorisation: advanced oxidation and CO_2 electroreduction with reticulated electrodes

PP30 **Beata Kurc**
Impact of carbon-based conductive additives on the electrochemical performance of Mo-doped Prussian blue cathodes for sodium-ion batteries

PP31 **Beata Kurc**
Investigation of metal sulphide-based anodes and graphene effects in sodium-ion batteries

PP32 **Borislava Mladenova**
Influence of proton-donor and proton-acceptor additives on the electrochemical characteristics of a vanadium redox flow battery

PP33 **Bruna Pedro**
Visualization of O_2 bubble evolution in PEM electrolysis cells: an experimental and simulation study

PP34 **Ewelina Rudnicka**
Synergistic effects of vanadium and cobalt Co-doping in Prussian blue analogues for high-performance sodium-ion batteries

PP35 **Ángela Moratalla**
Development and integration of metallic interconnectors for reversible solid oxide cells

PP36 **María Rosário de la Cruz**
Symmetric SOECs for efficient H_2O / CO_2 co-electrolysis

PP37 **Victor Lobo**
Evaluation of cobalt ion release from metal alloys and strategies to minimize its toxicity in biomedical applications

PP38 **Ana Baía**
Microbial electrolysis cell electrochemical response to increasing ethanol concentration

PP39 **Annabel Fernandes**
Electrochemical oxidation of textile effluents: towards cleaner processes and water reuse

PP40 **Antón Puga**
Design and evaluation of waste-derived biochar for the treatment of polluted water

PP41 **César Afonso**
Electrooxidation and electrocoagulation processes for the treatment of raw textile wastewater

PP42 **Verónica Poza-Nogueiras**
Removal of pharmaceuticals from water combining adsorption and electrochemical treatments

PP43 **Verónica Poza-Nogueiras**
Development of a paper-based electrochemical sensor for the detection of amisulpride in water

PP44 **Ding Ge**
Powder-to-powder electrochemical reduction of iron oxides: toward scalable, carbon-free iron production

PP45 **André Torres-Pinto**
H_2O_2-assisted photoelectrocatalysis for the elimination of pharmaceuticals from surface waters

Program (*cont.*)

Workshops | November 21, 2025 | 14:00 – 16:00

Workshop #1 | Electrochemical MIP sensor for naloxone analysis | Laboratory G103

Naloxone (NLX) is a key opioid antagonist used worldwide to rapidly reverse overdoses of narcotics by binding to central nervous system receptors. While it is generally safe at standard doses, higher doses can lead to serious side effects, including cardiovascular issues, seizures, and cognitive impairment. Accurate NLX analysis, particularly in urine, is essential in medication-assisted treatment for opioid use, helping to monitor proper usage and prevent drug misuse. In this workshop, a disposable electrochemical sensor for NLX detection will be developed using a molecularly imprinted polymer (MIP) as receptor. A thin and uniform NLX imprinted film will be electrochemically deposited onto a commercial screen-printed carbon electrode (SPCE). Following an efficient NLX extraction process, specific molecular cavities will be created on the SPCE surface, enabling highly selective and sensitive detection.

This hands-on workshop will cover:

- MIP-based sensor fabrication.
- Electrochemical analysis techniques.
- Selective detection of naloxone.

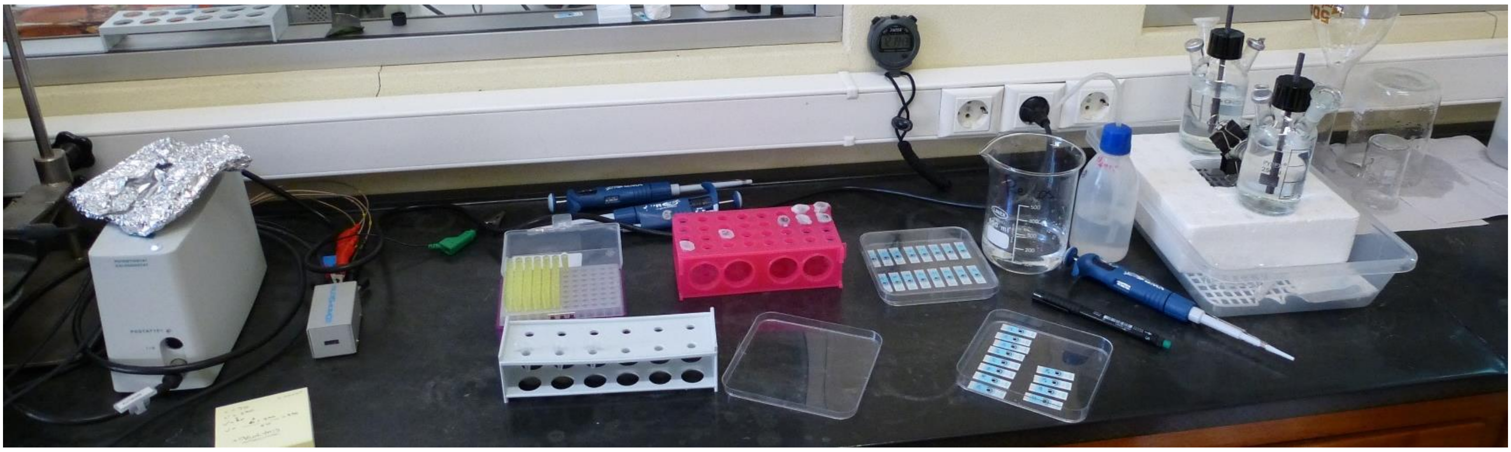
Workshop #2 | Metal-organic framework based electrochemical sensor for the analysis of a pharmaceutical pollutant | Laboratory G103

Pharmaceuticals are critical commodities for society but also constitute an environmental problem due to their misuse, negligent disposal and inefficient removal at wastewater treatment plants. The environmental monitoring of pharmaceuticals is very important to lay down regulations, preventive measures and courses of action. Electrochemical sensors are innovative analytical tools that can be applied for the in-situ detection of contaminants. This workshop envisages the development of a simple electrochemical sensor for the analysis of a widely prescribed pharmaceutical. The sensor will be based on the modification of a transducer with a metal-organic framework (MOF). This highly porous material enables the analyte's concentration on the sensor's surface, enhancing the analytical signal for a more efficient detection. The sensor's fabrication and characterization will cover the use of different electrochemical techniques: amperometry, cyclic voltammetry and square-wave voltammetry.

This hands-on workshop will cover:

- Fabrication of a MOF-based sensor involving synthesis and electrodeposition.
- Electrochemical characterization and analysis through different electrochemical techniques.
- Calibration of the sensor.

This workshop is organized under the scope of the project NATURIST 2022.07089.PTDC (doi: 10.54499/2022.07089.PTDC) funded by Portuguese national funds (FCT/MCTES, Fundação para a Ciência e a Tecnologia / Ministério da Ciência, Tecnologia e Ensino Superior).



Program (*cont.*)

Workshops (*cont.*)

Workshop #3 | High-performance cathodes for sodium ion batteries (SIBs) | Laboratory G305

As many are aware, we currently face a global energy transition aimed at reducing our reliance on fossil fuels. A key factor for this change is the integration of renewable energy sources. However, the intermittent nature of renewables such as solar and wind pose significant challenges in preserving a stable and reliable energy supply. To address this, effective energy storage systems is crucial. Several storage technologies are being explored to bridge the gap between energy production and demand, including supercapacitors, flywheels, and several battery chemistries. At VG CoLAB, our efforts are focused on sodium-ion batteries — an emerging and cost-effective alternative with strong potential for large-scale deployment.

To foster greater awareness and hands-on experience with this technology, we are organizing a practical workshop that will guide participants through the complete process of assembling sodium-ion batteries. This includes the synthesis of cathode materials, with a focus on Prussian Blue—a compound renowned for both its distinctive colour and its suitability as a cathode in sodium-ion systems. The workshop will also cover cathode fabrication and the assembly of coin cells, using safe and accessible materials.

As a highlight, we will present a working diorama powered by sodium-ion cells, demonstrating real-world applications and offering participants a comprehensive insight into the functionality and promise of this battery technology.

This hands-on workshop will cover:

- Synthesis of cathodes.
- Battery assembly process.
- Diorama with sodium batteries.

Workshop #4 | Nanoparticle-based electrochemical biosensor for sensitive food analysis | Laboratory G103

Commercial food products must undergo strict quality control procedures to ensure safety and compliance and provide accurate information to consumers. Labelling and health claims must be substantiated by robust scientific data. Therefore, the development and implementation of analytical methods for rapid, sensitive, and reliable analysis are critical. Voltammetric and amperometric biosensors have emerged as effective tools that address the analytical demands of the food industry, offering high specificity and operational efficiency. The integration of nanomaterials into biosensor designs, particularly gold nanoparticles, enhances the analytical performance by improving signal transduction, sensitivity, and overall robustness of the sensor. This workshop involves the construction and use of an electrochemical immunosensor for the detection of trace levels of potentially hazardous ingredients in food products. The experimental procedure consists of the electrodeposition of gold nanoparticles onto screen-printed electrodes and a sandwich-type immunoassay with amperometric detection. Additionally, analyte extraction from complex matrices and validation of the results using a conventional method will be addressed.

This hands-on workshop will cover:

- Electrode surface nanostructuration with gold nanoparticles.
- Sandwich-type assay with amperometric detection.
- Analysis of food samples.
- Comparison of the results with a conventional method.

This workshop is organized under the scope of the project Sens2BiteSafe (COMPETE2030-FEDER-00713900 (nº 16000)), funded by FEDER (COMPETE 2030) and Portuguese national funds (FCT/Ministro da Educação, Ciência e Inovação).

BOOK OF ABSTRACTS

Invited Lectures

[IL01]

Electrochemical aspects of the application of ZnAl layered double hydroxides (LDH) to corrosion protection

Alexandre Bastos[1]*, Mariana Raposo[1], Alexandra Santos[1], Celestino Gomes[1], Rui Sampaio[1], Frederico Maia[2], Cláudia Rocha[2], Kiryl Yasakau[1], João Tedim[1], M.G.S. Ferreira[1]

[1]DEMaC - Department of Materials and Ceramic Engineering, and CICECO - Aveiro Institute of Materials, University of Aveiro, 3810-193 Aveiro, Portugal
[2]Smallmatek - Small Materials and Technologies, Lda, 3810-075 Aveiro, Portugal

*acbastos@ua.pt

Over the last two decades, corrosion protection research has increasingly focused on the development of inhibitor-loaded nano-reservoirs. These systems allow the incorporation of soluble corrosion inhibitors that would otherwise compromise the stability of paint matrices. The reservoirs can be engineered to release their contents selectively - triggered by the onset of corrosion or upon exposure to harsh environmental conditions - thereby conserving unused containers for prolonged protection. A clear example of such nano-containers is layered double hydroxide (LDH) particles, known for their anion-exchange properties. This unique capability has been applied in a wide range of fields, including trace chemical adsorption, catalysis, drug delivery, energy storage, and CO_2 capture. In corrosion protection, LDH particles can scavenge aggressive anions like chlorides and sulphates while simultaneously releasing protective anionic inhibitors.

This work explores the application of ZnAl-LDH in various corrosion protection strategies, such as embedding the particles in paints [1] or incorporating them into mortar and concrete to protect reinforcing steel [2]. Furthermore, aluminium and zinc substrates were treated to form LDH-based surface films, improving both corrosion resistance and paint adhesion [3]. the synthesis and characterization of these materials are detailed, alongside with the corrosion resistance evaluation using electrochemical methods like polarization curves, electrochemical impedance spectroscopy (EIS), and the scanning vibrating electrode technique (SVET).

Funding

This work was developed within the scope of the project CICECO-Aveiro Institute of Materials, UIDB/50011/2020, UIDP/50011/2020 & LA/P/0006/2020, and projects LORCENIS (Horizon 2020 Grant agreement Nº 685445), RESINSURF (Interreg Sudoe S1/1.1/E0025) and Coat4Life (H2020-MSCA-RISE-2020 nº 101007430).

References

[1] J. Tedim, T.L.P. Galvão, K.A. Yasakau, et al., *Front. Chem.* **2022**, 10, 1048313.
[2] C. Gomes, Z. Mir, R. Sampaio, et al., *Materials* **2020**, 13, 1769.
[3] J. Tedim, M.L. Zheludkevich, A.N. Salak, et al., *Mater. Chem.* **2011**, 21, 15464.

[IL02]

Strategies for decentralizing clinical, food and environmental (bio)electroanalysis

M. Teresa Fernández-Abedul[1]*, Pablo Rioboó-Legaspi[1], Alejandro Rodríguez-Penedo[1], María Cerrato-Álvarez[1,2], Estefanía Costa-Rama[1]

[1]Department of Physical and Analytical Chemistry, University of Oviedo, Spain
[2]Department of Analytical Chemistry, University of Extremadura, Badajoz, Spain

*mtfernandeza@uniovi.es

(Bio)chemical analysis is rapidly progressing towards its decentralized version. This is an important milestone in the evolution of Analytical Chemistry, similarly to what happened when Instrumental Analysis emerged, or when Flow Injection Analysis appeared to automatize many analytical methodologies. All the milestones incorporated important advantages. Moreover, the integration with computers, both as active and passive interfaces, and the advances in materials and technologies, have given way to a new generation of tools and methodologies. Now, it is time for the decentralization of the analysis in all fields. In this context, electroanalysis is in its gold era. Miniaturized potentiostats, together with adaptable electrochemical cells, are playing an important role in this change. In addition, the simplicity of the procedures not only moves lab developments towards field applications but also allows obtaining information by everyone at any time. In turn, this would be converted into valuable knowledge-based decisions.

In this work, examples of electroanalytical platforms for application in the main fields of the analysis are presented. Apart from traditional cells, devices based on low-cost materials such as paper or transparency films combined with mass-produced materials such as pins, or pencil leads for out-of-box applications are commented. The *in-situ* determination of dyes or pharmaceuticals in waters is possible with small platforms [1]. The combination with bioreceptors allows integrating selectivity, especially in enzymatic and immunoelectrochemical assays. In this case, the electrochemical cell is the basis for the design of vertical flow assay platforms for clinical applications (*e.g.*, differential diagnosis of stroke), favoured by non-invasive sampling. Electrochemical detection fits well with other types of bioassays such as the amplification of genetic material, extending the analysis to other relevant biomarkers. Isothermal amplification of specific sequences (*e.g.* of *Streptococcus pneumoniae* or SARS-CoV-2) using LAMP procedures has been combined with innovative detection methodologies, including the use of electrocatalytic Pd nanoclusters [2]. LAMP procedures and electrochemical readout can be integrated into a single device to avoid carryout contamination [3].

Funding
This research was funded by MCIN/AEI/10.13039/501100011033 and the EU "NextGenerationEU"/ PRTR" (BiodivRestore Cofund2020, PIC2022-133007), by MCIU/AEI/10.13039/501100011033/FEDER (PID2020-118376RA-I00 and PID2023-148375OB-I00), and by the Government of Asturias and EU FEDER Program (IDE/2024/000694, SEKUENS agency). P.R.L. and A.R.P. were supported by BP21-029 and BP22-007 "Severo Ochoa", M.C.A by MS-18 "Margarita Salas" and E.C.R. by BG20-00027 "Beatriz Galindo" grants.

Acknowledgements
Authors want to acknowledge the technical support provided by the Servicios Científico-Técnicos of the University of Oviedo.

References

[1] M. Cerrato-Alvarez, P. Rioboó-Legaspi, E. Costa-Rama, et al., *Biosens. Bielectron.* **2025**, 267, 116851.
[2] A. Rodríguez-Penedo, P. Rioboó-Legaspi, A. González-López et al., *Adv. Healthc. Mater.* **2023**, 2202972.
[3] P. Rioboó-Legaspi, E. Costa-Rama, M.T. Fernández-Abedul, *Lab Chip* **2024**, 24, 4085.

[IL03]

High-Throughput and local probing of electrochemical interfaces

Daniel Martin-Yerga
Department of Chemistry and Materials Science, School of Chemical Engineering, Aalto University, Finland
daniel.martinyerga@aalto.fi

Two central challenges in electrochemical science are understanding how the structure and composition of electrode materials govern reactivity and performance, and efficiently identifying optimal process conditions across vast experimental spaces. Addressing these challenges is key to accelerating progress in the development of technologies for energy conversion and storage, catalysis, and sensing.

In this talk, I will show how scanning electrochemical cell microscopy (SECCM), particularly when integrated with complementary characterization techniques, offers a powerful approach to meet both needs. SECCM enables electrochemistry to be resolved at the micro- and nanoscale [1,2,3] revealing hidden local structure-function relationships and capturing dynamic interfacial transformations. Simultaneously, its automated, high-throughput capabilities facilitate rapid combinatorial screening of experimental conditions [4,5]. In essence, SECCM can accelerate mechanistic understanding and support the rational design of functional electrode materials. This modern, data-rich perspective opens new avenues for addressing critical scientific challenges in electrochemical technologies and lays the groundwork for more intelligent, even autonomous exploration, of electrochemical interfaces.

Funding
This research was funded by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreements no. 101026563 (NANODENDRITE) and the Research Council of Finland (no. 355569).

Acknowledgements
I would like to thank everyone who has contributed to my work in this area, particularly, Prof. Pat Unwin and Dr. Xiangdong Xu from University of Warwick.

References

[1] D. Martín-Yerga, A. Costa-García, P.R. Unwin, *ACS Sens.* **2019**, 4, 2173–2180.
[2] X. Xu, W.C. Howland, D. Martín-Yerga, et al., *ChemRxiv* **2024**.
[3] E.B. Tetteh, D. Valavanis, E. Daviddi, et al., *Angew. Chem. Int. Ed.* **2022**, 61, e202204963.
[4] D. Martín-Yerga, D.C. Milan, X. Xu, et al. *Angew. Chem. Int. Ed.* **2022**, 61, e202204225.
[5] D. Martín-Yerga, X. Xu, D. Valavanis, et al., *ACS Nano* **2024**, 18, 23032–23046.

[IL04]

Integrating biomolecules with electrodes: from electrochemical analysis to proof-of-concept biotechnological applications

Felipe Conzuelo

Instituto de Tecnologia Química e Biológica António Xavier, Universidade Nova de Lisboa,
Av. da República, 2780-157 Oeiras, Portugal

felipe.conzuelo@itqb.unl.pt

Electrochemical processes involving the transfer of electrons and the build-up of potential differences across interfaces are central processes in life. The study of redox proteins at the interface with electrode materials allows us to address fundamental biological questions. Through this understanding we can also make use of biological elements for the fabrication of hybrid electrode materials with different biotechnological applications. Among others, relevant examples include the development of biofuel cells for clean energy generation, and novel catalytic materials used in bioelectrosynthesis aiming at the conversion of surplus residues into valuable products. In particular, the photosynthetic protein complexes are highly abundant in nature and have an exceptionally high quantum yield, close to 100%, for the photon-to-electron conversion. As a result, there is a great interest in the coupling of these biomolecules with electrode materials for the development of semi-artificial biodevices that will enable the conversion of solar light energy into electrical power as well as the synthesis of valuable products. In addition, redox enzymes are highly active and selective biological catalysts, able to perform catalytic conversions with high yields under mild conditions, such as aqueous solutions, near-neutral pH, and ambient temperature and pressure. As will be shown, we can fabricate functional bioelectrodes that consist of electrically conductive materials and integrate isolated enzymes or photosynthetic complexes. Taking advantage of relatively simple but powerful electrochemical characterization tools, the biohybrid materials are investigated to assess electrochemical communication at the biotic/abiotic interface, ensuring appropriate immobilization and productive interaction between the biological entities and the electrode surface. Examples will be shown highlighting the possibility of performing electrochemical characterizations at the microscale using micro(bio)sensors for direct local analysis of chemical reactions with higher spatial and temporal resolution and our latest developments in hybrid biomaterials for energy conversion and carbon dioxide valorisation.

Funding

This work was supported by FCT - Fundação para a Ciência e a Tecnologia, I.P., through grant 2022.07024.PTDC, the researcher contract 2022.05842.CEECIND/CP1725/CT0001 under the Scientific Employment Stimulus – Individual Call 2022, MOSTMICRO-ITQB R&D Unit (UIDB/04612/2020, UIDP/04612/ 2020), and LS4FUTURE Associated Laboratory (LA/P/0087/2020).

[IL05]

Natural resources as core components of sustainable energy technologies

Tiago A.G. Duarte[1], Filipe M. Santos[1], Marisa C. Carvalho[2], Raul Machado[3,4],
Maria M.M. Silva[2,5], Verónica de Zea Bermudez[1,6], Rui F.P. Pereira[5]*
[1]CQ-VR, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal
[2]Department of Chemistry, University of Minho, Braga, Portugal
[3]Centre of Molecular and Environmental Biology (CBMA), University of Minho, Braga, Portugal
[4]IB-S- Institute of Science and Innovation for Bio-Sustainability, University of Minho, Braga, Portugal
[5]Centre of Chemistry, University of Minho, Braga, Portugal
[6]Department of Chemistry, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal

*rpereira@quimica.uminho.pt

Nature serves as a powerful inspiration for the development of renewable, multifunctional materials capable of addressing today's urgent environmental and energy-related challenges. Among the broad spectrum of natural, biodegradable, and abundant resources, proteins, polysaccharides, and other bio-based compounds stand out due to their inherent biocompatibility, structural diversity, and eco-friendliness. By harnessing these natural building blocks, it is possible to design high-performance materials with applications in advanced technologies such as energy storage, smart windows, and solar harvesting.

This talk explores recent progress in the development of bio-inspired materials, with a particular focus on the integration of natural polymers and carbon-based nanomaterials into functional devices. Recent advancements have introduced promising applications within the energy sector, highlighted by our pioneering contribution with the inaugural integration of silk fibroin as a solid polymer electrolyte in electrochromic devices and batteries [1,2]. The use of genetically engineered recombinant protein as matrix for the development of solid polymer electrolytes will be discussed. Sun-actuated thermotropic devices incorporating active SF-based films doped with innovative ionanofluids composed of natural-derived carbon dots and ionic liquids will be also presented [3].

Collectively, these advances illustrate the vast potential of natural materials, including genetically engineered recombinant protein polymers, as functional components to develop next-generation, environmentally conscious technologies.

Funding

This research was funded by FCT under the strategic funding UID/00686: CQ-UM/UM and FCT-UMinho under an Assistant Research contract (https://doi.org/10.54499/2023.07994.CEECIND/CP2841/CT0013). This research was also supported by FCT within the scope of the projects Centro de Química-Vila Real (CQ-VR) (CQVRUIBD/00616/2025), Centro de Química da Universidade do Minho (https://doi.org/10.54499/UID/00686/2025), SMART-E: Multi-sensing smart battery electrodes concept for in-situ operation monitoring (2022.04012.PTDC) and PRR A-MoVeR project – Mobilizing Agenda for the Development of Products and Systems towards an Intelligent and Green Mobility (operation 02/C05-i01.01/2022, PC646908627-00000069)."

References

[1] T.C.D. Fernandes, H.M.R. Rodrigues, F.A.A. Paz, et al., *J. Electrochem. Soc.* **2020**, 167, 070551.
[2] R.F.P. Pereira, R. Gonçalves, H.M.R. Gonçalves, et al., *Mater. Today Sustain.* **2020**, 9, 100041.
[3] T.A.G. Duarte, R.F.P. Pereira, B. Medronho, et al., *Chem. Mater.* **2024**, 36, 1136.

BOOK OF ABSTRACTS

SPE Prize Winners' Lectures

[SC01]

The electrochemical system: looking at the solution

Miguel A. Esteso
Universidad Católica de Ávila (UCAV), Calle Canteros s/n, 05005, Ávila, Spain
mangel.esteso@ucavila.es

As it is well known, an electrochemical system consists of two distinguishable phases: the electrodes (solid phase on whose surface the transfer of electrical charge occurs) and the surrounding ionic medium (phase in which the electrodes are embedded and in which ionic species move, transporting the electrical charge between anode and cathode).

The processes of electrical charge transfer across the electrode interface are very important, but just as important are the nature, composition, and physicochemical characteristics of the electrolyte. Therefore, knowing the characteristics and understanding the physicochemical behaviour of the electrolyte is essential (one might even say crucial).

This talk aims to turn the gaze to the solution, briefly focusing it on some of its physicochemical properties, such as conductivity and ionic transference numbers, electrolyte activity, mutual diffusion of the species present in the dissolved system, volumetric and sonometric properties of the solution, and the viscosity of the medium; all properties on which we have worked along these years of dedication to the Ionic Electrochemistry.

Acknowledgements

I want to express my gratitude to the teachers, friends, pupils, students and collaborators, who have accompanied me during these years and have made this research work possible.

[SC02]

Electrochemical route to green steel: challenges, insights and future perspectives

Daniela V. Lopes*, Jorge R. Frade, Andrei V. Kovalevsky
CICECO – Aveiro Institute of Materials, Department of Materials and Ceramic Engineering, University of Aveiro, 3810-193 Aveiro, Portugal
*daniela.rosendo.lopes@ua.pt

Steel is one of the most essential materials in our daily lives, contributing significantly to the global economy. About 1.9 million tonnes of steel were produced in 2023, generating about 1.92 million tonnes of CO_2 per tonne of crude steel [1], driven by societal demand. In fact, the established steelmaking route, the blast-furnace-basic-oxygen furnaces (BF-BOF), contributes to about 7-9% of the global CO_2 emissions [1,2]. The decarbonisation of the steelmaking sector requires disruptive alternatives to the conventional approach of steelmaking. Thus, alkaline electrowinning is gaining attention as a strategic electrochemical route to decarbonise the steel industry, electrochemically reducing iron oxides to metallic iron for subsequent steelmaking. Key aspects of this technology include the mild operating temperature (~100 °C) required and the potential to be powered by renewable energy. However, the mechanisms of iron oxides conversion to iron are still debatable in literature, while hydrogen evolution reaction (HER) plays an important role as a parasitic side reaction [3], negatively impacting the Faradaic efficiency. This work highlights recent advances in alkaline electrowinning of iron from iron oxides and provides new perspectives for the future of steelmaking.

Some case studies conducted by the authors explored different ceramic cathodes and alkaline ceramic suspensions for the electrochemical reduction of Fe_2O_3, Fe_3O_4, as well as other iron (hydro)oxides, achieving Faradaic efficiencies from 65 to 90%. Alternative feedstocks for the electrochemical cell were also considered, including feedstocks that mimicked industrial residues, to evaluate the effect of non-conductive phases. Thus, the presence of Al-, Mg-, Ti-containing phases as impurities was also tested and found to influence the electroreduction to Fe to some extent. Nevertheless, the inclusion of these elements in iron oxide-based matrices enables the processing of a wider range of raw materials, including industrial residues, with notable benefits for the circular economy and industrial symbiosis. The results obtained, combined with contributions from other partners in the SIDERWIN European project, contributed to demonstrating the technology at pilot scale. These findings establish a viable and sustainable electrochemical route to green steel, validated by pilot scale experiments showing an energy consumption of 9.7 GJ/tonne Fe. Alkaline electrowinning for steelmaking can foster technological advancement in the industry while promoting decarbonisation in the sector, with direct societal impact.

Funding

This research was funded by SIDERWIN European project (SIDERWIN- DLV-768788- Horizon 2020/SPIRE10).

Acknowledgements

The authors acknowledge CICECO-Aveiro Institute of Materials, UIDB/50011/2020, UIDP/50011/2020 & LA/P/0006/2020, financed by national funds through FCT/MCTES (PIDDAC). Daniela V. Lopes acknowledges the support of her Research Employment Contract funded by FCT (2023.07163.CEECIND/CP2840/CT0006).

References

[1] World Steel Association **2025**. World steel in figures 2025 - statistical report, Brussels. Available at: https://worldsteel.org/data/world-steel-in-figures/world-steel-in-figures-2025/ (Accessed on 09/09/2025).
[2] L. Kavalsky, V. Viswanathan, *J. Phys. Chem. C* **2024**, 128(35), 14611-14620.
[3] D.V. Lopes, M.J. Quina, J.R. Frade, et al., *Front. Mater.* **2022**, 9, 1010156.

BOOK OF ABSTRACTS

Oral Communications

[OC01]

Designing flexible organic cathodes for stable ion batteries

Katherine S. Bettencourt*, Ana S. Viana, Jorge P. Correia
Centro de Química Estrutural - Institute of Molecular Sciences, Departamento de Química e Bioquímica,
Faculdade de Ciências da Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal
*fc56587@alunos.fc.ul.pt

Lithium-ion Batteries (LIBs) are widely used sustainable energy sources for technological devices in our modern society. Despite their growing popularity, the discrepancy between their increased usage and the challenges of material scarcity and recycling, proves LIBs to be a future resource constraint and environmental hazard to sustainability. As a result, the focus towards alternative battery technologies that rely on easy to extract and recycle abundant metals has become significantly more relevant. Sodium-ion batteries are a promising option due to its abundance and chemical similarity to lithium. However, lithium-ion technology cannot be directly applied to sodium systems, since the larger sodium ions can destabilize crystal structures during battery cycles, making it necessary to develop new electrode materials [1].

Organic cathode materials have attracted attention for sodium-ion batteries due to their flexibility, sustainability, and cost-effectiveness. Carbonyl compounds and conducting polymers have particularly caught the attention for their application as cathodes, but their low energy densities limit their practical application [2]. To address this, this work focuses on combining both materials into a hybrid coating with improved stability that can also be modified to enhance specific capacity. Dopamine (DA) and 3,4-ethylenedioxythiophene (EDOT) were electropolymerized to merge their properties into a copolymer with improved performance. PDA offers strong surface adhesion [3] and easy chemical modification, while PEDOT is recognized for its conductivity and chemical stability [4].

The electrosynthesis of the PDA/PEDOT copolymer was studied under various applied potentials, electrolytes, and monomer ratios to optimize its performance as a cathode. Its physicochemical characterization confirmed the successful synthesis of a hybrid material, with the film exhibiting the pseudocapacitance of PEDOT and the quinone/catechol redox activity of PDA. Techniques such as FTIR, Raman, AFM, ellipsometry, *in-situ* UV-vis, and electrochemical analysis provided detailed information on the film's composition, morphology, thickness, and optoelectronic properties. When tested as a cathode, the copolymer showed higher stability and specific capacity than pristine PEDOT, retaining 96% of its capacity after 1500 cycles, demonstrating its potential as a platform for next-generation hybrid organic cathodes.

Funding

Centro de Química Estrutural is a Research Unit funded by FCT through projects UIDB/00100/2020 (https://doi.org/10.54499/UIDB/00100/2020) and UIDP/00100/2020 (https://doi.org/10.54499/UIDP/00100/2020). Institute of Molecular Sciences is an Associate Laboratory funded by FCT through project LA/P/0056/2020 (https://doi.org/10.54499/LA/P/0056/2020).

References

[1] P.K. Nayak, L. Yang, W. Brehm, et al., *Angew. Chem. Int. Ed.* **2018**, 57(1), 102-120.
[2] H. Zhang, Y. Gao, X.-H. Liu, et al., *Application. Adv. Funct. Mater.* **2022**, 32(4), 2107718.
[3] L.C. Almeida, R.D. Correia, B. Palys, et al., *Electrochim. Acta* **2021**, 386, 138515.
[4] D.R. Santos, J.F. Zeferino, A.S. Viana, et al., *Electrochim. Acta* **2025**, 518, 145760.

[OC02]

Ni(Ce,Zr)O_2 nanofibers with Ni exsolution as an advanced hydrogen electrode for high-temperature SOFCs

M.R. Serrano de la Cruz*, A. Moratalla, I. Ayuso, A. Pardo, N. Díaz, J. Broceño, C. Montes, R. Campana
Hydrogen National Centre (CNH2), Puertollano, Spain
*rosario.serrano@cnh2.es

The increasing energy demand, along with the pressing need to reduce greenhouse gas emissions, has driven the development of high-temperature solid oxide fuel cells (SOFCs), recognized as highly efficient technologies for the conversion of hydrogen and biogas into electricity [1,2].

In this study, Ni(Ce,Zr)O_2 nanofibers synthesized via electrospinning are presented, designed to function as hydrogen electrodes in SOFCs fuelled with biomethane, aiming to optimize the electrocatalytic properties and stability of the material. The fibres were subjected to controlled thermal treatments to induce the exsolution of nickel nanoparticles on their surface, a process that improves electrocatalytic activity and resistance to carbon deposition during operation with various fuels [1,2].

Structural and morphological characterization of the nanofibers was performed using X-ray diffraction (XRD), scanning electron microscopy (SEM), and specific surface area analysis via the BET method, allowing the evaluation of crystallinity, nanoparticle distribution, and material porosity. Once optimized, the nanofibers were deposited onto a YSZ electrolyte prepared by tape casting, using ultrasonic spraying to achieve a homogeneous distribution and optimal electrical contact with the substrate. Additionally, a GDC barrier layer and an LSM oxygen electrode were sequentially deposited using the same technique, completing the SOFC cell configuration.

The electrochemical performance was evaluated through polarization curves, electrochemical impedance spectroscopy (EIS), and durability tests using hydrogen, biogas, and methane reformate as fuels. The results demonstrate that nickel exsolution significantly improves the efficiency and durability of the anode, enhancing its resistance to carbon deposition. These findings confirm the potential of these nanofibers for SOFC applications operating with complex renewable fuels.

Funding
This work has been developed as part of Energy and Renewable Hydrogen Program of the Complementary R&D&I Plans of the Ministry of Science and Innovation, funded by the European Union NextGenerationEU within the Framework of Component 17 of the Recovery, Transformation and Resilience Plan (ref C17.I01.P01) and as part of PID2020-115935RA-C44 and PID2024-162053OB-C31 funded by Ministerio de Ciencia e Innovación (Gobierno de España) and Agencia Estatal de Investigación (AEI) and SBPLY/24/180225/000095.

References

[1] G. Cipriani, V. Di Dio, F. Genduso, et al., *Int. J. Hydrogen Energy* **2014**, 39(16), 8482-8494.
[2] G. Renau, *Temas Debate* **2022**, 335, 25-27.

[OC03]

Tailored 3D-printed photopolymer-derived carbon materials for advanced electrocatalytic systems

Noelia Corrochano[1,2]*, Ricardo da Silva Furlan[3], Fernando Martínez[1,2,] Jose L. Diaz de Tuesta[1,2]
[1]Chemical and Environmental Engineering Group, ESCET, Spain
[2]Instituto de Investigación de Tecnologías para la Sostenibilidad, Rey Juan Carlos University, C/Tulipán s/n, 28933, Móstoles, Madrid, Spain
[3]Department of Chemistry, Universidade Tecnológica Federal do Paraná (UTFPR), Via do Conhecimento Km 1, Pato Branco 85503-390, Brazil
*noelia.cguijarro@urjc.es

Stereolithographic 3D printing is a versatile technique for producing well-defined photopolymers with complex geometries, which can be carbonized to develop carbon monoliths with potential for several applications, such as adsorption, advanced oxidation processes (AOPs) or electrochemical processes. AOPs allow the oxidation of pollutants through their reaction with hydroxyl radicals ($HO^\bullet$), generated via catalytic decomposition of H_2O_2 in presence of iron. Electro-Fenton (EF) is a viable alternative due to the *in situ* electrogeneration of H_2O_2 and Fe (II) regeneration at the cathode [1,2,3].

In this work, the catalytic and electrochemical properties of photopolymer-derived carbons were assessed in EF. Gyroid photopolymers (named PDD based on the precursors used in their synthesis: pentaerythritol tetraacrylate, divinylbenzene and diethylhexyl phthalate) were synthesized via stereolithography in a 3D printer using a tailored resin [1]; 0.1 wt.% of iron nanoparticles were also added to obtain an iron-doped polymer (Fe-PDD). Polymers were subjected to: (i) oxidation with air at 300ºC, and (ii) pyrolysis with N_2 at 850ºC, resulting in C-PDD material. In addition, steam was introduced in the final step to obtain activated carbons (A-C-PDD and Fe-A-C-PDD) (Fig. 1a). Carbons reached BET surface areas values up to 1692 m^2/g. Rotating Ring Disk Electrode (RRDE) tests (Fig. 1b) show that A-C-PDD has higher electroactivity and selective H_2O_2 generation, achieving almost 100% of H_2O_2 yield at -0.9 V and total electron-transfer number (n) close to 2, according to the two-electron pathway in the oxygen reduction reaction. For this reason, activated carbon materials were tested at -0.9 V in the electrocatalytic degradation of phenol (Fig. 1c). Firstly, an adsorption cycle was conducted until equilibrium (24 h), resulting in around 70% of phenol removal. Secondly, electrocatalysis was performed in a three-electrode cell (42 h), using carbons as cathodes. Fe-A-C-PDD removed 80% of residual phenol and 26% of total organic carbon (TOC), while A-C-PDD achieved only 46% and 6%, respectively. This increased degradation and mineralization is due to higher amounts of $HO^\bullet$ are formed caused by the iron embedded in the material.

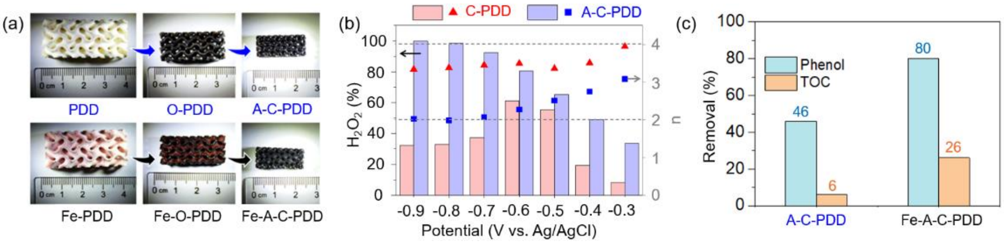


Figure 1. (a) Gyroid materials synthesized; (b) RRDE tests (c) electrocatalytic degradation of phenol.

Funding
This research was funded by the research grants 2022-T1/AMB-23946 and CNS2024-154264.

References

[1] H. Steldinger, A. Esposito, K. Brunnengräber, et al., *Adv. Sci.* **2019**, 6, 1901340.
[2] A.S. Silva, J.L. Diaz de Tuesta, A. Henrique, et al., *Chem. Eng. J.* **2024**, 499, 156574.
[3] K. Zhao, X. Quan, S. Chen, et al., *Chem. Eng. J.* **2018**, 354, 606.

[OC04]

Biodegradable electrochemical sensor for the analysis of quercetin and rutin in grape extracts

Geanderson E. de Almeida[1], Cláudio G. S. Macedo[1], Ismagno A. de Carvalho[1],
Manuela N. da Silva[1], Káliton P. Mororó[1], Márcia E. M. Nunes[1], Thays B. P. Vilante[1],
Fábio O. S. Ribeiro[3], Amando O. Matias[1], Emanuel A. O. Farias[1,2,3], Carla Eiras[1]*

[1]Laboratório de Pesquisa e Desenvolvimento de Novos Materiais e Sistemas Sensores, Universidade Federal do Piauí, Teresina, Piauí 64049-550, Brazil
[2]Universidade Estadual do Vale do Acaraú, Camocim, Ceará, Brazil
[3]Núcleo de Pesquisa em Biodiversidade e Biotecnologia, Universidade Federal do Delta do Parnaíba, Parnaíba, Piauí, Brazil

*eirasc@ufpi.edu.br

The demand for sustainable analytical technologies has driven the development of biodegradable sensors for monitoring bioactive compounds in the environment [1]. Flavonoids such as quercetin (QCT) and rutin (RU), widely found in fruits like grapes (*Vitis vinifera* L.), exhibit significant antioxidant properties, making their quantification essential for quality control and nutritional studies [2]. This study proposes a disposable and biodegradable electrochemical sensor based on a gelatine biopolymeric matrix for stencil-printed electrodes (StPE), using a conductive ink composed of multi-walled carbon nanotubes (MWCNTs) and a polysaccharide extracted from the exudate of *Amburana cearensis* [StPE(Gelatine/MWCNTs-GAmb], for the simultaneous detection of QCT and RU. The sensor exhibited distinct redox mechanisms: adsorption-controlled for QCT and diffusion-controlled for RU, involving two electrons and two protons, as confirmed by pH and scan rate studies [3]. Analytical curves obtained by differential pulse voltammetry showed linear responses in the range of 1–100 µM, with detection limits of 0.02558 µM for QCT and 0.009070 µM for RU. Tests with common interferents found in grape matrices indicated interference below 10%. The quantification of QCT and RU in grape extracts showed good agreement with literature values. Soil assays confirmed the sensor's biodegradability, with structural degradation observed after 10 days. Electrochemical stability was maintained for up to 180 days. These results demonstrate the potential of StPE(Gelatine/MWCNTs-GAmb) as an efficient, selective, and environmentally friendly alternative for electrochemical analysis of flavonoids in food matrices.

Funding

This research was funded by MCTI/CNPq under Grant Nos. 442845/2023-5 and 310764/2023-8.

References

[1] J.S. Stefano, L.O. Orzari, H.A. Silva-Neto, ey al., *Curr. Opin. Electrochem.* **2022**, 32, 100893.
[2] Deepika, P.K. Maurya, *Molecules* **2022**, 27(8), 2498.
[3] S.M. Vealan, M. Ramcharan, K. Asokan, et al., *Electrochim. Acta* **2024**, 207,112187.

[OC05]

Electrochemical lactate sensing via molecularly imprinted polymers for advanced fetal monitoring

J. Barbosa[1,2]*, M.M. Silva[2], R. Queirós[1]
[1]INL - International Iberian Nanotechnology Laboratory, Avenida Mestre José Veiga, 4715-330 Braga, Portugal
[2]Chemistry Centre of the University of Minho (CQ-UM), Campus de Gualtar, 4710-057 Braga
*jpbarbosa87@hotmail.com

Current methodologies for monitoring fetal physiological parameters during labour exhibit significant limitations due to their invasive and outdated nature [1]. The need for advanced sensing platforms, less invasive, and enabling real-time assessment of critical biomarkers such as lactate, is essential for ensuring optimal maternal and neonatal outcomes [2]. This study presents an electrochemical sensor for selective lactate detection based on a molecularly imprinted polymer (MIPs) achieved by electropolymerization of 3-aminophenylboronic acid (3-APBA) as a functional biocompatible monomer [3] and lactate as the template molecule (Fig.1). The polymer was assembled on two different working electrodes (WE) materials, carbon and gold, and evaluated at three modification stages: at bare electrode, after 3-APBA/lactate polymer electropolymerization and after lactate removal (MIP formation) using cyclic voltammetry and electrochemical impedance spectroscopy. All steps were also followed with Scanning Electron Microscopy (SEM). For the carbon WE, the bare surface showed a high peak current (i_p) of 110 μA and charge-transfer resistance (R_{ct}) of 1.0 kΩ, which dropped to a 4.3 μA i_p and increased to 42.5 kΩ R_{ct} with the polymer formation. After lactate removal, the i_p increased to 11.7 μA and the R_{ct} decreased to 8.2 kΩ, confirming template removal. On gold, the bare electrode showed an i_p of 2.9 μA and a R_{ct} of 0.9 kΩ. Polymerization reduced the i_p to 0.5 μA. Although the R_{ct} is not reported due to high resistance, these results confirm that film formation blocked the WE surface. After lactate removal, the i_p reached 1.2 μA, and R_{ct} was 353.7 kΩ, still indicating a substantial polymer barrier. Preliminary rebinding tests in buffer show an increase of R_{ct} with an increase of lactate in the MIPs. These results confirm the presence of the polymer after electropolymerization and after the template removal, allowing further assays, in buffer and biological samples for lactate detection.

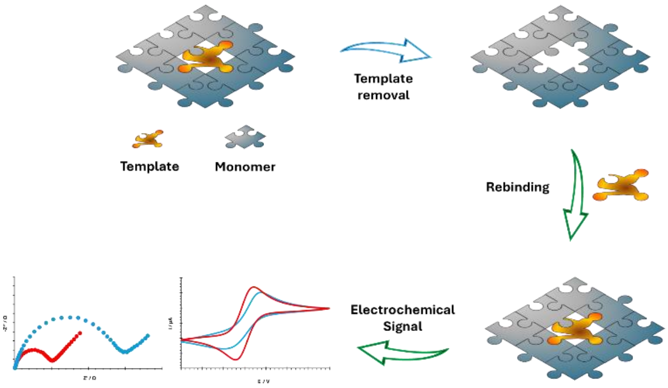


Figure 1. Lactate MIP-based sensor assembly and electrochemical signals.

Funding
This research was funded by the project Biosensor4Intrapartum from Health from PT Innovation Pack, PRR-C630926586-00465198 and Fundação para a Ciência e a Tecnologia (FCT) through UID/00686/2023 (CQ-UM) and the PhD grant (2024.02785.BDANA).

References

[1] A.J. Rosenbaum, R.M. Smith, E.M. Hade, et al., *J. Matern. Fetal Neonatal. Med.* **2020**, 33, 2348-2353.
[2] G. Lamé, E.G. Liberati, A. Canham, et al., *BMJ Quality & Safety* **2024**, 33, 246-256.
[3] C. Animashaun, G. Slaughter, *Biosens. Bioelectron.: X* **2025**, 26, 100659.

[OC06]

Conductive bio-inspired copolymers as versatile platforms for biosensing: insights into the electropolymerisation mechanism

Diana M. Carneiro*, Jorge P. Correia, Ana S. Viana

Centro de Química Estrutural, Institute of Molecular Sciences, Departamento de Química e Bioquímica,
Faculdade de Ciências da Universidade de Lisboa, Campo Grande, 1749-016, Lisboa, Portugal

*dianamcarneiro@alunos.fc.ul.pt

The design of innovative materials for biosensing applications remains a critical challenge, with continued efforts directed toward enhancing both sensor stability and sensitivity [1]. Amperometric enzyme-based biosensors, in particular, require reliable enzyme immobilisation along with efficient electrochemical signal transduction. Bio-mimetic polymers such as polycatecholamines – most notably polydopamine (PDA) and polynorepinephrine (PNE) – have been explored as versatile platforms in both optical and electrochemical [2] biosensing. Due to the presence of both catechol and amine functional groups, these materials exhibit strong adhesive properties, allowing the robust and stable attachment of biorecognition elements to the sensor surface. Nevertheless, their application in amperometric sensing is limited by their intrinsically low electrical conductivity, which negatively impacts both their electrochemical growth and signal transduction efficiency.

This study aims to broaden the bioelectrochemical applications of polycatecholamines by integrating their strong adhesive properties with the high electronic conductivity of conventional conducting polymers, such as polypyrrole (PPy). In this context, catecholamine and pyrrole monomers were co-electropolymerised to generate hybrid copolymers – PDA/PPy and PNE/PPy – featuring catechol pendant groups and a conductive polymeric backbone [3]. Comprehensive physicochemical characterisation was performed to evaluate their redox activity, dielectric properties, film thickness, morphology, surface adhesiveness, and wettability. The copolymerisation process demonstrated a synergistic effect, leading to enhanced film growth and electroactivity compared to the respective pristine polymers. These copolymer matrices were further functionalised with different enzymes and their biocatalytic performance demonstrated strong potential for the electrochemical detection of diverse target analytes.

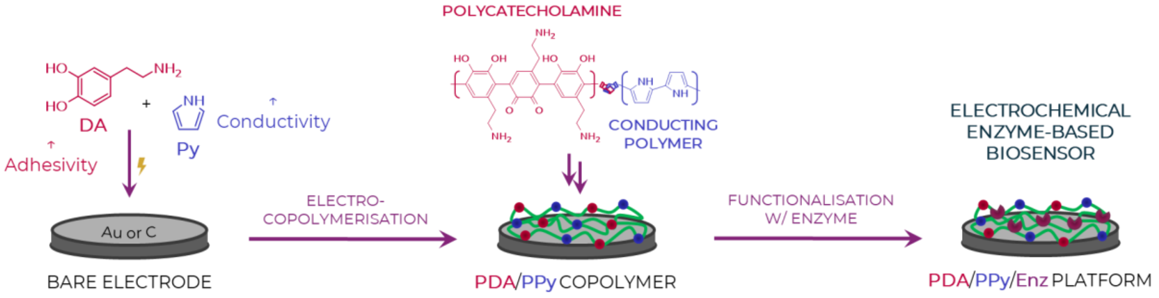


Figure 1. Two-steps electrocopolymerisation / functionalisation of PDA/PPy copolymers.

Funding

Centro de Química Estrutural is a Research Unit funded by Fundação para a Ciência e a Tecnologia through projects UIDB/00100/2020 and UIDP/00100/2020. Institute of Molecular Sciences is an Associate Laboratory funded by Fundação para a Ciência e a Tecnologia through project LA/P/0056/2020.

References

[1] M.H. Fakhr, et al., *Biosens. Bioelectron.* **2024**, 19, 100503.
[2] L.C. Almeida, J.F. Zeferino, C. Branco, et al., *Bioelectrochem.* **2025**, 161, 108826.
[3] D.M. Carneiro, L.C. Almeida, D.R. Santos, et al., *Electrochim. Acta* **2025**, 524, 146004.

[OC07]

Sustainable bifunctional electrodes from waste-derived hydrochar for electro-Fenton applications

Ismael González-González[1,2]*, Ana Cruz del Álamo[1], José Luis Díaz de Tuesta[1,2], Raúl Molina[1,2], M. Isabel Pariente[1], Fernando Martínez[1,2]

[1]Chemical and Environmental Engineering Group, ESCET, Spain
[2]Instituto de Investigación de Tecnologías para la Sostenibilidad, Rey Juan Carlos University, Móstoles, Spain
*ismael.gonzalez@urjc.es

The occurrence of recalcitrant pollutants in water demands sustainable treatments beyond conventional methods. Among advanced oxidation processes, the electro-Fenton (EF) method is highly effective but limited in its homogeneous form by acidic conditions and sludge generation [1]. Heterogeneous EF processes employing carbon-based catalysts have emerged as a promising approach, offering enhanced stability and improved H_2O_2 selectivity [2], thanks to their potential use as bifunctional electrodes. However, the development of low-cost carbon electrodes remains essential to enable large-scale implementation. In this way, hydrothermal carbonization (HTC) provides a scalable route to hydrochar precursors for efficient carbon-based electrodes [3]. In this work, two hydrochars were selected as carbon precursors: one from refinery sludge with high ash content (HCR) and another from orange peel with low ash content (HCO). Both were subjected to a one-step chemical activation with KOH and nitrogen functionalization using urea (1:3:3 KOH:Urea:HC), followed by pyrolysis at 850 °C. The resulting materials were blended with varying ratios of carbon black (CB) and 5% PTFE to fabricate the electrodes. This formulation aimed to optimize H_2O_2 generation from CB while promoting its subsequent reaction with the metal naturally content of the hydrochar, producing hydroxyl radicals for the degradation of phenol used as a model pollutant. For comparison, additional tests were also performed using the raw-hydrochars without activation-functionalization mixed with CB, in order to evaluate the impact of the activation and functionalization steps on the electrochemical performance of the electrodes. For HCO-based electrodes, hydrochar loadings of 5, 15, and 30% were tested, while for HCR, the proportions were limited to 5, 10, and 15% due to its much higher metal and ash content (≈60% after activation vs. ≈6% for HCO). As shown in Fig.1, phenol degradation of up to ~75% was achieved with HCO, reaching the maximum at 30% of hydrochar content, whereas HCR electrodes did not exceed ~10% degradation under the tested conditions. These results suggest that HCO is more suitable for EF applications, likely due to a more favourable balance between carbon matrix and ash content, combined with the higher porosity developed during activation (900 m^2/g). In contrast, the excessive ash fraction in HCR restricts porosity development (150 m^2/g) and limits the number of active sites available for radical generation. Therefore, future experiments will include an acid washing step of HCR to remove its ash content partially, promoting the development of higher specific surface area. Then, the treated material will be subjected to the same activation and functionalization procedure prior to electrode fabrication.

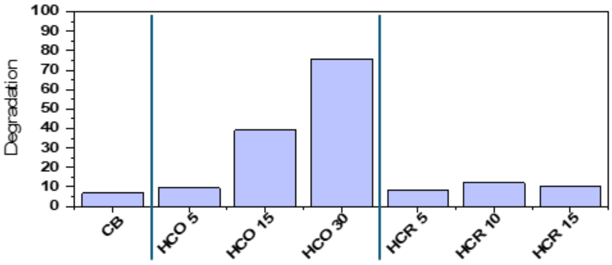


Figure 1. Phenol degradation efficiency using HCO and HCR electrodes. Conditions: 0.05M Na_2SO_4 electrolyte, natural pH, initial phenol concentration of 50 ppm and reaction time of 60 min.

Funding
This research was funded by PID2021-122883OB-I00.

References

[1] F. Deng, J. Jiang, I. Sirés, *Carbon Lett.* **2023**, 33(1), 17-34.
[2] A. Ahmad, P. Kumar, S.P. Singh, *J. Environ. Chem. Eng.* **2025**, 13(3), 117109.
[3] M. Sevilla, A.B. Fuertes, *Carbon* **2009**, 47(9), 2281-2289.

[OC08]

Phosphorus recovery from cheese whey wastewater through electroless struvite precipitation using magnesium anodes

Vasco B. Fernandes[1], Daliany M. Farinon[1,2], Annabel Fernandes[1,2], Jefferson E. Silveira[3], Albertina Amaro[1,2], Juan A. Zazo[3], Carlos Y. Sousa[1,2]*

[1]Department of Chemistry, Universidade da Beira Interior, R. Marquês D'Ávila e Bolama, 6201-001 Covilhã, Portugal
[2]Fiber Materials and Environmental (FibEnTech-UBI), Universidade da Beira Interior, R. Marquês D'Ávila e Bolama, 6201-001 Covilhã, Portugal
[3]Chemical Engineering Department, Universidad Autónoma de Madrid, Ctra. Colmenar km. 15, 28049 Madrid, Spain

*carlos.vieira.sousa@ubi.pt

The growing fertilizer requirements to ensure agricultural production have triggered the development of phosphorus recovery technologies, in a strategy to avoid phosphate rock mining by providing an alternative phosphorus source to fertilizer production [1]. These processes are based on a circular economy approach, with phosphorus being precipitated from wastewater as valuable fertilizers [2]. Among the different recovery methods, electrochemical ones present several advantages such as local pH adjustment without chemical input, faster treatment time, lesser sensitivity to operational fluctuations, and lower co-precipitation of micropollutants [2-4]. Struvite ($NH_4MgPO_4 \cdot 6H_2O$) is one of the possible products of electrochemical precipitation, with the advantage of simultaneously recovering phosphorus and nitrogen, and the disadvantage of requiring magnesium dosage [5]. In this work, a magnesium alloy (AZ31) was used as an anode and combined with a stainless-steel cathode through an electroless process. The influence of ammonium, chloride, and sulphate ions was evaluated by analysing phosphorus removal and magnesium corrosion. All the ions had important and different roles in the process. Sulphate ion was found to accelerate magnesium corrosion, while chloride ion kept anode activity longer, probably through pitting corrosion. Ammonium ion also showed the ability to accelerate the anode corrosion, although it occurred through a different mechanism when compared to sulphate ion. The analyses of the obtained solids showed that the struvite purity increased when the ammonium ion was present simultaneously with sulphate or chloride ions. This research contributes to the knowledge of electroless struvite recovery by identifying suitable wastewater in which this promising technology can be further applied.

Acknowledgements

The authors are very grateful for the support granted by the Research Unit of Fiber Materials and Environmental Technologies (FibEnTech-UBI), through the Project reference UIDB/00195/2020, funded by the Fundação para a Ciência e a Tecnologia, IP/MCTES through national funds (PIDDAC), and DOI: 10.54499/UIDB/00195/2020. Annabel Fernandes acknowledges FCT and the University of Beira Interior for the research contract CEECINST/00016/2021/CP2828/CT0006 under the scope of the CEEC Institutional 2021, funded by FCT (https://doi.org/10.54499/CEECINST/00016/2021/CP2828/CT0006).

References

[1] C.Y. Sousa, I. Gomes, A. Amaro, et al., *Rev. Environ. Sci. Bio-Technol.* **2025**, 24(2), 377-398.
[2] Y. Ren, W. Zheng, X. Duan, et al., *Environ. Funct. Mater.* **2022**, 1(1), 10-20.
[3] Y. Wang, P. Kuntke, M. Saakes, et al., *Water Res.* **2022**, 209, 117891.
[4] B. Song, R. Wang, W. Li, et al., *J. Hazard. Mater.* **2024**, 478, 135505.
[5] A. Hug, K.M. Udert, *Water Res.* **2013**, 47(1), 289-299.

[OC09]

Electrochemical procedures coupled to CYP450 metabolism for control and environment risk analysis of transdermal patches

José Pedro Silva*, Célia G. Amorim, Alberto da Nova Araújo
REQUIMTE/LAQV, Departamento de Ciências Químicas, Faculdade de Farmácia, Universidade do Porto,
R. Jorge Viterbo Ferreira, 228, 4050-313 Porto, Portugal
*up201705721@up.pt

Nowadays, the delivery of pharmaceutical compounds for the sustained treatment of certain diseases is performed through the application of transdermal patches. These can bypass the first-pass metabolism, allowing for an effective and fast therapeutic activity, along with a malleable profile capable of adapting to the various types of drugs [1].

However, this treatment contributes to an emerging environmental problem – namely, the increasing concentrations of pharmaceutical compounds and their metabolites in water bodies —which results from various sources, including improper disposal of patches. This situation is quite concerning since certain drugs have been observed to induce significant negative effects on the living organisms present in these biomes [2].

Thereby, within this work, it is described the development of an analytical electrochemical method for in vitro control of the progesterone formulations and potential contamination after-use levels, based on the combination of both microfluids and electrochemistry principles (Fig.1). It highlights the study of plasticized membrane optimization, along with mention of Cytochrome P450 gelation, for compound metabolic assessment. The equipment reduced cost, portability and low sample and reagents consumption, along with the reduction of effluent wastes, is demonstrated and compared with the previously described analytical proposed methodologies [3].

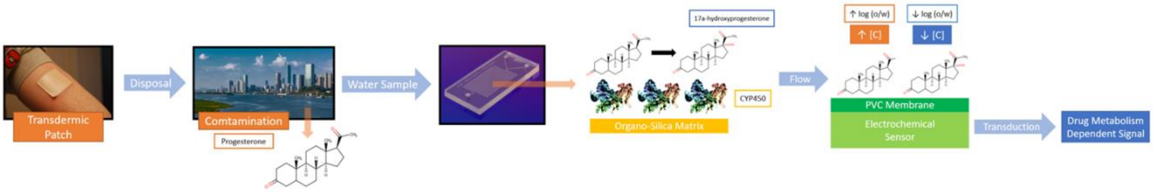


Figure 1. Schematic Representation of the proposed detection method principles.

Funding
This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements
José Pedro Silva thanks FCT/MCTES- Ministério da Ciência, Tecnologia e Ensino Superior and ESF (European Social Fund) through NORTE 2020 (Programa Operacional Região Norte) for his PhD grant ref. 2023.00756.BD.

References

[1] W.F. Wong, K.P. Ang, G. Sethi, et al., *Medicina* **2023**, 59, 778.
[2] P. Verlicchi, M. Al Aukidy, E. Zambello, *Sci. Total Environ.* **2012**, 429, 123-155.
[3] F. Kivlehan, F. Garay, J. Guo, et al., *Anal. Chem.* **2012**, 84(18), 7670-7676.

[OC10]

Advancing covalent organic polymer-based sensors for saxitoxin detection

Lurdes Gonçalves[1,2]*, Miguel Chaves[1], Bernardo A Nogueira[1], Laura Rodriquez-Lorenzo[1], Laura M Salonen[1,3], Raquel Queirós[1], Célia G Amorim[2], Begoña Espiña[1], Marília Barreiros dos Santos[1]

[1]INL - International Iberian Nanotechnology Laboratory, Avenida Mestre José Veiga, 4715-330 Braga, Portugal
[2]REQUIMTE/LAQV, Faculty of Pharmacy, University of Porto, Portugal
[3]CINBIO, University of Vigo, 36310 Vigo, Spain

*lurdes.goncalves@inl.int

Saxitoxin (STX) is a potent neurotoxin produced by cyanobacteria and dinoflagellates, widely recognised as one of the major causes of paralytic shellfish poisoning [1]. Due to its acute toxicity, the World Health Organisation (WHO) has set a guideline value of 3 µg/L (10 nM) for STX in drinking water [2]. Current analytical techniques, such as high-performance liquid chromatography–mass spectrometry and enzyme-linked immunosorbent assay, are constrained by high costs, or limited reagent stability, underscoring the need for portable, sensitive, and robust sensors. These limitations point to an urgent need for detection methods that are not only sensitive and reliable but also readily deployable in the field. In our previous work, we developed a proof-of-concept electrochemical sensor based on a carboxyl-functionalised covalent organic polymer (COP, TpPa-COOH) [3]. The sensor surface was modified with a sulphur terminated self-assembled monolayer (SAM) to attach the gold nanoparticle composite COP-AuNPs. The sensor showed a linear response to STX in the micromolar range (3–10 µM), with an estimated limit of detection of 2.4 µM. Despite these promising results, the detection limit remained above regulatory thresholds, while reproducibility and stability were not fully established. To address these limitations, a full study of surface modification is being conducted to reduce the variability of the SAM and enhance the attachment of the COP. Different complementary techniques are being employed to characterise the different stages of sensor construction, including quartz crystal microbalance (QCM), scanning electron microscopy, confocal Raman microscopy, electrochemical impedance spectroscopy (EIS) and voltammetry. Ongoing experiments aim to determine whether these sensors can deliver improved reproducibility, an extended dynamic range, and lower detection limits compared with the initial setup. This work-in-progress highlights the potential of COP-nanocomposite platforms as next-generation tools for the environmental monitoring of cyanotoxins.

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements

To the project AIHABs (411), granted under the Water JPI, JPI Oceans, and JPI AMR joint call Aquatic Pollutants, with support from the European Commission and Fundação para a Ciência e a Tecnologia (FCT) under grant agreements No. 869178-AquaticPollutants and Aquatic/0005/2020 and FCT/MECI. L.G. acknowledges FCT for the PhD grant ref. 2024.06242.BDANA. L.R.-L. acknowledges funding from FCT through the Scientific Employment Stimulus Program (2020.04021.CEECIND). L.M.S. acknowledges financial support through the Ramón y Cajal grant RYC2020-030414-I funded by MICIU/AEI/10.13039/501100011033 and by "ESF–Investing in your future".

References

[1] X. Bai, W. Gong, Y. Guo, et al., *Analyst* **2023**, 148, 2327-2334.
[2] World Health Organization, Cyanobacterial toxins: saxitoxins. Guidelines for Drinking-water Quality and Guidelines for Safe Recreational Water Environments, WHO: Geneva, **2020**, pp 1-29.
[3] T. Wang, S. Fernandes, J. Araújo, et al., *J. Hazard. Mater.* **2023**, 452, 131247.

[OC11]

Electropolymerized hydrogel-MIP biosensor for myoglobin detection

Marcus V. Monteiro[1]*, Manuel Azenha[1], Tiago G. Teixeira[2], José A. Ribeiro[3]*
[1]CIQUP/IMS, Departamento de Química e Bioquímica, Faculdade de Ciências da Universidade do Porto,
Rua do Campo Alegre, s/n, Porto 4169-007, Portugal
[2]Atrys Portugal Centro Médico Avançado, Rua Prof. Doutor Serafim Pinto Guimarães, nº 222 4520-103 Espargo,
Santa Maria da Feira, Portugal
[3]INESC TEC – Institute for Systems and Computer Engineering, Technology and Science, Faculdade de Ciências
da Universidade do Porto, 4169-007 Porto, Portugal
*marcusmonteiro14@gmail.com | jose.ribeiro@fc.up.pt

Cardiovascular diseases (CVD) are disorders that affect the heart and blood vessels, such as coronary artery disease, hypertension, and acute myocardial infarction, seriously compromising patients' health. According to the WHO, in 2021, CVDs were responsible for 23% of deaths worldwide [1]. In this context, the early CVD diagnosis, particularly in point-of-care (POC), is essential for prevention, effective treatment, and reduction of complications.

Myoglobin, a ~18 kDa hemoprotein present in the heart and skeletal muscles, is an important cardiac biomarker due to its rapid release after cardiac injury, being fundamental in the early diagnosis of acute myocardial infarction (AMI). Its levels increase within 1-3 h of the onset of symptoms, peak 4-12 h later, and normalize after 24 h [2]. Recently, several highly sensitive and fast-response electrochemical biosensors have been developed targeting this circulating biomarker [3,4]. However, many are restricted to centralized clinical settings and/or require expensive bioreceptors, such as antibodies, lacking long-term stability while having ethical dilemmas associated with their production. Molecularly imprinted polymers (MIPs) are a promising alternative to biological antibodies used in these devices. Particularly, hydrogel-based MIPs are capable of analyte recognition while facilitating the removal of template molecules due to the ability of swelling or shrinking in response to changes in pH or temperature [5].

The objective of this work is to develop an innovative, miniaturized, and portable electrochemical device, similar to a glucometer, for the selective detection and quantification of myoglobin in human serum in a minimally invasive manner, allowing the accurate diagnosis and monitoring of CVDs in POC. The nanostructured imprinted hydrogel films were directly prepared on the electrode surfaces in simple and cost-effective manner through the electrochemical polymerization of acrylamide-based monomers (N-isopropylacrylamide, N-(3-Aminopropyl)methacrylamide hydrochloride), an approach that remains relatively unexplored so far, enhancing the selectivity and sensitivity of the electroanalysis.

Funding

M.V.M. acknowledges FCT - Fundação para a Ciência e a Tecnologia, I.P. for the funding through the research grant number DOI 10.54499/2024.03860.BDANA, CIQUP (DOI: 10.54499/UIDP/00081/2020) and LA/P/0056/2020 (IMS). This work is co-funded by the European Regional Development Fund (ERDF) through the COMPETE 2030 program under Portugal 2030 and FCT within project eSPRcancer, with reference 15242 (COMPETE2030-FEDER-00890700) (https://doi.org/10.54499/15242 (COMPETE2030-FEDER-00890700)).

Acknowledgements

The author acknowledges the future collaboration and intellectual support of Atrys Portugal.

References

[1] WHO - World Health Organization. The top 10 causes of death. https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death
[2] A.M. Hasan-Abad, V. Ramezani; M.A. Esmaili, et al., *Anal. Bioanal. Electrochem.* **2024**, 16, 786-808.
[3] H.Y. Lee, J.S., Choi, P. Guruprasath, et al., *Anal. Sci.* **2015**, 31, 699-704.
[4] Y. Liu, B. Sun, Y. Wu, et al., *Microchem. J.* **2025**, 215, 114449.
[5] A.T. Silva, R. Figueiredo, M. Azenha, *ACS Sensors* **2023**, 8, 2898-2920.

[OC12]

Electrochemical (bio)assays for food safety and quality evaluation

Henri P.A. Nouws*, Maria Freitas, Ricarda Torre, José Pedro Rocha, Patrícia Rebelo,
João G. Pacheco, Cristina Delerue-Matos

REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal

*han@isep.ipp.pt

Food is increasingly associated with health and well-being, so there is a growing demand for healthy foods that are nutritionally rich but whose safety is guaranteed. Quality control throughout the entire production chain does not prevent the presence of substances/constituents that can cause adverse reactions in the consumer. Worldwide there is legislation in force that sets strict standards for food safety and quality. This legislation constitutes a major challenge for many food business operators because of the resources needed to accurately quantify several substances/constituents at all points of the production chain; the most widely used methods (e.g., ELISA, PCR, (LC-)MS) for this task involve expensive equipment that must be operated by specialized analysts, which constitutes a hurdle for resource-limited companies. Therefore, small, portable, disposable, cheap, and easy to use devices could be a valuable tool to control allergens in food products.

In this presentation several electrochemical (bio)sensing approaches (immunosensors and molecularly imprinted polymer-based sensors), employing a variety of materials and detection techniques, will be presented as promising alternatives to monitor food safety and quality along the production chain.

Funding

This research received financial support through the project "Sens2BiteSafe - Allergen Analysis Breakthroughs: Enhancing Food Safety with Electrochemical Paper-based Analytical Devices" (COMPETE2030-FEDER-00713900 (nº 16000)), funded by FEDER (COMPETE 2030) and Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministro da Educação, Ciência e Inovação) and from Portuguese national funds (FCT/MECI) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements

Maria Freitas and João Pacheco are thankful for their contracts (2022.00490.CEECIND/CP1724/CT0007 and 2023.07458.CEECIND/CP2842/CT0002) financed by FCT/MCTES-CEEC Individual Program. Patrícia Rebelo is contracted through the Sens2BiteSafe project.

[OC13]

Electrochemical molecularly imprinted polymer devices for analytical applications

João G. Pacheco[1]*, Isabel Seguro[1,2], Patrícia Rebelo[1], Henri P.A. Nouws[1],
Cristina Delerue-Matos[1]

[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]REQUIMTE/LAQV, Departamento de Química e Bioquímica, Faculdade de Ciências, Universidade do Porto
Rua do Campo Alegre, s/n, 4619-007 Porto, Portugal

*jpgpa@isep.ipp.pt

Electrochemical sensors present several attributes that make them attractive for commercial applications, including simplicity, compact size, high sensitivity, fast response, and versatility. They operate by coupling a selective recognition layer with an electrochemical transducer (electrode), thereby providing valuable information about the composition of a system. Despite the large number of publications and patents in this field, only a few devices - most notably the glucometer - have reached successful commercialization. One of the main obstacles lies in the widespread use of biological recognition elements (e.g., antibodies and enzymes), which often suffer from low stability, stringent operational requirements, high costs, and poor reproducibility [1]. Molecularly imprinted polymers (MIPs) have emerged as one of the most promising alternatives for the design of synthetic biomimetic recognition systems. MIPs are synthetic polymers obtained by polymerization of functional monomers and crosslinker molecules in the presence of a template. After polymerization, the template molecule is extracted and a polymer matrix, with sites complementary in shape, size and functionality to the imprinted molecule, is obtained and showing favoured affinity to the template molecule compared to other molecules. Compared with natural receptors, MIPs offer notable advantages such as robustness, tolerance to chemical and thermal variations, ease of preparation, reusability, and low cost [2]. The integration of MIPs into electrochemical sensors has already demonstrated significant potential in environmental, food, and biomedical applications. Ongoing research in this area highlights their role as versatile platforms bridging fundamental science with real-world analytical challenges [3]. In this work different strategies for constructions of MIPs electrochemical devices, developed applications and futures perspectives are discussed.

Funding

This research received financial support through the project “Sens2BiteSafe - Allergen Analysis Breakthroughs: Enhancing Food Safety with Electrochemical Paper-based Analytical Devices” (COMPETE2030-FEDER-00713900 (nº 16000)), funded by FEDER (COMPETE 2030) and Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministro da Educação, Ciência e Inovação).

Acknowledgements

This work also received financial support from Portuguese national funds (FCT/MECI) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos, and the project PaperSenseMIP PTDC/QUI-QAN/3899/2021 (DOI: 10.54499/PTDC/QUI-QAN/3899/2021) from FCT/MCTES. João Pacheco is thankful for his contract (2023.07458.CEECIND/CP2842/CT0002) funded by FCT/MCTES. Patrícia Rebelo is grateful for her contract from the Sens2BiteSafe project. Isabel Seguro is grateful to FCT for her PhD grant (2022.12344.BD). The authors are also grateful to the project BioReset (BiodivRestore-406 / DivRestore/0002/2020, DOI: 10.54499/DivRestore/0002/2020) funded through the 2020-2021 Biodiversa+ and Water JPI joint call for research projects, under the BiodivRestore ERA-NET Cofund (GA N°101003777), by the EU and FCT.

References

[1] S. Xu, Y. Li, Y. Zhang, *Trac-Trends Anal. Chem.* **2023**, 164, 117097.
[2] G. Vasapollo, S. Scorrano, L. Mergola, *Polymer Int.* **2022**, 71(4), 421-433.
[3] H. Zhang, L. Chen, J. Li, *Biosens. Bioelectron*. **2024**, 240, 115691.

[OC14]

Magnetic hybrid nanoplatform-modified screen-printed electrodes for enhanced electrochemical immunosensing approaches

Maria Freitas[1]*, Joana S. Teixeira[2], Ricarda Torre[1], Clara R. Pereira[2], Cristina Delerue-Matos[1], Henri P.A. Nouws[1]

[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]REQUIMTE/LAQV, Departamento de Química e Bioquímica, Faculdade de Ciências, Universidade do Porto,
Rua do Campo Alegre, 4169-007 Porto, Portugal

*mccfs@isep.ipp.pt

The integration of nanomaterials into the design of electrochemical immunosensors can markedly enhance the analytical signal. Their application in the transducer surface enables the development of robust nanoplatforms for effective bioreceptor immobilization, a typically challenging step. Carbon-based nanomaterials are attractive due to their capacity to interact physically with antibodies, enabling a straightforward and cost-effective immobilization process, with carbon nanotubes (CNTs) standing out for their ability to promote direct electron transfer between the electrode and the bioreceptor [1]. Nonetheless, enhancing the performance of CNT-based biosensors requires systematic optimization of their physicochemical properties, with a focus on the functionalization of their surface with magnetic nanoparticles [2]. Electrochemical biosensors, particularly immunosensors, have had significant advancements through the application of nanomaterials. The rising incidence of food allergies has been a major impetus for innovation in this field, as electrochemical immunosensors offer high sensitivity, rapid response time, and cost-effectiveness, making them well-suited for on-site allergen detection to support food safety and regulatory compliance [3]. In this work, a hybrid magnetic nanomaterial of oxidized carbon nanotubes functionalized with manganese(II) ferrite nanoparticles (CNT_O@$MnFe_2O_4$) was applied to a screen-printed carbon electrode (SPCE) to create a specific nanoplatform for the voltammetric signal amplification in the analysis of a celery protein (Api g 1), a major food allergen. After the bioreceptor immobilization, the allergen was detected in a sandwich-type assay using an alkaline phosphatase (AP)-labelled detection antibody. The addition of 3-indoxyl phosphate and silver ions allowed the detection of the immunological reaction through linear sweep voltammetry (LSV). The modified SPCE/CNT_O@$MnFe_2O_4$ platform hugely increased (750×) the electrochemical signal, compared to the bare SPCE. The developed sensor was developed for the analysis of Api g 1, and an extremely low limit of detection was achieved (32 pg/mL). The sensor's selectivity and applicability were successfully evaluated by analysing twenty commercial food products and the results were validated with a traditional enzyme-linked immunosorbent assay (ELISA) method.

Funding

This research received financial support through the project "Sens2BiteSafe - Allergen Analysis Breakthroughs: Enhancing Food Safety with Electrochemical Paper-based Analytical Devices" (COMPETE2030-FEDER-00713900 (nº 16000)), funded by FEDER (COMPETE 2030) and Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministro da Educação, Ciência e Inovação) and from Portuguese national funds (FCT/MECI) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements

Maria Freitas is thankful for her contract (2022.00490.CEECIND/CP1724/CT0007, DOI: 10.54499/2022.00490.CEECIND/CP1724/CT0007) financed by FCT/MCTES-CEEC Individual Program Contract.

References

[1] S. Kumar, H.K. Sidhu, A.K. Paul, et al., *Sens. Diagn.* **2023**, 2(6), 1390-1413.
[2] G. Rajeev, A.J. Cowin, N.H. Voelcker, et al., *Front. Chem.* **2019**, 7, 438.
[3] J.S. Teixeira, M. Freitas, C. Oliveira, et al., *Food Chem.* **2024**, 460, 140733.

[OC15]

A copper-based metal-organic framework sensor for rapid and reliable detection of the diabetes drug metformin

Miguel Tavares*, Cristina Delerue-Matos, Simone Morais, Álvaro Torrinha
REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
*maltr@isep.ipp.pt

Metformin (MET), as one of the most worldwide consumed pharmaceutical products, is nowadays classified as a contaminant of emergent concern as result of its persistent presence in various aquatic environments at alarming concentrations that can lead to serious ecological impacts [1]. In this regard, creating new and improved sensing systems can enable an efficient and reliable monitorization program towards the safety and quality of the environment and living organisms. In this work, an electrochemical sensor was developed aiming the detection of MET in environmental samples. This sensor was built with carbon paper (CP) as core transducer material containing a copper-derived metal-organic framework (named Cu-BTC) formed directly onto the carbon surface via layer-by-layer (LbL) synthesis under ambient conditions. The intrinsic properties of Cu-BTC (e.g. high surface area) along with its complexation capabilities towards MET [2] play a significant role in boosting electrochemical performance of CP/Cu-BTC. Cyclic voltammetry was initially used for electrochemical characterizations of CP/Cu-BTC in the presence and absence of analyte. The results confirmed the typical redox activity of MET at + 0.9 V (anodic peak). The sensor optimization was carried out by differential pulse voltammetry technique and comprised electrolyte pH, technique parameters and pre-concentration steps. Environmental samples, namely fish and wastewater were used to assess the real applicability of the developed sensor under complex matrices, at optimized conditions.

Funding
The authors are grateful for financial support from the project NATURIST 2022.07089.PTDC, (doi.org/10.54499/2022.07089.PTDC) funded by Portuguese national funds (FCT/MCTES, Fundação para a Ciência e a Tecnologia and Ministério da Ciência, Tecnologia e Ensino Superior).

Acknowledgements
This work also received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos. Miguel Tavares is grateful to FCT for his PhD grant (2022.13624.BD). Álvaro Torrinha thanks FCT for funding through the Scientific Employment Stimulus-Individual Call with ref. 2022.04357.CEECIND (https://doi.org/10.54499/2022.04357.CEECIND/CP1724/CT0015).

References

[1] Y. Zheng, Y. Shao, Y. Zhang, et al., *Toxics* **2024**, 12(7), 483.
[2] D.A. Rusanov, J. Zou, M.V. Babak, *Pharmaceuticals* **2022**, 15(4), 453.

[OC16]

DNA-based electrochemical biosensors for authenticating the botanical origin of honey

Stephanie L. Morais[1], Michelle Castanheira[1,2], Marlene Santos[3], Valentina F. Domingues[1], Cristina Delerue-Matos[1], M. Fátima Barroso[1]*

[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]Departamento de Química, Faculdade de Ciências, Universidade do Porto, Porto, Portugal
[3]REQUIMTE/LAQV, Escola Superior de Saúde, Instituto Politécnico do Porto, Porto, Portugal

*mfb@isep.ipp.pt

Food fraud and food safety are increasingly alarming global issues for the food industry and different regulatory agencies since the number of adulterated foods continue to enter national and international markets undetected [1]. These fraudulent goods not only result in an annual revenue loss of billions but also pose many risks to the consumers' health [1,2]. Among the most frequently adulterated food products is honey. Honey is a natural, high-quality and highly valued sweetener prized for its rich nutritional profile and multiple health benefits [2]. However, due to its rising market demand, honey is frequently subjected to fraudulent practices, such as the addition of sugar, syrups or lower-quality honeys to premium honeys, as well as misrepresenting its botanical and/or geographical origin [2,3]. In this study, an electrochemical DNA-based biosensor to detect the presence of *Erica arborea* – a prominent plant species in Portugal – in commercial honey samples was designed and developed. Analysing public databases, a specific DNA probe, targeting *E. arborea*, was selected. The sensor's methodology resulted from the sandwich hybridization reaction between the *E. arborea*-specific DNA-target sequence and its complementary probe on screen-printed gold electrodes. To increase the enzymatic amplification signal, the complementary probe was divided in two shorter sequences: one modified with a thiol group – DNA-capture probe – and the other with a fluorescein isothiocyanate label – DNA-signalling probe. A mixed self-assembled monolayer composed of the DNA-capture probe and mercaptohexanol was also applied to enhance the hybridization efficiency. Moreover, cyclic voltammetry and electrochemical impedance spectroscopy were performed to characterize the modifications to the electrodes' surface. Consequently, a linear concentration was obtained in a 0.03 to 2.00 nM range. This sensor was then successfully applied to the detection of the *E. arborea* DNA in commercial honey samples. Thus, the developed sensor offers a rapid, sensitive, and cost-effective method for verifying honey authenticity and ensuring honey quality and safety.

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos and from the project ALGAESAFE: EFSA European Food Risk Assessment Fellowship (EU-FORA) Programme.

Acknowledgements

MFB thanks FCT for the FCT Investigator contract (2020.03107.CEECIND). Stephanie Morais (2023.028929.BD) and Michelle Castanheira (2023.05159.BDANA) are grateful to FCT and the European Union (EU) for their grants financed by POPH-QREN-Tipologia 4.1-Formação Avançada, funded by Fundo Social Europeu (FSE) and Ministério da Ciência, Tecnologia e Ensino Superior (MCTES).

References

[1] R.K. Bannor, K.K. Arthur, D. Oppong, et al., *J. Agric. Food Chem.* **2023**, 14, 100686.
[2] G. Zhang, W. Abdulla, *Food Control* **2022**, 138, 108992.
[3] C. Grosso, S. Soares, A. Silva, et al., *Foods* **2025**, 14, 963.

[OC17]

Turning endogenous resources into power: *Juniperus brevifolia* biomass for efficient (electro)catalysts

Diana M. Fernandes[1]*, Inês S. Marques[1], Andreia F. Peixoto[1], Ana Seca[2,3]
[1]REQUIMTE/LAQV, Dep. Chemistry and Biochemistry, Faculty of Science, University of Porto, Porto, Portugal
[2] REQUIMTE/LAQV, Dep. Chemistry, University of Aveiro, Campus de Santiago, Aveiro, Portugal
[3] University of the Azores, Faculty of Sciences and Technology, cE3c- Centre for Ecology, Evolution and Environmental Changes, Azorean Biodiversity Group, CHANGE–Global Change and Sustainability Institute, Ponta Delgada, Portugal
*diana.fernandes@fc.up.pt

The global economy's sharp growth, extreme fossil fuel consumption and the continuous increase of population have been forcing the development of more sustainable catalytic processes as well as renewable energy technologies to overcome environmental degradation and the current energy crisis. Among the most viable electrochemical energy storage and conversion systems are fuel cells, metal-air batteries, and supercapacitors. The oxygen reduction reaction (ORR) and oxygen evolution reaction (OER) are crucial in electrochemical devices like metal–air batteries and reversible fuel cells [1]. However, both ORR and OER require expensive and scarce precious metal electrocatalysts, making them difficult to use on a large scale. This has stimulated the quest for new, non-expensive, and highly active electrocatalysts during the last years [2,3].

Therefore, a series of Co/N-doped biochar catalysts were prepared by mechanochemical synthesis using the different parts of *Juniperus brevifolia* (leaves, bark and wood). Activation under chemical/physical experimental conditions resulted in surface areas 972 > BET > 145 m^2/g. The successful preparation of electrocatalysts was confirmed by XPS, XRD, Raman and SEM/EDS. The most promising results for both ORR and OER were obtained with Co/N-JBL presenting similar ORR performance to the state-of-the-art Pt/C and OER overpotential (η_{10}) of 0.45 V vs RHE. To enlarge the catalysts' potential applications, they were tested in the catalytic transfer hydrogenation (CTH) of furfural. Using 80 μL of formic acid as hydrogen donor, Co/N-JBL achieved 100% conversion and 65.67% selectivity for furfuryl alcohol. Furthermore, optimization studies and reusability tests were also performed, confirming their robustness.

These results demonstrate that Co/N-biochars derived from *Juniperus brevifolia* exhibit dual functionality as catalysts, offering high efficiency in oxygen reactions and promising performance in catalytic biomass upgrading.

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements

I.S.M. thanks FCT for the PhD fellowship 2022.10224.BD. D.M.F. and A.F.P. thank FCT for funding through the Individual Call to Scientific Employment Stimulus (Ref. 2021.00771.CEECIND/CP1662/CT0007 and through the Institutional Call – Laboratórios Associados (Ref. CEECINSTLA/00029/2022), respectively).

References

[1] C. Freire, D. M. Fernandes, M. Nunes, et al., *ChemCatChem* **2018**, 10, 1703.
[2] R. Ramos, V. K. Abdelkader-Fernández, R. Matos, et al., *Catalysts* **2022**, 12, 207.
[3] I.S. Marques, B. Jarrais, R. Ramos, et al., *Catal. Today* **2023**, 418, 114080.

[OC18]

Advances in PEM fuel cell sustainability: performance impact of eco-binders

J. Isidro[1]*, A.B Megias[1], I. Martin[2], A. Carrasco[2], J. Rodríguez[1], R. Campana[1]

[1] Centro Nacional de Experimentación en Tecnologías de Hidrógeno y Pilas de Combustible, Prolongación Fernando el Santo s/n, 13500 Puertollano, Ciudad Real, Spain
[2]Facultad de Ciencias y Tecnologías Químicas, Universidad de Castilla-La Mancha (UCLM), Av. Camilo José Cela, 10, 13071, Ciudad Real, Spain

*julia.isidro@cnh2.es

The present work addresses two main limitations of Proton Exchange Membrane Fuel Cells (PEMFCs): the high cost of platinum group metal (PGM) catalysts and the environmental impact associated with fluorinated polymer binders [1]. Taking this last issue into consideration, an alternative methodology for membrane electrode assembly (MEA) fabrication is proposed, combining reduced platinum loading with a biodegradable, renewable, and non-toxic gelatine-based eco-binder.

Four MEA configurations were prepared using Pt/C (40% wt) catalysts with binder-to-catalyst mass ratios ranging from 0 to 100% wt./wt. and platinum loadings of 0.15 and 0.10 mgPt/cm^2. Nafion NR211 was employed as membrane, carbon paper H23C2 as substrate, and ethanol solution as dispersant. The catalyst inks were deposited on the microporous layer of gas diffusion electrodes (GDEs). Electrochemical characterization comprised activation, polarization curves to determinate the maximum power density, and electrochemical impedance spectroscopy (EIS) to quantify ohmic, charge transfer, and mass transport losses [2]. The best-performing MEAs underwent accelerated stress tests and morphological analysis by scanning electron microscopy (SEM).

The results obtained in the absence of a binder (0 wt.% binder–catalyst) indicate that a maximum power density comparable to that achieved with Nafion-based catalytic inks can be obtained, regardless of whether air or O_2 is used as the oxidant. Specifically, power densities of 211.7 mW/cm^2 (air) and 412.2 mW/cm^2 (O_2) were reached, compared to 203.5 mW/cm^2 and 430.9 mW/cm^2, respectively, obtained in previous experiments employing Nafion as the binder. However, this trend was not maintained under operating conditions with increased backpressure, where Nafion-based electrodes exhibited the expected improvement in efficiency with higher backpressure.

In contrast, optimized gelatine-based eco-binders delivered electrochemical performance equivalent to or exceeding that of Nafion MEAs. Moreover, reducing the platinum loading from 0.15 to 0.10 mg Pt/cm^2 did not significantly affect efficiency. These results validate gelatine as a sustainable and effective alternative to fluorinated binders, supporting the development of cost-efficient and environmentally friendly PEMFC systems aligned with climate neutrality objectives.

Funding

This work was carried out within the Renewable Energy and Hydrogen Program, included in the Complementary R&D&I Plans of the MICIN, and funded by the European Union NextGenerationEU within the framework of Component 17 of the Recovery, Transformation and Resilience Plan (C17.I01.P01), and as part of the E3Tech-Plus Network funded by the Ministry of Science and Innovation (Government of Spain).

Acknowledgements

“Programa primera Experiencia Profesional”, grant number 2022-C23.I01.P02.S0020-0000295” funded by the MICIN and “Programa INVESTIGO”, grant number PINVE-13-0011/2024 funded by the European Union.

References

[1] D. Bresser, D. Buchholz, A. Moretti, et al., *Energy Environ. Sci.*, **2018**, 11, 3096-3127.
[2] G. Athanasaki, A. Jayakumar, A.M. Kannan, *Int. J. Hydrogen Energy* **2023**, 48(6), 2294-2313.

[OC19]

Optimizing current collector and flow-field geometry for enhanced gas removal in PEM electrolyzers

Kostadin V. Petrov*, Bruna G. Pedro
HyLab – Green Hydrogen Collaborative Laboratory, Portugal
*Kostadin.petrov@hylab.pt

Green hydrogen from renewable-powered water electrolysis is a promising route to decarbonize sectors such as ammonia and steel production. Proton-exchange membrane (PEM) electrolyzers are particularly suited for integration with fluctuating renewable sources due to their operational flexibility in terms of minimal load and shutdown resistance. However, large-scale deployment is hindered by high electricity and material costs. Energy efficiency becomes critical at current densities above ~1.5 A/cm^2, where mass transport limitations arise - especially on the anode side, where oxygen evolution restricts water access and local oxygen saturation causes overpotential losses. These effects are often overlooked in laboratory-scale studies that employ unrealistically high-water flow rates.

In this work, we developed a two-dimensional continuum model that couples electrochemistry with multiphase flow to quantify the influence of water and oxygen transport on energy efficiency. The model, validated experimentally with different porous transport layers (PTLs), is used to evaluate and optimize flow-field and current collector geometries. Results show that conventional designs create stagnant zones with poor water replenishment, leading to higher oxygen saturations in the catalyst layer. We propose alternatives that enhance mass transfer, while accounting for heat generation and contact resistance. Additionally, PTLs were found to impact current density distribution, leading to efficiency penalties of up to ~4%.

By applying industrially relevant flow conditions, our work provides more representative insights for scale-up. Optimized current collector and flow-field designs can improve PEM electrolyzer efficiency at high current densities, ultimately lowering the cost of green hydrogen production.

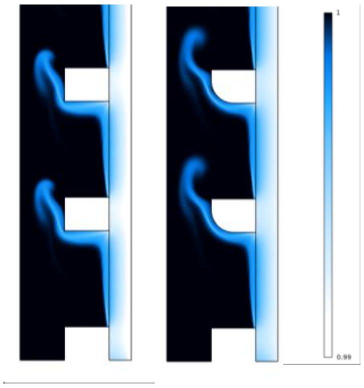


Figure 1. Water volume fraction in porous transport layer and flow channel. a) standard current collector design and b) proposed design.

Funding

This research was funded by the call RE-C05-i02 – Missão Interface N.º 01/C05-i02/2022 of the Portuguese Recovery and Resilience Plan, and the Base Funding Project of Collaborative Laboratory, managed by ANI – Agência Nacional de Inovação.

References

[1] S. Alkhaldi, M. Aziz, A. Amrite, et al., *J. Appl. Electrochem.* **2025**, 55, 327-343.
[2] B.N.D. van Haersma Buma, M. Peretto, Z.M. Matar, et al., *Heliyon* **2023**, 9(7), e17999.

[OC20]

Advances in the development and characterization of solid oxide fuel cells and electrolysis cells

A. Moratalla[1]*, M.R. Serrano de la Cruz[1], I. Ayuso[1], A. Pardo[1], N. Díaz[1], J. Broceño[1], C. Montes[1], L. Sanchez - Beato[2], R. Campana[1]

[1]Hydrogen National Centre (CNH2), Puertollano, Spain
[2]IDavinci, Madrid, Spain
*angela.moratalla@cnh2.es

The transition toward sustainable energy is driving the development of solid oxide fuel cells (SOFCs), recognized for their high efficiency and low emissions [1]. Their performance is determined by the cell configuration and the materials employed. The National Hydrogen Centre (CNH2) has developed technologies for planar and tubular SOFCs, assessing their electrochemical behaviour. Among the most commonly used electrolytes are yttria-stabilized zirconia (YSZ), the reference material due to its stability and low cost, and scandia-stabilized zirconia (ScSZ), which exhibits higher ionic conductivity in the intermediate temperature range (700–850 °C), thereby enabling reduced operating temperatures at the expense of higher cost [2, 3]. In electrolyte-supported configurations, the electrolyte was prepared by tape casting, while the electrodes were deposited by ultrasonic spraying, employing NiO-YSZ as the hydrogen electrode, GDC as the barrier interlayer, and LSM as the oxygen electrode. Additionally, SOEC systems with NiO-YSZ cathode-supported configurations were developed and characterized, as these enable the co-electrolysis of CO_2 and H_2O to produce syngas (H_2 and CO), promote thin electrolytes, and achieve lower resistance, thereby reducing mechanical stress. Finally, the electrochemical performance was analysed through polarization curves (I-V-P) and electrochemical impedance spectroscopy (EIS), allowing for a detailed characterization of the cells under different operating conditions. The results demonstrated high ionic conductivity and efficient charge transfer at the electrodes, confirming the effectiveness of the employed configurations and their balance between efficiency, durability, and structural stability.

Funding

This work has been developed as part of Energy and Renewable Hydrogen Program of the Complementary R&D&I Plans of the Ministry of Science and Innovation, funded by the European Union NextGenerationEU within the Framework of Component 17 of the Recovery, Transformation and Resilience Plan (ref C17.I01.P01) and as part of PID2020-115935RA-C44 and PID2024-162053OB-C31 funded by Ministerio de Ciencia e Innovación (Gobierno de España), and Agencia Estatal de Investigación (AEI) and SBPLY/24/180225/000095 and SBPLY/21/180501/000255 (Junta de Comunidades de Castilla-La Mancha).

References

[1] B. Yang, J. Wang, M. Zhang, et al., *Energy Convers. Manag.* **2020**, 213, 112856.
[2] A. Kumar, A. Jaiswal, M. Sanbui, et al., *Scripta Mater.* **2016**, 121, 10-13.
[3] N.A. Arifin, A.A. Afifi, A. Samreen, et al., *Solid State Ionics* **2023**, 399, 116302.

[OC21]

Performance of SO_2 depolarized electrolysis in the presence of N_2 and CO_2 gases for green hydrogen generation

Hanane Boumeriame[1,2]*, Agustina de Olivera[1,2,3], Miguel Ángel Rodríguez-Cano[3],
Iñaki Requena[3], Justo Lobato[3], Francisca Moreira[1,2], Vítor Vilar[1,2], Manuel A. Rodrigo[3]

[1]LSRE-LCM - Laboratory of Separation and Reaction Engineering – Laboratory of Catalysis and Materials, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
[2]ALiCE - Associate Laboratory in Chemical Engineering, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
[3]Department of Chemical Engineering. Faculty of Chemical Sciences & Technologies. University of Castilla-La Mancha, Campus Universitario s/n, 13071 Ciudad Real, Spain

*hanane@fe.up.pt

The increasing global energy demand, combined with the urgent need to limit climate change, has accelerated the pursuit of sustainable and carbon-neutral fuels. Among these, hydrogen (H_2) stands out as a key element of future low-carbon energy systems, owing to its gravimetric energy density, its versatility in sectors such as transportation and chemical feedstocks, and its potential for carbon-free production [1]. Among various H_2 production technologies, sulphur dioxide (SO_2)-depolarized electrolysis (SDE) has gained increasing attention as a promising and energy-efficient alternative to conventional water electrolysis. In this process, SO_2, a common industrial pollutant, serves as the anodic reactant, replacing the oxygen evolution reaction (OER). This substitution reduces the theoretical cell voltage required for water electrolysis from 1.23 V to 0.158 V vs RHE, resulting in substantially lower energy consumption [2,3]. However, most existing studies focus on idealized systems using pure SO_2, which does not reflect the composition of actual industrial emissions [3]. SO_2 steams are typically mixed with other gases such as nitrogen (N_2) and carbon dioxide (CO_2), which may influence electrolyzer performance. This study aims to address this existing knowledge gap by evaluating the operational performance of an SO_2 electrolyzer under simulated industrial flue gas conditions. Specifically, the effect of introducing controlled concentrations of N_2 and CO_2 into the SO_2 feed was evaluated. Electrochemical characterization techniques, including polarization curves, electrochemical impedance spectroscopy (EIS), and chronoamperometry, were employed to evaluate cell efficiency, resistance, and long-term stability. The results reveal that the presence of N_2 and CO_2 negatively affects the electrochemical performance of the SDE system.

Acknowledgements

This work is financially supported by: (i) ATE - Alliance for Energy Transition (56) co-funded by the Recovery and Resilience Plan (PRR) through the European Union, and (ii) UID/50020 of LSRE-LCM - Laboratory of Separation and Reaction Processes – Laboratory of Catalysis and Materials - funded by Fundação para a Ciência e a Tecnologia, I.P. /MCTES through national funds; and ALiCE, LA/P/0045/2020 (DOI: 10.54499/LA/P/0045/2020). Vítor Vilar and Francisca Moreira acknowledge FCT for the financial support (ref.: CEECIND/01317/2017 (DOI: 10.54499/CEECIND/01317/2017/CP1399/CT0010) and CEEC-IND/CP2834/CT0009 (DOI: 10.54499/2023.07337.CEECIND/CP2834/CT0009), respectively).

References

[1] H. Boumeriame, A. Cherevan, D. Eder, et al., *J. Colloid Interface Sci.* **2023**, 652, 2158.
[2] S. Diaz-Abad, I. Requena, M.A. Rodrigo, et al., *J. Power Sources* **2024**, 606, 234513.
[3] A.J. Krüger, H.M. Krieg, D. Bessarabov, *Int. J. Hydrogen Energy* **2015**, 40, 4450.

[OC22]

Thin-film poly(azo-BBY)-AgNP impedimetric platform for miRNA-122

Miqueias de Lima Portugal[1]*, Patrícia M. Seraphim[2], Felismina Moreira[3], Marcos F.S. Teixeira[1]
[1]Electroanalytical Sensors Research Group (GPES), School of Science and Technology, São Paulo State University (FCT/UNESP), Presidente Prudente, SP, Brazil
[2]Research Group in Physiology (GPFis), School of Science and Technology, São Paulo State University (FCT/UNESP), Presidente Prudente, SP, Brazil
[3]Laboratory for Research and Innovation in Sensors Engineering (LabRISE), Centro de Inovação em Engenharia e Tecnologia Industrial (CIETI), Instituto Superior de Engenharia do Porto (ISEP), Porto, Portugal
*marcos.fs.teixeira@unesp.br

We report an ultrasensitive impedimetric genosensor for the detection of microRNA-122 (miRNA-122), a clinically relevant biomarker for hepatocellular carcinoma. The sensing interface is a poly(azo-BBY) thin film doped with Ag nanoparticles (poly(azo-BBY)–AgNP) electropolymerized directly on fluorine-doped tin oxide (FTO). A thiolated single-stranded DNA probe complementary to miRNA-122 was immobilized on the nanocomposite film and the surface was backfilled with bovine serum albumin to minimize nonspecific adsorption. The stepwise assembly and target hybridization were monitored by electrochemical impedance spectroscopy (EIS). The genosensor provided a clear, concentration-dependent increase in charge-transfer resistance upon exposure to miRNA-122 standards. Using a four-parameter logistic fit, the limit of detection was estimated at 0.051 fg/mL, outperforming many state-of-the-art miRNA sensors. The combination of the conductive/ catalytic contribution of AgNPs with the azo-polymer matrix yields a stable thin-film platform that enables label-free, minimally invasive analysis. These results highlight poly(azo-BBY)–AgNP films as promising transducers for early cancer diagnostics centred on circulating microRNAs.

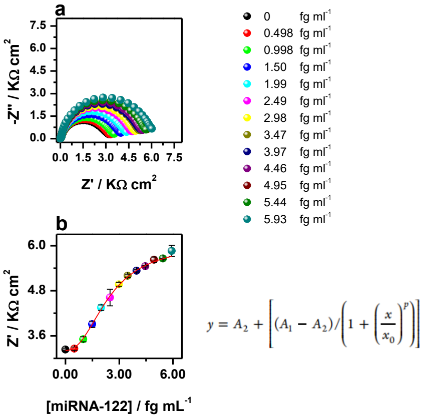


Figure 1. (a) Nyquist plots recorded after hybridization with increasing miRNA-122 concentrations on the poly(azo-BBY)–AgNP genosensor; (b) calibration curve (ΔR_{ct} vs. log C) fitted with a four-parameter logistic (4PL) model, used to estimate the limit of detection (LOD = 0.051 fg/mL).

Funding
This research was funded by FAPESP, 2024/08769-6 and 2025/06396-0.

Acknowledgements
The authors acknowledge the infrastructure support from the department of chemistry and biochemistry from the infrastructure and grants as well the GPFis at FCT UNESP For the bioassays' expertise.

References

P.C.M. Pizzol, M.L. Portugal, H.F. Trevizan, et al., *ACS Appl. Electron. Mater.* **2025**, 7(8), 3486-3500.

[OC23]

Amplification-free photoelectrochemical biosensor for the detection of FLT3 mutations in acute myeloid leukaemia

Rui Campos[1]*, Félix Moron Uceda[1,2], Alexandra Teixeira[1], Paula Ludovico[3,4], Sara Abalde-Cela[1], Lorena Diéguez[1]
[1]INL - International Iberian Nanotechnology Laboratory, Avenida Mestre José Veiga, 4715-330 Braga, Portugal
[2]Francisco de Vitoria University, Ctra. Pozuelo-Majadahonda KM 1.800. 28223, Madrid, Spain
[3]Life and Health Sciences Research Institute (ICVS), School of Health Sciences, University of Minho, 4710-057 Braga, Portugal
[4] ICVS/3B's – PT Government Associate Laboratory, 4710-057 Braga, Portugal
*rui.campos@inl.int

Acute Myeloid Leukaemia (AML) is a heterogeneous hematologic malignancy where mutations in the FLT3 gene are strongly correlated with poor prognosis and therapy resistance. Thei rapid and accurate detection of such mutations is critical for guiding therapy. Current gold-standard techniques, polymerase chain reaction (PCR) and next-generation sequencing (NGS), are accurate but time-consuming, costly, and infrastructure-dependent.

We present a photoelectrochemical (PEC) biosensor enabling amplification-free detection of FLT3 mutations, clinically validated for the first time. The assay employs a dual-probe sandwich design: a biotinylated capture probe and a photosensitizer-labelled detection probe. Upon hybridization, light-triggered singlet oxygen ($^1O_2$) generation produces a measurable photocurrent, allowing single-base discrimination.

Importantly, the PEC assay was successfully applied to genomic DNA extracted from lumbar puncture fluid and bone marrow aspirates, without the need for amplification. Results were benchmarked against NGS, confirming both accuracy and clinical relevance. This platform offers a fast, cost-effective, and clinically relevant diagnostic tool with strong potential for point-of-care AML testing.

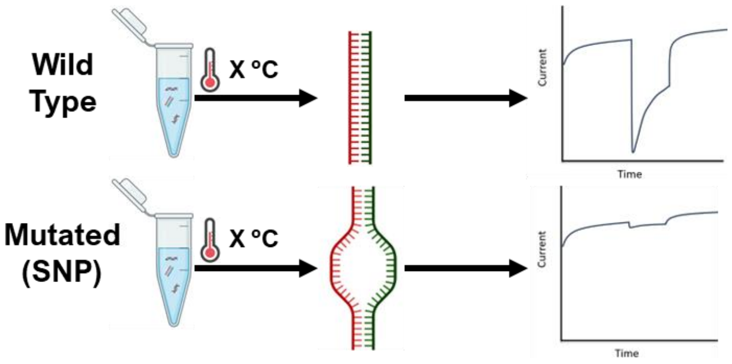


Figure 1. Schematic of the assay. Above the melting temperature of the mutant duplex, its hybridization is less stable, enabling discrimination between mutant and wild-type DNA.

Funding
This research was funded by the project health from Portugal (C630926586-00465198), supported by Component C5 – Capitalisation and Business Innovation, under the Portuguese Resilience and Recovery Plan, through the NextGenerationEU Fund.

References

[1] C. Cumbo, F. Tarantini, L. Anelli, et al., *Blood Rev.* **2022**, 54, 100928.
[2] S.T. Shanmugam, R. Campos, S. Trashin, et al., *Bioelectrochem.* **2024**, 158, 108698.

[OC24]

Next-generation dual-doped Prussian blue analogue as a high-capacity cathode for sodium-ion batteries

Ewelina Rudnicka[1]*, Beata Kurc[1], Karol Rytel[2], Damian Burzyński[3], Kamil Kędzierski[2], Stanisław Mikulski[3], Leszek Kasprzyk[3]

[1]Faculty of Chemical Technology, Poznan University of Technology, Poland
[2]Faculty of Materials Engineering and Technical Physics, Poznan University of Technology, Poland
[3]Faculty of Control, Robotics and Electrical Engineering, Poznan University of Technology, Poland

*ewelina.rudnicka@put.poznan.pl

Prussian Blue analogues (PBAs) have emerged as promising cathode materials for sodium-ion batteries due to their open crystal framework, ease of synthesis, and low production costs. Their cubic structure facilitates reversible Na^+ ion intercalation, while transition metal centres support redox activity. However, pristine PBAs often suffer from limited electrical conductivity, structural imperfections, and moisture-related instability [1,2].

In this study, we introduce a novel dual-doped Prussian Blue analogue (MoCo-PBA), incorporating both molybdenum and cobalt, synthesized via a coprecipitation method. Comprehensive structural, morphological, spectroscopic, and electrochemical characterizations were performed. X-ray diffraction confirmed the formation of a pure cubic phase ($Fm\overline{3}m$) with a refined lattice parameter of 10.19 Å, indicating successful dopant integration without disrupting the host lattice. Scanning electron microscopy revealed a mesoporous architecture formed by nanocrystals ranging from 100 to 300 nm in size. Energy-dispersive X-ray spectroscopy verified the presence of Mo, Co, Fe, C, N, and O, with localized compositional variations that influence electrochemical behaviour.

Nitrogen adsorption (BET) measurements showed a high surface area of 101.5 m^2/g, supporting improved ion transport. Electrochemical performance was evaluated using Swagelok-type cells with metallic sodium as both counter and reference electrodes, and an electrolyte consisting of 1 M $NaClO_4$ in EC:DMC (1:1 by weight). The cathode was prepared as a composite of MoCo-PBA, conductive carbon, and PVdF binder. Cyclic voltammetry revealed Fe–CN redox transitions, and galvanostatic charge–discharge tests indicated pseudocapacitive behaviour. The material delivered a high initial specific capacity of approximately 150 mAh/g at a current density of 10 mA/g.

These findings highlight the potential of MoCo-PBA as a cost-effective and high-performance cathode material for sodium-ion battery technologies, combining enhanced conductivity, structural robustness, and superior capacity.

Funding

This research was funded by the Ministry of Science and Higher Education, grant number 0212/SIGR/2401.

References

[1] Y. Xiao, J.Xiao, H. Zhao, et al., *Small* **2024**, 20, 2401957.
[2] S. Sun, X. Jiang, Z. Wang, et al., *Dalton Trans.* **2025**, *Accepted Manuscript*.

[OC25]

Zero gap water electrolyze – metal-based electrodes, diaphragm / separator electrode assembly and possibility for stack regime

G. Borisov*, E. Petkucheva, N. Borisov, B. Mladenova, J. Iliev, E. Slavcheva

Institute of Electrochemistry and Energy Systems, Bulgarian Academy of Sciences, Acad. G. Bonchev Str.,10,
1113 Sofia, Bulgaria

*gal.rusev@iees.bas.bg

Alkaline zero-gap water electrolyzers are an emerging technology for producing ultra-high-purity hydrogen (>99.9999%), offering compact design, high current densities, wide operating temperature range (20–95 °C), and energy efficiency above 75%.

This study reports the electrochemical performance of a pilot-scale DUAL Cell electrolyzer, equipped with a ceramic diaphragm (Zirfon Perl 500) and multilayer electrodes. Both anode and cathode are based on nickel foam supports, carrying a microporous active layer of nickel powder bound with PTFE (Teflon) and modified via a deep-and-dry surface treatment.

Electrode activity and corrosion resistance were assessed in 25% KOH using cyclic and linear voltammetry. A current density of 0.2A/cm² was achieved at 2 V without degradation. The electrodes were then assembled into a laboratory prototype of the DUAL Cell [Utility Model No. 5061], which combines features of alkaline and PEM electrolyzes.

After in situ diaphragm conditioning, the system delivered 1.2 A/cm² at 80 °C and 2 V, showing stable performance and reproducible behaviour of both cells during prolonged testing. Final validation in a small laboratory stack with hybrid electrical interconnection confirmed the scalability and robustness of the developed concept.

Funding

This research was carried out with the financial support of the National Recovery and Resilience Plan of the Republic of Bulgaria, co-funded by the European Union, under project No. BG-RRP-2.017-0027, titled 'Hydrogen generator in modular zero-gap design'.

[OC26]

From shrimp shell waste to dual catalysts for energy and biomass valorisation

Inês S. Marques*, Andreia F. Peixoto, Diana M. Fernandes
REQUIMTE/LAQV, Dep. Chemistry and Biochemistry, Faculty of Science, University of Porto, Porto, Portugal
*up201608306@fc.up.pt

The energy and chemical industries still rely heavily on fossil fuels as their primary source of carbon. Biomass is a renewable alternative which enables the closure of the carbon cycle and strengthens the role of biorefineries [1]. Shrimp shells are a currently discarded waste product, yet they provide a feedstock rich in heteroatoms to produce functional biochars. Converting them into electrocatalysts is attractive due to the tuneable properties of biochars, their renewable nature and low production cost.

In this study, cobalt N-doped biochar electrocatalyst were synthesized from shrimp shells using a solventless ball milling approach with melamine as the nitrogen source, followed by functionalization with cobalt through wet impregnation. The activation of the biochar under chemical and physical experimental conditions resulted in the production of highly porous structures with high surface areas. The successful preparation of the functionalized catalysts was verified by XPS, XRD, Raman and SEM/EDS [2]. The electrocatalytic performance was investigated for oxygen reduction and evolution reactions (ORR/OER) and for the electro(catalytic) hydrogenation of furfural. The furfural hydrogenation pathway was studied through a comparative analysis of catalytic transfer hydrogenation (CTH) and electrocatalytic hydrogenation (ECH). Although CTH achieved high conversion rates under conventional catalytic conditions, ECH exhibited similar selectivity towards furfuryl alcohol, while requiring less energy and using water as a hydrogen donor, thus eliminating the need for external hydrogen sources.

The electrocatalyst Co/N-CC exhibited good electrocatalytic performance in OER, with maximum current densities of 25.65 and 37.11 mA/cm^2 and overpotentials values of 0.52 and 0.46 V for 0.1 M and 1 M KOH electrolyte, respectively. For ORR Co/N-CC demonstrate favourable performance in 0.1 M KOH, with diffusion limiting current densities of -3.38 mA/cm^2, potential onset values of 0.85 V vs. RHE and Tafel slope of 42 mV/dec. In CTH with 80 µL of formic acid, conversion reached 82.39%, with 95.59% selectivity towards furfuryl alcohol. ECH at -1.35 V and -1.25 V vs. Ag/AgCl yielded conversion of 89.02% and 65.23%, respectively, as well as selectivity of 62.8% and 91.12%, and faradaic efficiencies (FE) of 14% and 18.77%.

These results demonstrate the dual applicability of shrimp shell-derived biochars as efficient electrocatalysts for ORR/OER in energy conversion, and as catalytic platforms for upgrading furfural. Overall, this work advances the development of clean, safe and scalable biomass-derived catalysts, supporting the transition towards an integrated, self-sustaining biorefinery [3].

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements

I.S.M. thanks FCT for PhD fellowship 2022.10224.BD. D.M.F. and A.F.P. thank FCT for funding through the Individual Call to Scientific Employment Stimulus (Ref. 2021.00771.CEECIND/CP1662/CT0007 and through the Institutional Call – Laboratórios Associados (Ref. CEECINSTLA/00029/2022), respectively.

References

[1] X. Chen, H. Yang, Z. Zhong, et al., *Green Chem.* **2017**, 19, 2783–2792.
[2] I.S. Marques, B. Jarrais, R. Ramos, et al., *Catal. Today* **2023**, 418, 114080.
[3] R. Ramos, V.K. Abdelkader-Fernandez, R. Matos, et al., *Catalysts* **2022**, 12, 207.

[OC27]

Beyond conventional lithium-ion battery anodes

L. Truta[1]*, T. Charana[1], S. Luis[1], D. Esteves[1], J. Gonçalves[1], J. Calado[2]
[1]CeNTI - Centre for Nanotechnology and Smart Materials, Portugal
[2]Lifthium Energy, Portugal
*ltruta@centi.pt

Lithium-ion batteries (LIBs) are emerging as the energy storage solution across a wide range of applications due to their remarkably high energy density, power density, and long cycle life. These characteristics make LIBs particularly well-suited for use in industrial applications, including uninterruptible power supplies and large-scale energy storage systems.

As global demand intensities for high-performance batteries, attention is shifting beyond conventional LIB technologies. A leading area of innovation is the development of lithium metal batteries, which use lithium metal as the anode material. Lithium metal offers a significantly higher theoretical specific capacity (3860 mAh/g) than graphite (372 mAh/g), unlocking the potential for 4th and 5th generation batteries, including solid-state systems with energy densities that could double those of current LIBs.

A key aspect of advancing 4th generation energy storage technologies lies in the efficient and safe synthesis of high-purity lithium metal. A critical step in the synthesis process involves the use of lithium chloride (LiCl) as a precursor, particularly when derived as a byproduct from industrial chemical processes. This approach presents a strategic opportunity, not only adding value to existing industrial outputs but also offering reliable and scalable feedstock for lithium metal production. Despite this potential, the synthesis of high-purity lithium metal remains a technical challenge, requiring precise control over the chemical and physical properties throughout the process to ensure both safety and material quality.

This work presents the study of lithium metal synthesis parameters via electrolysis of molten salts and their performance as anodes of NMC (nickel-manganese-cobalt) coin cells, comparing with cells using commercial lithium metal. Electrochemical performance was evaluated using different techniques, including electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV), and charge/discharge testing.

Funding

This research was developed within the scope of the project “NGS – New Generation Storage” [C644936001-00000045], financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union.

[OC28]

Comparative study of gas-diffusion electrodes based on non-platinum catalyst for advanced fuel cells and metal-air systems

Reneta Boukoureshtlieva*, Branimir Banov

Institute of Electrochemistry and Energy Systems “Acad. Evgeni Budevski” - Bulgarian Academy of Sciences, Sofia, Bulgaria

*r.boukoureshtlieva@iees.bas.bg

Worldwide growing energy needs, environmental pollution and health problems are the main motivation to develop and implement environmentally friendly solution for generation and storage of energy. Metal-air systems are compact and light energy source with high energy density and recently have been intensely researched as promising and efficient batteries for various applications. A great advantage of the Metal-air systems is the utilization of atmospheric oxygen to be reduced electrochemically on a Gas-Diffusion Electrode. Oxygen is an ideal electron acceptor for Metal-air batteries and Fuel Cells because of its high redox potential, availability, and sustainability. However, the Oxygen Reduction Reaction (ORR) is kinetically sluggish, resulting in a large proportion of potential loss. In order to overcome these limitations, catalysts are often used to lower the overpotentials and accelerate the kinetics of the Oxygen Reduction Reaction. One of the main challenges is the development of efficient and stable cathode catalysts for the electrochemical reduction of O_2. By far, Pt and Pt-based catalysts (PGMs) have been extensively used, due to their catalytic efficiency in Gas-Diffusion Electrodes. But the high cost and low availability have significantly lowered their utilization in Metal-air batteries.

A variety of non-precious metal catalysts have been developed for Gas-Diffusion Electrodes applications including carbon-based catalysts, carbon supported composite catalysts, Me-based catalysts. Carbon-based catalysts are mostly used because of their highly developed surface area, suitable morphology, chemical stability, good electric conductivity and comparatively low price.

It is supposed that the ORR catalyst used is simple to synthesize, cost-effective, durable after long-term operation, and tolerant to poisoning.

This research presents the experience in the field of investigation and application of various carbon-based catalysts as efficient non-precious metal catalysts for Oxygen Reduction Reaction in different types of electrochemical Metal-air systems including Zn-air flow-fuel cell. Catalysts prepared by pyrolysis of active carbon impregnated doped with some N-4 chelate compounds are also studied. The presented results cover various Metal-air systems with different types of electrolytes. Finally, insights into the remaining challenges are provided and directions for future perspectives and research are presented.

Funding

This work was supported by the NSP SD program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under the grant agreement no. Д01-74/19.05.2022.

[OC29]

Novel NaSICon-type as negative electrode materials for post-lithium batteries

Samiha Lafhal[1], Soraia El Moutchou[1], Eva Bräutigam[2], Birgit Esser[2,3], Noha Sabi[1],
Hicham Ben Youcef[1], Hasna Aziam[1]*

[1]High Throughput Multidisciplinary Research Laboratory (HTMR), College of Chemical Sciences and Engineering (CCSE), Mohammed VI Polytechnic University (UM6P), Lot 660 Hay Moulay Rachid, Ben Guerir, 43150, Morocco
[2]Institute of Organic Chemistry II and Advanced Materials, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm, Germany
[3]Helmholtz Institute Ulm (HIU), Helmholtzstraße 11, 89081 Ulm, Germany

*Hasna.aziam@um6p.ma

To meet the growing demand for energy and ensure green energy transition, the development of efficient energy storage systems is crucial, especially post-lithium technologies. Thanks to their interesting properties, NaSICon (Na Super Ionic CONductors) materials have attracted considerable attention. They consist of a three-dimensional framework, high ionic conductivity, and structural/ thermal stabilities [1]. Their potential for electrochemical energy storage was studied by many research groups [2-5]. In this work, a novel NaSICON-type material prepared using sol-gel route followed by calcination at 800 °C. Pure ZCP NaSICon-phase was obtained (Fig.1a) and no additional impurity peaks were detected. The electrochemical properties of ZCP were studied vs. metallic Li and Na at 1C-rate and over 0.01 – 3.0 V voltage window delivering high specific discharge capacities of around 600 mAh/g (Fig.1b) and 250 mAh/g (Fig.1c) after 10 cycles, respectively.

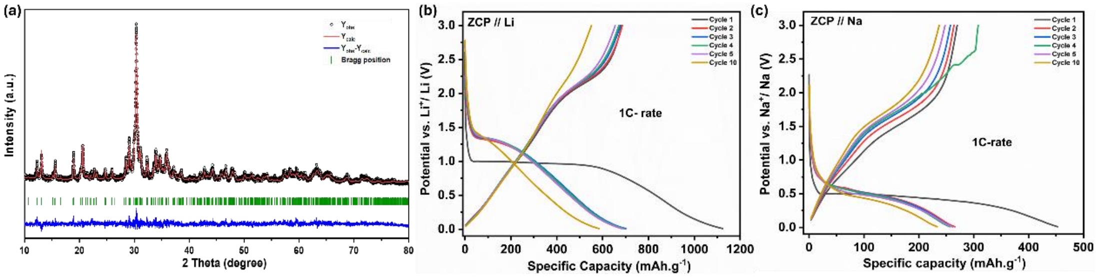


Figure 1. (a) Refined XRD diffractogram, charge/ discharge profile vs. voltage in **(b)** Li, **(c)** Na half cells of ZCP NaSICon-type material.

Funding
This research was funded by OCP foundation & UM6P Ben Guerir – Morocco.

Acknowledgements
Dr. Hasna Aziam acknowledges POLiS Cluster of Excellence for the POLiS Award for Early and Mid-Career Female Researchers 2025.

References

[1] J. Xiao, B. Zhang, J. Liu, et al., *Nano Energy* **2024**,127, 109730.
[2] M. Amou, H. Aziam, B. Larhrib, et al., *J. Power Sources* **2022**, 532231310.
[3] Q. Fu, B. Schwarz, Z. Ding, et al., *Adv. Sci.* **2023**,10, 2207283.
[4] Q. Fu, B. Guo, W. Hua, et al., *Small* **2023**, 19, 2304102.
[5] S. Zhao, C. Li, X. Zhang, et al., *Sci. Bull.* **2023**, 68, 56–64.

[OC30]

Novel inorganic filler for composite solid electrolytes in all-solid-state lithium-metal batteries

Oueldna Nouredine*, Bakkardouch Soukaina, Abouricha Souhaib, Ben Youcef Hicham

High Throughput Multidisciplinary Research Laboratory (HTMR), College of Chemical Sciences and Engineering (CCSE), Mohammed VI Polytechnic University (UM6P), Morroco

*Nouredine.oueldna@um6p.ma

Solid-state batteries (SSBs) promise high energy density and improved safety, yet achieving concurrent gains in ion transport and thermal stability in CSEs remains challenging. We investigate polyethylene-oxide (PEO)/LiTFSI SHEs reinforced with functionalized titanium-oxide nanorods (F-TiO_2) as multifunctional fillers designed to depress PEO crystallinity, enlarge the amorphous phase, and enhance flame-retardant behaviour while maintaining electrochemical robustness. Membranes incorporating F-TiO_2 were fabricated and characterized for structure, transport, safety, and electrochemical properties. The F-TiO_2 additives effectively reduced PEO crystallinity and expanded the amorphous fraction, yielding higher segmental mobility. The resulting CSEs achieved Li^+ conductivity above 1.10^{-4} S/cm at 70 °C and an electrochemical stability window up to 5.8 V vs Li^+/Li. In addition, the membranes exhibited improved flame-retardant characteristics and promising cycling performance under galvanostatic testing. These results identify F-TiO_2 nanorods as powerful, multifunctional additives that unlock a balanced set of transport and safety features in PEO-based CSEs. The demonstrated combination of conductivity, high-voltage stability, and flame retardancy advances the practical deployment of SSBs for electrified transportation and renewable-integrated grids.

Funding
This research was funded by OCP Foundation/UM6P.

References

[1] F. Schmaltz, T. Hartmann, L. Wicke, et al., *Adv. Energy Mater.* **2023**, 13, 2301886.
[2] X. Lu, Y. Wang, X. Xu, et al., *Adv. Energy Mater.* **2023**, 13, 2301746.
[3] N. Oueldna, N. Sabi, H. Ben Youcef, *J. Energy Storage* **2024**, 86, 111254.

[OC31]

Investigating novel high-entropy NASICON-type material as positive electrode for next-generation sodium-ion batteries

S. El Moutchou[1], L. Fkhar[2], H. Oubaha[2], A. Mahmoud[2], N. Sabi[1], H. Ben Youcef[1], H. Aziam[1]*
[1]High Throughput Multidisciplinary Research Laboratory (HTMR), Mohammed VI Polytechnic University (UM6P), Lot 660, Hay Moulay Rachid, 43150 Ben Guerir, Morocco
[2]GREEnMat, Institute of Chemistry B6, University of Liège, 4000 Liège, Belgium
*Hasna.aziam@um6p.ma

Owing to their abundance, wide distribution, and cost advantages over lithium, sodium-ion batteries (NIBs) are considered strong candidate for large-scale and stationary energy storage in next-generation systems [1]. However, the design of competitive positive electrode materials for NIBs is crucial to advance this technology. Phosphorus-based NASICON-type material $Na_3V_2(PO_4)_3$ (NVP) is among the most studied material in the literature due to its high theoretical capacity of 117 mAh/g [2]. However, the NVP faces challenges such as low electronic conductivity, unfavourable phase transitions at high voltage and sluggish Na_+ ion diffusion kinetics [3]. To address these challenges, high-entropy concept capitalizes on the synergistic effects of multielement to improve the electronic conductivity and the overall electrochemical performance of the battery [4]. In this study, we investigated novel high-entropy $Na_{3.4}(M^1M^2M^3M^4M^5M^6)_{0.2}V(PO_4)_3$ (denoted as NVP-HE6, M: transition metal) by incorporating equimolar ratios of six metals. The NVP-HE6 was synthesized with sol-gel assisted Pechini method in the presence of single-walled carbon nanotubes (SWCNT). The electrochemical results reveal an initial discharge capacity of 160 mAh/g at current rate of 0.2C with coulombic efficiency of 99% and retention of 70% after 200 cycles at 1 C in the voltage range of 1.0 – 4.4 V *vs.* Na^+/Na. Sodium storage in NVP-HE6 is predominantly governed by a diffusion-controlled mechanism, as evidenced by the high diffusion coefficient of Na^+ within the electrode material as confirmed by GITT test. These results mark a significant step forward in advancing both the fundamental understanding and practical application of next-generation NIBs.

References

[1] M. Chen, Q. Liu, S. Wang, et al, *Adv. Energy Mater.* **2019**, 9, 1803609.
[2] G. Du, S. Wang, M. Zheng, *Solid State Ionics* **2018**, 317, 229-233.
[3] Y. Zhou, G. Xu, J. Lin, et al., *Nano Energy* **2024**, 128, 109812.
[4] S. El Moutchou, N. Sabi, N. Oueldna, et al., *J. Energy Storage* **2024**, 98, 113078.

[OC32]

Electrochemical CO_2 reduction to formate using biomass-derived gas diffusion electrodes

Guillermo Díaz-Sainz[1]*, Jose Antonio Abarca[1], Iker Uriarte-Porres[1], Álvaro Ramirez[2], Martín Muñoz-Morales[2], Angel Irabien[1], Javier Llanos[2], Manuel Alvarez-Guerra[1]

[1]Departamento de Ingenierías Química y Biomolecular, Universidad de Cantabria, Avenida de los Castros s/n, 39005 Santander, Spain

[2]Department of Chemical Engineering, Faculty of Chemical Sciences & Technologies, Ciudad Real, Universidad de Castilla-La Mancha, Ciudad Real 13071, Spain

*diazsg@unican.es

Anthropogenic activities, particularly the combustion of fossil fuels, have led to a substantial increase in greenhouse gas emissions, driving climate change. In response, the United Nations' COP28 has set an ambitious target to reduce global emissions by 43 % by 2030, with the goal of limiting the average global temperature rise to 1.5 °C. Among the array of CO_2 mitigation strategies, Carbon Capture and Utilization (CCU) has emerged as a particularly promising approach. In this context, the electrochemical reduction of CO_2 to value-added chemicals provides a dual benefit: it curbs CO_2 emissions while enabling the sustainable production of compounds such as formic acid and formate [1].

Gas diffusion electrodes (GDEs) are essential components in CO_2 electroreduction, with the microporous layer (MPL) playing a key role in preventing flooding and facilitating efficient catalyst-electrolyte interactions. Conventional MPLs, typically based on carbon black such as Vulcan XC-72R, pose environmental and health concerns. To overcome these limitations, this study explores the use of biomass-derived materials, specifically lignocellulosic sources, processed through hydrothermal carbonization, pyrolysis, and chemical activation.

The results indicate that GDEs incorporating a 50wt% mixture of biomass-derived carbon and Vulcan XC-72R achieve high formate concentrations (1.8 g/L) and Faradaic efficiency toward formate (80%) at 90 mA/cm^2, performance comparable to or exceeding that of GDEs fabricated solely with commercial Vulcan XC-72R [2]. These findings demonstrate the potential of sustainable biomass-derived materials to replace up to 50% of carbon black, reducing reliance on non-renewable resources while maintaining efficient electrochemical CO_2 conversion to value-added chemicals [3].

Funding

The authors gratefully acknowledge financial support through projects PLEC2022-009398 (MCIN/AEI/10.13039/501100011033 and European Union Next GenerationEU/PRTR), PID2022-138491OB-C31 and PID2022-141265OB-I00 (MICIU/AEI/10.13039/501100011033 and FEDER, UE) and the Complementary Plan in the area of "Energy and Renewable Hydrogen" (funded by Autonomous Community of Cantabria, Spain, and the European Union Next GenerationEU/PRTR). The present work is related to CAPTUS Project. This project has received funding from the European Union's Horizon 2020 - Research and Innovation Framework Programme under grant agreement No 101118265. Jose Antonio Abarca gratefully acknowledges the predoctoral research grant (FPI) PRE2021-097200.

References

[1] K. Fernández-Caso, G. Díaz-Sainz, M. Alvarez-Guerra, et al., *ACS Energy Lett.* **2024**, 8, 1992-2024.
[2] G. Díaz-Sainz, M. Alvarez-Guerra, J. Solla-Gullón, et al., *J. CO2 Util.* **2019**, 34, 12-19.
[3] G. Díaz-Sainz, J.A. Abarca, I. Uriarte-Porres, et al., *Chem. Eng. J.* **2025**, 522, 167825.

[OC33]

Electrocoagulation treatment of coffee capsule recycling wastewater with compressed recovered aluminium electrodes

Inês Marcelo[1], João R. Silva[1,2,3], Luís M. Castro[1,2,3], Maria J. Moreira[1,2], Cândida M. Malça[1,4], Ana Sofia Fajardo[1,2,3]*

[1]Polytechnic University of Coimbra, Rua da Misericórdia, Lagar dos Cortiços, S. Martinho do Bispo, 3045-093 Coimbra, Portugal
[2]University of Coimbra, CERES, Department of Chemical Engineering, 3030-790 Coimbra, Portugal.
[3]Research Center for Natural Resources, Environment and Society (CERNAS), Polytechnic University of Coimbra, Bencanta, 3045-601 Coimbra, Portugal
[4]Centre for Rapid and Sustainable Product Development, Polytechnic of Leiria, Leiria, Portugal

*sofia.fajardo@ipc.pt

The rapid growth of coffee capsule consumption has raised pressing environmental concerns, not only due to the solid waste generated but also because the recycling process produces wastewater rich in organic load, suspended solids, and metal residues. Addressing this challenge, this study explores, for the first time, the use of compressed aluminium (Al) recovered from discarded coffee capsules as electrodes in the electrocoagulation (EC) for wastewater treatment. This innovative approach simultaneously valorises waste, lowers treatment costs, and strengthens circular economy strategies.

Comprehensive characterization of synthetic and real wastewaters was carried out, including pH, conductivity, chemical oxygen demand (COD), total organic carbon (TOC), total nitrogen (TN), and total suspended solids (TSS). The optimization of the EC process was first performed using synthetic effluent under different operational conditions: initial pH (3.0–9.0), current intensity (0.13–1.0 A), interelectrode distance (0.50–4.0 cm), and agitation speed (100–900 rpm). After optimization, the process was applied to a real wastewater from the coffee capsule recycling industry to validate treatment efficiency under practical conditions.

The results showed that EC with compressed recovered Al electrodes achieved a remarkable COD removal of 70% (from an initial 22,000 mg O_2/L) under optimized conditions (initial pH: 3.0; current intensity: 0.50 A; interelectrode distance: 0.50 cm; agitation speed: 300 rpm) after 30 min of treatment, with competitive energy consumption and efficiency. The recovered aluminium electrodes exhibited satisfactory durability and stability, confirming their viability as a sustainable alternative to conventional aluminium plates.

The findings highlight the dual environmental benefits of this strategy: mitigating pollution from recycling wastewater and giving new life to aluminium waste. This work paves the way for more sustainable practices in the coffee capsule industry and illustrates the broader potential of integrating waste valorisation with wastewater treatment.

Funding

This research was funded by the Foundation for Science and Technology (FCT, Portugal) through national funds allocated to the research units: Research Centre for Natural Resources, Environment and Society - CERNAS (DOI: 10.54499/UIDP/00681) and Chemical Engineering and Renewable Resources for Sustainability – CERES (DOI: 10.54499/UIDB/00102/2020 (Base funding), DOI: 10.54499/UIDP/00102/2020 (Programmatic funding)). Additional support was provided by the project with DOI: 10.54499/2022.09696.BDANA (João R. Silva) and the institutional scientific employment program-contract with DOI: 10.54499/CEECINST/00077/2021/CP2798/CT0003 (Ana S. Fajardo).

Acknowledgements

The authors thank Bio4Plas, as an industrial innovation partner, for providing the effluent and recovered aluminium used in this work.

[OC34]

Treatment of natural dyeing wastewaters by electrochemical oxidation

Bárbara Saraiva[1,2]*, Nuno Belino[1,3], Rui Miguel[1,3], Víctor López-Grimau[4], Valentina Buscio[4], João Carvalho[5], Annabel Fernandes[1,2]

[1]Fiber Materials and Environmental Technologies (FibEnTech-UBI), Universidade da Beira Interior, R. Marquês de D'Ávila e Bolama, 6201-001 Covilhã, Portugal
[2]Department of Chemistry, Universidade da Beira Interior, R. Marquês de D'Ávila e Bolama, 6201-001 Covilhã, Portugal
[3]Department of Textile Science and Technology, Universidade da Beira Interior, R. Marquês de D'Ávila e Bolama, 6201-001 Covilhã, Portugal
[4]Instituto de Pesquisa Têxtil (INTEXTER), Universitat Politècnica de Catalunya-Barcelona Tech, Carrer Colom 15, 08222 Terrassa, Spain
[5]FITECOM, S.A., 6200-823 Covilhã, Portugal

*barbara.m.saraiva@ubi.pt

The increasing demand for sustainable textile dyeing practices has led to the growing use of natural dyes. However, the treatment of the resulting wastewaters remains a challenge due to the presence of auxiliary chemicals [1,2]. This study investigates the electrochemical oxidation (EO) of wastewater generated from the eco-dyeing of linen fabrics using an extract from *Punica granatum* (pomegranate). A comparative evaluation of different anode materials, including boron-doped diamond (BDD) and mixed metal oxides, was conducted. The BDD anode demonstrated superior performance in chemical oxygen demand removal, organic compounds mineralization, and energy efficiency. Optimization studies revealed that EO with BDD at 50 A/m² achieves effective treatment with minimal energy consumption. Treated wastewater was successfully reused in new dyeing processes, with no significant differences in colorimetric parameters or fastness properties compared to dyeings performed with fresh water. The findings demonstrate the feasibility of integrating EO and wastewater reuse into circular water strategies for eco-friendly dyeing processes, highlighting BDD as a promising anode material for industrial applications.

Funding

This research was funded by Fundação para a Ciência e a Tecnologia, FCT, project UIDB/00195/2020 and research contract CEECINST/00016/2021/CP2828/CT0006, and by the GIATEX Project 01/C05-i11/2024.PC644943052-00000050, financed by the Recovery and Resilience Plan.

Acknowledgements

The authors acknowledge the Research Unit of Fiber Materials and Environmental Technologies (FibEnTech-UBI) through the Project reference UIDB/00195/2020 funded by FCT through national funds (PIDDAC) (https://doi.org/10.54499/UIDB/00195/2020), Aquitex - Acabamentos Químicos Têxteis, S.A. for providing the natural dyes and associated auxiliary products, and Fitecom - Comercialização e Industrialização Têxtil, S.A. for supplying the fabrics used in this study. A. Fernandes acknowledges FCT and the University of Beira Interior for the research contract CEECINST/00016/2021/CP2828/CT0006 under the scope of the CEEC Institutional 2021, funded by FCT (https://doi.org/10.54499/CEECINST/00016/2021/CP2828/CT0006).

References

[1] S. Dutta, S. Adhikary, S. Bhattacharya, et al., *J. Environ. Manage.* **2024**, 353, 120103.
[2] B. Pizzicato, S. Pacifico, D. Cayuela, et al., *Molecules* **2023**, 28, 5954.

[OC35]

Circular economy through algae: a novel pathway for CO_2 valorisation

Sandra Maldonado[1,2]*, Raúl García-Cervilla[2], Gabriela Roa-Morales[1], Reyna Natividad[1],
Justo Lobato[2], Manuel A. Rodrigo-Rodrigo[2]

[1]Joint Research Centre in Sustainable Chemistry (CCIQS)UAEM-UNAM, highway Km. 14.5, Unit San Cayetano,
Toluca - Atlacomulco, 50200 Toluca de Lerdo, Mexico
[2]Department of Chemical Engineering, University of Castilla-La Mancha, Ciudad Real, Spain

*sandramaria.maldonado@alu.uclm.es

In recent years, atmospheric CO_2 levels have increased considerably, causing severe environmental damage [1]. To address this issue, diverse CO_2 capture and transformation technologies have been proposed. Among them, microalgae represent a promising alternative, not only for CO_2 mitigation and air purification [2], but also as a source of value-added products with potential applications as biofuels. Previous studies have demonstrated that microalgae can efficiently produce organic matter, thereby positioning them as a relevant feedstock for electro-refinery processes [3].

This study focuses on *Chlorella vulgaris* due to its high photosynthetic efficiency, rapid growth rate, and remarkable CO_2 uptake capacity [4,5]. A laboratory-scale algae cultivation system was developed to achieve CO_2 fixation. Once sufficient biomass was obtained, the algal suspension was processed in a continuous parallel electrolysis system equipped with a boron-doped diamond (BDD) anode and a stainless-steel cathode. This configuration enabled the hydrolysis of algal matter into various carboxylic acids, such as: formic, acetic, oxalic, oxamic, and malonic acids.

In parallel, an electrodialysis cell with an anionic membrane was employed. The cathodic chamber was fed with the algal suspension, while the anodic chamber received 0.1 M NaOH as electrolyte. This setup facilitated the migration of carboxylates into the cationic chamber, thereby increasing their concentration while simultaneously reducing the carboxylic acid content in the anionic chamber.

Overall, this process aims to capture CO_2 from the atmosphere while generating value-added byproducts such as formic acid, a key raw material for hydrogen batteries. The proposed approach contributes to reducing fossil fuel dependence and supports the principles of the circular economy by promoting sustainability and decarbonization.

Funding

This work was supported by CONACYT project (320965) for financial support from Mexican government. This work was supported by Spanish Ministry of Science, Innovation and Universities through the ElectroRefin4O project (PID2022-138401OB-I00).

References

[1] I. Hernandez-Mireles, R. Van Der Stel, E. Goetheer, *Energy Procedia* **2014**, 63, 7954-7958.
[2] D. Moreira, J.C.M. Pires, *Bioresour. Technol.* **2016**, 215, 371-379.
[3] Y. Liang, T. Kashdan, C. Sterner, et al., Algal Biorefineries. In: A. Pandey, R. Höfer, M. Taherzadeh, K.M. Nampoothiri, C. Larroche (eds.), *Industrial Biorefineries & White Biotechnology*, Amsterdam, The Netherlands: Elsevier B.V., 2015, pp 35-90.
[4] A.H. Alami, S. Alasad, M. Ali, et al., *Sci. Total Environ.* **2021**, 759, 143529.
[5] K. Santhoshkumar, S. Prasanthkumar, J. George Ray, *Am. J. Plant Sci.* **2015**, 6(15), 2453-2460.

Book of Abstracts

Poster Presentations

[PP01]

A paper-like self-powered biosensor for detection of lactate

Álvaro Torrinha*, Isabel Seguro, João G. Pacheco, Cristina Delerue-Matos, Simone Morais
REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
*tor@isep.ipp.pt

L-lactate (or lactic acid) is a key clinical biomarker associated with metabolic function and oxygen transport. It also contributes to performance optimization in sports and exercise [1], making its biomonitoring in physiological fluids clinically significant. The development of novel, miniaturizable analytical systems are currently essential to meet affordable, environmentally sustainable and easy-to-use proposals [2]. Therefore, the objective of this work was the development of a paper-like self-powered enzymatic biosensor for determination of L-lactate. This biosensor is based on a biofuel cell comprising the lactate oxidase enzyme on the anode and bilirubin oxidase on the cathode. The transducers used as anode and cathode were made of paper-like substrate with inkjet-printed gold nanoparticles modified posteriorly with multi-walled carbon nanotubes and, then, with the respective immobilized enzymes. Cyclic voltammetry was used for electrochemical characterizations of the bioanode and biocathode in the presence and absence of enzymatic substrates, L-lactate and oxygen, respectively. The results confirmed that the bioanode worked either through mediated or unmediated electron transfer principles. Amperometry was subsequently performed to characterize the sensitivity of both bioanode and biocathode towards their substrates, being therefore studied as individual biosensors. Ultimately, the bioanode and biocathode were connected into a biofuel cell, being then characterized by linear sweep voltammetry in increasing concentrations of L-lactate (maintaining the oxygen level constant), which confirmed the capacity of the biofuel cell to work as self-powered biosensor (without the need of external energy supply) for determination of L-lactate.

Funding

The authors are grateful for financial support from the project NATURIST 2022.07089.PTDC (doi: 10.54499/2022.07089.PTDC) funded by Portuguese national funds (FCT/MCTES, Fundação para a Ciência e a Tecnologia and Ministério da Ciência, Tecnologia e Ensino Superior).

Acknowledgements

This work also received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos, and the project PaperSenseMIP PTDC/QUI-QAN/3899/2021 (DOI: 10.54499/PTDC/QUI-QAN/3899/2021) from FCT/MCTES. Álvaro Torrinha and João Pacheco thank FCT for funding through Scientific Employment Stimulus-Individual Calls (2022.04357.CEECIND/CP1724/CT0015 and 2023.07458.CEECIND/CP2842/CT0002, respectively). Isabel Seguro thanks FCT and ESF (European Social Fund) through POCH (Programa Operacional Capital Humano) for her PhD grant (2022.12344.BD).

References

[1] M. Certo, A. Llibre, W. Lee, et al., *Trends Endocrinol. Metab.* **2022**, 33, 722-735.
[2] Y. Ding, L Yang, J. Wen, et al. *Sensors* **2025**, 25, 2045.

[PP02]

Electrochemical detection of venlafaxine in fish

Petra Albuquerque, Miguel Tavares, Vitória Dibo, Cristina Delerue-Matos, Simone Morais, Álvaro Torrinha*

REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal

*tor@isep.ipp.pt

The improper disposal of pharmaceuticals has become a growing concern due to their negative effects caused to the aquatic ecosystems. As such, human health can also be affected directly or indirectly, so it is of increased significance the development of affordable, sustainable and easy-to-use sensors capable of rapidly monitoring these pollutants in environmental samples [1]. Thus, the objective of the present work was the development of an electrochemical sensor for determination of venlafaxine, a widely prescribed antidepressant drug functioning as serotonin and norepinephrine reuptake inhibitor [2]. The developed sensor uses a carbon paper transducer modified by electrodeposition with an iron-based metal-organic framework (MOF), specifically MIL-100. This modification resulted in a higher voltametric peak (at 0.7 V vs Ag/AgCl) compared with the bare electrode. Square-wave voltammetry was then employed for optimizing the venlafaxine signal, namely electrolyte pH, technique parameters and analyte deposition. Calibration curves obtained under optimized conditions originated a submicromolar limit of detection, with sensor achieving also good performance regarding possible interfering compounds. Recovery studies were ultimately performed in spiked fish samples achieving acceptable accuracy in this complex type of solid sample. This electrochemical sensor demonstrated promising features to be applied as an environmental sensor for venlafaxine determination.

Funding

The authors are grateful for financial support from the project NATURIST 2022.07089.PTDC (doi: 10.54499/2022.07089.PTDC) funded by Portuguese national funds (FCT/MCTES, Fundação para a Ciência e a Tecnologia and Ministério da Ciência, Tecnologia e Ensino Superior).

Acknowledgements

This work also received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos. M.T. and V.D. thank FCT for their PhD grants (2022.13624.BD and 2023.04202.BD, respectively). Á.T. thanks FCT for funding through the Scientific Employment Stimulus Individual Call (DOI:10.54499/2022.04357.CEECIND/CP1724/CT0015).

References

[1] M. Tavares, S. Morais, Á. Torrinha, *Trac-Trends Anal. Chem.* **2025**, 47, e00271.
[2] J. Smajdor, K. Fendrych, A. Górska-Ratusznik, *Micromachines* **2025**, 16, 423.

[PP03]

Analytical strategy based on enzymatic biosensors for the quantification of urea in milk samples

Briyitte Sofia Salazar Torres[1]*, Maria Célia Tavares[2], Célia G. Amorim[3], Alberto A. Araújo[3], Maria C.B.S.M. Montenegro[3], Ana Paula Silveira Paim[1]

[1]Universidade Federal de Pernambuco, Pernambuco, Brazil
[2]Istituto Federal de Alagoas, Campus Arapiraca, Alagoas, Brazil
[3]REQUIMTE/LAQV, Faculdade de Farmácia, Universidade do Porto, Porto, Portugal
*briyitte.sofiasalazar@ufpe.br

Urea, synthesized in the liver, is mainly excreted in urine through the kidneys, preventing the excessive accumulation of nitrogen in the body [1]. Urea is also found in milk, appearing as a non-protein nitrogen compound derived from protein metabolism in the rumen of cows, typically in concentrations ranging from 18 to 40 mg/dL. However, due to its high nitrogen content, urea has been fraudulently used to adulterate milk, a practice that compromises product quality and poses a risk to public health. Values above the maximum permitted limit (70 mg/ dL) can cause severe adverse effects, including liver failure, ulcers, and even cancer [2]. Considering these risks, this study aims to ensure quality control and food safety by monitoring urea concentration in milk samples using potentiometric biosensor with immobilized urease on a polysulfone. Thus, the reaction urease with urea substrate is specific and its hydrolysis can generate ammonium, which can be detected by an ion-selective membrane.

For the construction of the ammonium ion-selective membrane electrode, the synthesis of copper hexacyanoferrate (CuHCF) was first carried out following an adapted methodology from Xu et al. [3]. Subsequently, a CuHCF dispersion (20 mg/mL) in 5% (w/w) PSF solution in NMP was prepared. The suspension (20 µL) was deposited onto graphite carbon electrodes (d = 8 mm), previously polished and washed, followed by phase inversion in water (2 × 10 min) [4]. The reference electrode was Ag/AgCl. Several parameters were evaluated, including membrane formation mode (drop or dip coating), conditioning time. After validating the sensitivity to NH_4^+, the enzyme immobilization process was initiated, initially using aliquots of urease solution and glutaraldehyde. The drop-cast membrane was selected for its higher reproducibility and lower error. The average slope was 45.7 ± 5.4 mV (n = 3). Enzyme immobilization was confirmed by the typical enzymatic curve, with increasing substrate concentrations raising the signal until reaching a plateau. The method shows promise for urea determination in milk, but further optimization and analytical validation are required.

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements

The authors thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES, PDSE, process n° 88881.127876/2025-01), the Universidade Federal de Pernambuco, the Conselho Nacional de Desenvolvimento Científico e Tecnológico of Brazil (CNPq, process no. 200357/2025-5), the Instituto Federal de Alagoas (IFAL, process no. 2304.016602/2024.83), and the University of Porto.

References

[1] O.I. Adeyomoye, C.O. Akintayo, K.P. Omotuyi, et al., *Indian J. Nephrol.* **2022**, 32(6), 539-545.
[2] R. Ramesh, P. Puhazhendi, Kumar, et al., *Mater. Sci. Eng. C* **2015**, 49, 786.
[3] L. Xu, L. Zhong, Y. Tang, et al., *Anal. Chem.* **2022**, 94(29), 10487-10496.
[4] L.A. Zambrano-Intriago, C.G. Amorim, A.N. Araújo, et al., *Sci. Total Environ.* **2023**, 855, 158865.

[PP04]

Innovative electrochemical methods for monitoring the therapeutic levels of paroxetine and escitalopram oxalate

Emanuel A. O. Farias[1,2,3], Gabriela R. da Silva[3], Káliton P. Mororó[1], Geanderson E. de Almeida[1], Durcilene A. Silva[3], Carla Eiras[1]*

[1]Laboratório de Pesquisa e Desenvolvimento de Novos Materiais e Sistemas Sensores, Universidade Federal do Piauí, Teresina, Piauí 64049-550, Brazil
[2]Universidade Estadual do Vale do Acaraú, Camocim, Ceará, Brazil
[3]Núcleo de Pesquisa em Biodiversidade e Biotecnologia, Universidade Federal do Delta do Parnaíba, Parnaíba, Piauí, Brazil

*eirasc@ufpi.edu.br

Considered the "disease of the century," depression is a psychiatric disorder that causes brain changes in regions associated with memory, emotions, and cognitive functions. Consequently, the use of antidepressants has increased significantly in recent decades. Notable among these drugs are paroxetine (PRX) and escitalopram oxalate (ESO), both belonging to the class of selective serotonin reuptake inhibitors (SSRIs), widely prescribed for the treatment of the disease [1]. In this context, determining the concentration of these compounds in the body is essential for therapeutic monitoring, especially in the context of personalized medicine. In this study, two electrochemical sensors were developed for the detection of PRX and EOS. For PRX, a pyrolytic graphite electrode (PGE) modified with a nanocomposite of cashew gum (CG), multiwalled carbon nanotubes (MWCNTs), and polyaniline (PANI) was used. For ESO, miniaturized alternative electrodes were fabricated from kraft paper using the pen drawing technique, using conductive ink based on graphite powder and toluene-free PVC glue (G-PVC) [2]. The Kraft/G-PVC working area was subsequently modified with MWCNTs dispersed in a solution of polysaccharide extracted from *Amburana cearensis* (GAmb) [3]. At the same time, commercial silver ink was applied to the reference electrode. The analyses were performed in Britton-Robinson buffer (pH 7.65) for ESO and in monobasic/basic potassium phosphate solution (pH 7.00) for PRX, using cyclic, square-wave, and differential pulse voltammetry. In the PGE/CG-MWCNTs-PANI sensor, PRX presented an irreversible oxidation process at +0.95 V. In contrast, ESO, in the Kraft/G-PVC/MWCNTs-GAmb sensor, exhibited two irreversible oxidation processes at +0.70 V and +0.87 V. In both cases, the surface modification promoted an increase in the electrochemical response, approximately fivefold for PRX and fourfold for ESO, compared to the unmodified electrodes. In initial tests, the PGE/CG-MWCNTs-PANI sensor presented limits of detection and quantification of 8.15 μM and 27.20 μM for PRX, respectively. The Kraft/G-PVC/MWCNTs-GAmb sensors reached limits of detection and quantification of 31.9 μM and 106.30 μM for ESO. The results demonstrate that the developed sensors are promising, affordable, and effective alternatives for the sensitive and selective detection of PRX and ESO, contributing to advances in therapeutic monitoring in clinical and research contexts.

Funding

This research was funded by MCTI/CNPq under Grant Nos. 442845/2023-5 and 310764/2023-8.

References

[1] M.K.L. Silva, G.S. Sousa, R.P. Simões, et al., *J. Solid State Electrochem.* **2021,** 25, 581-586.
[2] G.T.S. Araújo, L.C. Faustino, R.M.P. Silva, et al., *Microchim. Acta* **2025**, 191, 192.
[3] G.E. de Almeida, K.P. Mororó, E.A.O. de Farias, et al., *J. Appl. Electrochem.* **2025**, 55, 509-525.

[PP05]

Mesoporous carbon aerogel matrix for meldola blue as sensing platform for H_2O_2 electroanalytical detection

Ramonnye Ofentse[1], Fort Carmen Ioana[2]*, Mbaiwa Foster[2], Turdean Graziella Liana[2]

[1]School of Pure and Applied Sciences, Department of Chemical and Forensic Sciences, Botswana International University of Science and Technology, Boseja, Palapye, Botswana
[2]"Babes-Bolyai" University, Faculty of Chemistry and Chemical Engineering, Department of Chemical Engineering, Centre of Electrochemistry and Non-conventional Materials, 11, Arany Janos St., 400028 - Cluj-Napoca, Romania

*ioana.fort@ubbcluj.ro

Porous materials such as carbon [1,2], clays [3], and metal oxides like titanium dioxide [4] are frequently employed in electrochemical research, particularly in the construction of electrodes. These materials often serve as modifiers, enhancing the electrochemical performance by improving surface area, conductivity, and catalytic activity. Meldola's Blue (M), a redox-active dye with notable electrocatalytic properties [5], synergizes effectively with the carbon aerogel matrix (C), which offers a high surface area, excellent conductivity, mechanical resilience, and cost-efficiency [1,2]. This combination yields a novel nanocomposite (MC) that stands out as a promising and competitive electrode modifier for advanced electrochemical applications.

Although numerous studies have explored the use of carbon aerogel nanocomposites in the fabrication of carbon-based electrodes, the incorporation of the MC nanocomposite presents notable advantages for enhancing the electrochemically high-performance of electrodes.

The newly developed glassy carbon electrodes (GCEs), modified with the MC nanocomposite, demonstrate promising performance in the electroanalytical detection of hydrogen peroxide (H_2O_2). These MC-based electrodes were fabricated via a drop-casting technique. Their electrochemical behaviour, along with their sensitivity and selectivity toward H_2O_2, was thoroughly evaluated using electrochemical methods (cyclic voltammetry, electrochemical impedance spectroscopy, amperometry). The electroanalytical parameters obtained for the modified glassy carbon electrode (GCE) highlight its stability, sensitivity, and reproducibility in the determination of hydrogen peroxide (H_2O_2). Validation through the analysis of pharmaceutical samples further confirmed the electrode's high performance and practical applicability in real-world electrochemical sensing.

Acknowledgements
Ramonnye Ofentse thanks the financial support of the UE Erasmus+ Program for his research stay at "Babes-Bolyai" University, Cluj-Napoca (Romania).

References

[1] C.I. Fort, L.C. Cotet, A. Vulpoi, et al., *Sens. Actuator B-Chem.* **2015**, 220, 712.
[2] C.I. Fort, L.C. Cotet, V. Danciu, et al., *Mater. Chem. Phys.* **2013**, 138, 893.
[3] C.I. Fort; A. Sanou, M. Coulibaly, et al., *Sens. Actuator B-Chem.* **2024**, 418, 136326.
[4] J.S. Hidalgo, É. Tóth, H. Jankovics, et al., *Chemosensors* **2023**, 11, 576.
[5] I.C. Ladiu, I.C. Popescu, L. Gorton, *J. Solid State Electrochem*. **2005**, *9*, 296.

[PP06]

Considerations in the electrochemical detection of viral proteins using molecularly imprinted polymers: monkeypox A29 case study

Dmitrij Gritsok[1]*, Sérgio F. Sousa[2], Martin Hedström[3], Maria C.B.S.M. Montenegro[1], Célia Gomes Amorim[1]

[1]REQUIMTE/LAQV, Department of Chemical Sciences, Faculty of Pharmacy, University of Porto, Porto, Portugal
[2]REQUIMTE/LAQV, BioSIM – Department of Medicine, Faculty of Medicine, University of Porto, Porto, Portugal
[3]Division of Biotechnology and Applied Microbiology, Department of Process and Life Science Engineering, Lund University, Lund, Sweden

*gritsok.dmitrij@gmail.com

Electrochemical biosensors based on molecularly imprinted polymers (MIPs) are widely explored as selective recognition platforms for proteins, with strong potential in viral diagnostics [1,2]. Yet, imprinting complex proteins remains a challenge due to structural variability, surface interactions, and polymer behaviour [3]. In this work, we present methodological considerations for protein imprinting through a case study of the Monkeypox virus A29 protein. Protein sequence alignment studies and computational modelling using AlphaFold3 were employed to investigate the three-dimensional structure of A29. The models revealed difficulties in assembling stable oligomeric states and suggested the presence of extended, non-globular domains. Such flexible regions may promote non-specific adsorption on electrodes and contribute to the complication of the imprinting process. To evaluate this possibility further, MIPs were fabricated on DropSens 220AT gold screen-printed electrodes by electropolymerization of pyrrole or o-phenylenediamine. Electrochemical impedance spectroscopy (EIS), square-wave voltammetry (SWV), and differential pulse voltammetry (DPV) were used to characterize polymer films and binding responses. Poly(pyrrole) produced more conductive but less reactive layers, whereas poly(o-phenylenediamine) yielded denser and more adsorption-prone films. In both cases, hydration played a critical role: EIS signals varied significantly when electrodes were incubated in phosphate-buffered saline, underlining the influence of polymer swelling and ionic environment on sensor reproducibility. Despite unsuccessful protein detection under the tested conditions, the study highlights several factors often underreported in the literature: protein conformation and flexibility, non-specific adsorption, polymer hydration effects, and the reproducibility of screen-printed electrodes, particularly regarding cleaning and batch-to-batch variation. These insights emphasize the need for more detailed methodological reporting and for integrating computational predictions with experimental design. This contribution aims to stimulate discussion on the limitations and refinements required to advance MIP-based electrochemical biosensors from proof-of-concept studies toward reliable diagnostic platforms.

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements

Dmitrij Gritsok thanks FCT for his PhD research grant with ref. PRT/BD/154971/2023 established within EUGLOH–U.Porto protocol.

References

[1] D. Gritsok, M. Hedström, M.C.B.S.M. Montenegro, et al., *Biosens. Bioelectron.* **2025**, 287, 117678.
[2] G. Pilvenyte, V. Ratautaite, R. Boguzaite, et al., Biosensors **2023**, 13(6), 620.
[3] Y. Li, L. Luo, Y. Kong, et al., *Biosens. Bioelectron.* **2024**, 249, 116018.

[PP07]

Construction of electrochemical genosensors for the identification of the polymorphism (c.100C>T, rs1065852) located in the CYP2D6*10 gene

Renata Santos[1], Stephanie L. Morais[1], Michelle Castanheira[1], João G. Pacheco[1],
Henri P.A. Nouws[1], Hygor F. Fernandes[2], Iris Féria[3], Giovanny Pinto[2], M. Fátima Barroso[1]*
[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]Grupo de Estudos Em Genética Humana e Médica (GEHMED), Laboratório de Genética e Biologia Molecular, Universidade Do Delta Do Parnaíba (UFDPar), Parnaíba 64202-020, PI, Brazil
[3]Unidad de Investigación Médica en Enfermedades Neurológicas, Hospital de Especialidades, "Dr. Bernardo Sepúlveda", Centro Médico Nacional Siglo XXI, Instituto Mexicano del Seguro Social, Ciudad de México, México.
*mfb@isep.ipp.pt

Pharmacogenetics enables the personalization of therapy based on genetic variants that modulate drug response [1-3]. The CYP2D6 gene, responsible for the metabolism of various psychotropic drugs, presents the rs1065852 polymorphism, which defines the CYP2D6 10 allele. This allele is associated with an intermediate metabolizer phenotype, resulting in reduced enzymatic activity and an increased risk of suboptimal clinical response.

In this context, a disposable electrochemical genosensor was developed for the rapid and specific detection of the rs1065852 polymorphism. The approach involved immobilizing a 25-base thiolated oligonucleotide sequence on gold screen-printed electrodes (GSPE) via a self-assembled monolayer composed of thiolated DNA (-SH group) and mercaptohexanol (MCH), followed by a sandwich hybridization reaction with a complementary single-stranded DNA sequence labelled with fluorescein and monitored using voltammetric techniques, specifically chronoamperometry.

The developed genosensor demonstrated high sensitivity, selectivity, and reproducibility (RSD of 17.65% and 23.79%). The fully complementary DNA target sequence (Target T) produced an electrochemical signal 56.81% higher than that of the DNA target sequence containing the polymorphism (Target C). These results indicate that the genosensor represents a rapid, precise, and robust analytical tool with potential for clinical pharmacogenetics, enabling individualized optimization of epilepsy therapy.

Funding

This work received financial support from the project “NeuroDevice: Challenging the Analytical Diagnosis of Neurodevelopmental Disorders: Pioneering Neurochemical Devices", funded by FEDER funds (COMPETE 2030) and national funds by FCT/MECI (Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação), operation no. 15875, with reference COMPETE2030-FEDER-00699000. This work also received financial support from Portuguese national funds (FCT/MECI) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos, and from the Instituto Mexicano del Seguro Social and Fundación IMSS thought the project R-2025-785-016 and was partially supported by Programa Iberoamericano de Ciencia y Tecnología para el Desarrollo (CYTED) (through Red 223RT141).

Acknowledgements

MFB and JP are grateful for the FCT Investigator: 2020.03107.CEECIND-DOI:10.54499/2020.03107.CEECIND/CP1596/CT0005 and 2023.07458.CEECIND, respectively. Michelle Castanheira (2023.05159.BDANA) and Stephanie Morais (2023.028929.BD) are grateful to FCT and the European Union (EU) for their grants financed by POPH-QREN-Tipologia 4.1-Formação Avançada, funded by Fundo Social Europeu (FSE) and Ministério da Ciência, Tecnologia e Ensino Superior (MCTES).

References

[1] T. Barbosa, S.L. Morais, R. Carvalho, et al., *Chemosensors* **2025**, 13(7), 248.
[2] T. Barbosa, S.L. Morais, E. Pereira, et al., *Genes* **2025**, 16(4), 372.
[3] S.L. Morais, J.M.C.S. Magalhães, V.F. Domingues, et al., *Talanta* **2023**, 264, 124692.

[PP08]

Low-cost paper-based electrochemical genosensors for polymorphism detection

Renata Santos[1], Stephanie L. Morais[1], Michelle Castanheira[1], João G. Pacheco[1], Henri P.A. Nouws[1], Carla Eiras[2], Hygor F. Fernandes[3], Iris Féria[4], Giovanny Pinto[3], M. Fátima Barroso[1]*

[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto, Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]R&D Laboratory for New Materials and Sensor Systems (MATSENS), Federal University of Piauí, Teresina, Piauí 64049-550, Brazil
[3]Grupo de Estudos Em Genética Humana e Médica (GEHMED), Laboratório de Genética e Biologia Molecular, Universidade Do Delta Do Parnaíba (UFDPar), Parnaíba 64202-020, PI, Brazil
[4]Unidad de Investigación Médica en Enfermedades Neurológicas, Hospital de Especialidades, "Dr. Bernardo Sepúlveda", Centro Médico Nacional Siglo XXI, Instituto Mexicano del Seguro Social, Ciudad de México, México

*mfb@isep.ipp.pt

Early disease identification can have a substantial influence on patient outcomes. It can improve the precision and efficiency of identifying diseases if realistic examples of diagnostic tool use in underdeveloped countries are supplied. Furthermore, providing more information on the kinds of diseases that may be discovered early utilizing these technologies can assist readers in understanding the significance of early detection. Consider the constraints or problems of deploying these diagnostic techniques in distant places with limited access to medical care. In recent years, electrochemical sensors that utilize paper as a substrate have emerged as promising tools for detecting several analytes, namely proteins, enzymes and nucleic acids in biological fluids [1].

In this work, a low-cost paper electrochemical DNA-based sensor was developed for the detection of genetic variations associated with diseases derived from the central nervous system [2]. The construction of this disposable platform was based on the detection of the electrochemical signal generated during the biochemical DNA hybridization reaction.

Funding

This work received financial support from the project "NeuroDevice: Challenging the Analytical Diagnosis of Neurodevelopmental Disorders: Pioneering Neurochemical Devices", funded by FEDER funds (COMPETE 2030) and national funds by FCT/MECI (Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação), operation no. 15875, with reference COMPETE2030-FEDER-00699000. This work also received financial support from Portuguese national funds (FCT/MECI) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos, and from the Instituto Mexicano del Seguro Social and Fundación IMSS thought the project R-2025-785-016 and was partially supported by Programa Iberoamericano de Ciencia y Tecnología para el Desarrollo (CYTED) (through Red 223RT141).

Acknowledgements

MFB and JP are grateful for the FCT Investigator: 2020.03107.CEECIND-DOI:10.54499/2020.03107.CEECIND/CP1596/CT0005 and 2023.07458.CEECIND, respectively. Michelle Castanheira (2023.05159.BDANA) and Stephanie Morais (2023.028929.BD) are grateful to FCT and the European Union (EU) for their grants financed by POPH-QREN-Tipologia 4.1-Formação Avançada, funded by Fundo Social Europeu (FSE) and Ministério da Ciência, Tecnologia e Ensino Superior (MCTES).

References

[1] S.R. Benjamin, F. Lima, V.A. Nascimento, et al., *Biosensors* **2023**, 13, 689.
[2] S.L. Morais, J.M.C.S. Magalhães, V.F. Domingues, et al., *Talanta* **2023**, 264, 124692.

[PP09]

A new electrochemical sensor based on chitosan-diazonium functionalized MWCNTs matrix for the detection of heavy metals

Faye Déthié[1], Fort Carmen Ioana[2], Turdean Graziella Liana[2]*, Lo Momath[1]

[1]Laboratoire de Chimie Physique Organique et d'Analyses Environnementales, Département de Chimie, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, Dakar, Sénégal

[2]"Babes-Bolyai" University, Faculty of Chemistry and Chemical Engineering, Department of Chemical Engineering, Centre of Electrochemistry and Non-conventional Materials, 11, Arany Janos St., 400028 - Cluj-Napoca, Romania

*graziella.turdean@ubbcluj.ro

In recent decades, the intensification of anthropogenic and industrial activities has led to a significant increase in the natural concentration of heavy metal (HM) ions in environmental matrices, including water, air, and soil [1,2]. The high accumulation of metal ions in ecosystems, encouraged by their non-biodegradable properties, has led to contamination of the food chain, particularly a deterioration in water quality [3]. Thus, to ensure food safety and prevent damage caused by heavy metal ions, an electrochemical sensor based on MWCNTs functionalized with diazonium and chitosan for detecting metal ions (Cd, Pb, and Zn) in water was developed, for the first time. The sensor's physicochemical properties were analysed using SEM, XRD, XPS, Raman, FT-IR, and UV–Vis characterisation methods. Electrochemical performances, including charge transfer resistance, capacitive behaviours, and kinetic reactions on the electrode's surface, were assessed using electrochemical impedance spectroscopy (EIS) and cyclic voltammetry (CV). Simultaneous electroanalysis of Pb^{2+}, Cd^{2+}, and Zn^{2+} by square-wave anodic stripping voltammetry (SWASV), under optimal experimental conditions, demonstrated the sensor's very high sensitivity and excellent selectivity, with very low limit of detection (LODs) of 51.7 nM Pb^{2+}, 141.2 nM Cd^{2+}, and 433.6 nM Zn^{2+} over a linear range of 0 to 16 nM HM ions. Additionally, testing the sensor's applicability on natural tap water samples from Cluj-Napoca (Romania) yielded satisfactory results, with a standard deviation of less than 5%, compared to AAS standardised measurements.

Acknowledgements

D. Faye thanks the financial support offered by the "Eugen Ionescu" fellowship of the Agence Universitaire de la Francophonie (AUF) for his research stay at "Babes-Bolyai" University, Cluj-Napoca (Romania).

References

[1] S. Laschi, P.S. Sfragano, F. Tadini-Buoninsegni, et al., *Analyst* **2024**, 149, 4249.
[2] S.F. Sulthana, U.M. Iqbal, S.B. Suseela, et al., *ACS Omega* **2024**, 9, 25512.
[3] C.I. Fort, A. Sanou, M. Coulibaly, et al., *Sens. Actuator B-Chem.* **2024**, 418, 136326.

[PP10]

Simultaneous electrochemical analysis of fish and crustacean allergens

Clara Esteban-Sanz[1,2], Maria Freitas[1]*, Patricia Galán-Malo[3], María D. Pérez[2],
Cristina Delerue-Matos[1], Henri P.A. Nouws[1]

[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]Departamento de Producción Animal y Ciencia de los Alimentos, Facultad de Veterinaria, Instituto
Agroalimentario de Aragón (IA2) (Universidad de Zaragoza-CITA), Miguel Servet, 177, 50013 Zaragoza, Spain
[3]ZEULAB S.L., Polígono Plaza, Bari, 25 Duplicado, 50197 Zaragoza, Spain

*mccfs@isep.ipp.pt

The presence of food allergens in commercial food products is subject to strict regulatory requirements and must be clearly indicated on product labels. Nonetheless, the unintended or unreported presence of allergenic residues can pose significant health risks to sensitized individuals [1]. Therefore, reliable analytical techniques that enable rapid and efficient detection are essential for both consumer safety and quality control within the food industry. While electrochemical biosensors have been widely reported for the detection of individual allergens, the development of platforms capable of simultaneous multi-allergen analysis presents distinct advantages in terms of efficiency, cost-effectiveness, and practicality in routine food monitoring [2,3]. A biosensor capable of simultaneously detecting Parvalbumin (PV) and Tropomyosin (TPM) (major fish and crustacean protein allergens, respectively) is essential for comprehensive allergen screening of aquatic-derived foods.

In this study, anti-PV and anti-TPM antibodies were immobilized on a dual screen-printed carbon electrode (dual SPCE), followed by the addition of the sample and horseradish peroxidase (HRP)-conjugated secondary antibodies. The antigen–antibody interactions were detected using 3,3′,5,5′-tetramethylbenzidine (TMB) as the enzymatic substrate, recording the electrochemical signal by chronoamperometry. The developed multiplexed sensor allows rapid analysis (1h) with adequate precision (CV < 10%) and minimal cross-reactivity, a considerable challenge in simultaneous electrochemical analysis. Various sample treatment protocols were studied, and the impact of food processing on allergen detectability was assessed. The results were validated using a conventional Enzyme-Linked Immunosorbent Assay.

Funding

This work received financial support through the project "Sens2BiteSafe - Allergen Analysis Breakthroughs: Enhancing Food Safety with Electrochemical Paper-based Analytical Devices" (COMPETE2030-FEDER-00713900 (nº 16000)), funded by FEDER (COMPETE 2030) and Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministro da Educação, Ciência e Inovação) and Portuguese national funds (FCT/MECI) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements

Maria Freitas is thankful for her contract (2022.00490.CEECIND/CP1724/CT0007, DOI: 10.54499/2022.00490.CEECIND/CP1724/CT0007) financed by FCT/MCTES-CEEC Individual Program Contract. Clara Esteban is grateful for her predoctoral grant (Subvenciones para la contratación de personal investigador predoctoral en formación - Convocatoria 2022-2026, Nº 8806) financed by Gobierno de Aragón (Spain).

References

[1] EC Regulation (EU) No 1169/2011. *Provision of Food Information to Consumers* **2011**.
[2] R. Torre, M. Freitas, J.S. Teixeira, et al., *Microchem. J.* **2024**, 206, 111662.
[3] J.P. Rocha, M. Freitas, D. Geraldo, et al., *Food Chem.* **2024**, 446, 138889.

[PP11]

Design of paper-based electrochemical sensors with molecularly imprinted polymers for selective omeprazole detection in water

Isabel Seguro[1,2], Cristina Delerue-Matos[1], João G. Pacheco[1]*
[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]REQUIMTE/LAQV, Departamento de Química e Bioquímica, Faculdade de Ciências, Universidade do Porto, Rua do Campo Alegre, 4619-007 Porto, Portugal
*jpgpa@isep.ipp.pt

Inkjet-printed electrochemical devices are emerging as analytical tools for monitoring food, environmental and clinical samples, due to their high reproducibility and versatility. This new approach also provides mass production and miniaturization of analytical platforms [1]. Although paper-based platforms have been used for several years, by their compatibility with different detection methods (such as colorimetry, electrochemistry, luminescence) the use of these platforms is growing especially for point-of-care use [2]. To enhance selectivity to electrochemical detection, recognition elements as enzymes, proteins, antibodies or molecularly imprinted polymers, are usually coupled with working electrodes. Molecularly imprinted polymers (MIP) are tailor-made materials with selective binding sites for specific analytes. It is a well stablished technology that offers high chemical and physical stability, and fast response together with easy and affordable production [3]. Omeprazole is a proton pump inhibitor, and it is used to treat conditions with high acid content in stomach. As with other therapeutic drugs, the effects of omeprazole in the environment remains uncertain, as they are released into the environment without proper treatment. The demand for point-of-use devices is clear, since the presence of pharmaceuticals in the environment is widely documented, and fast and cheap analysis are valuable. Herein we present an electrochemical MIP-sensor, prepared on a paper-based platform, for the selective detection of Omeprazole. The electrochemical cell was inkjet-printed with gold and silver commercially available inks. Electrochemical measurements were performed by differential pulse voltammetry, with a linear working range between 0.50 µM and 50 µM. The proposed sensor also presented good selectivity when tested with similar molecules. Furthermore, recovery experiments were performed using river and well water samples with recoveries above 89%.

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos. and project PaperSenseMIP (PTDC/QUI-QAN/3899/2021, doi: 10.54499/PTDC/QUI-QAN/3899/2021).

Acknowledgements

I.S. is grateful to FCT for her PhD grant (2022.12344.BD). The authors are also grateful to the project BioReset (BiodivRestore-406 / DivRestore/0002/2020, DOI: 10.54499/DivRestore/0002/2020) funded through the 2020-2021 Biodiversa+ and Water JPI joint call for research projects, under the BiodivRestore ERA-NET Cofund (GA N°101003777), by the EU and FCT.

References

[1] S. Cinti, N. Colozza, I. Cacciotti, et al., *Sens. Actuator B-Chem.* **2018**, 265, 155-160.
[2] E. Noviana, C.S. Henry, *Curr. Opin. Electrochem.* **2021**, 23, 1-6.
[3] L. Chen, X. Wang, W. Lu, et al., *Chem. Soc. Rev.* **2016**, 45, 2137.

[PP12]

Inkjet-printed paper-based electrode modified with a molecularly imprinted polymer for the voltammetric detection of venlafaxine

Inês Martins[1], Isabel Seguro[1], Patrícia Rebelo[1], Ivan Veloso[2], M. Natália D.S. Cordeiro[2],
Henri P.A. Nouws[1], Cristina Delerue-Matos[1], João G. Pacheco[1]*

[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]REQUIMTE/LAQV, Departamento de Química e Bioquímica, Faculdade de Ciências, Universidade do Porto,
Rua do Campo Alegre, 4619-007 Porto, Portugal

*jpgpa@isep.ipp.pt

The occurrence of emerging contaminants such as pharmaceuticals in the environment is a growing concern [1,2]. Venlafaxine (VLX), for example, tends to accumulate and negatively affects both human and animal health, including alterations in fish metabolism and behaviour [3]. In this study, we present a voltammetric molecularly imprinted polymer (MIP) paper-based electrochemical sensor for rapid VLX detection in water. The electrochemical cell was fabricated by inkjet-printing electrodes on Tough-Print waterproof paper with a Dimatix DMP 2850 printer (Fujifilm). Conductive silver ink was used for the reference electrode and electrical connections, while conductive gold ink was employed for the working and counter electrodes. The working electrode was further modified with carbon ink via drop-casting.
Selectivity was achieved by electropolymerizing a MIP directly onto the working electrode surface, using sulfanilic acid as the functional monomer and VLX as the template. Key preparation parameters were optimized, yielding an imprinting factor of 63, a linear response from 5.0 to 75.0 µM, limits of detection and quantification of 0.25 and 0.82 µM, respectively, and high precision (CV = 2.0 %). Application to water samples demonstrated recoveries of 85 - 97 %, confirming the sensor's suitability for real-world monitoring.

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos, and project PaperSenseMIP (PTDC/QUI-QAN/3899/2021, doi: 10.54499/PTDC/QUI-QAN/3899/2021).

Acknowledgements

João Pacheco is thankful for his contract (2023.07458.CEECIND/CP2842/CT0002, doi: 10.54499/2023.07458.CEECIND/CP2842/CT0002) financed by FCT/Ministério da Ciência, Tecnologia e Ensino Superior (MCTES) – CEEC Individual Program Contract. Patrícia Rebelo is grateful for her grant from the FCT-funded project PaperSenseMIP (PTDC/QUI-QAN/3899/2021, doi: 10.54499/PTDC/QUI-QAN/3899/2021). Inês Martins thanks FCT and ATHENA (Advanced Technology Higher Education Network Alliance) for her PhD grant (2024.15663.PRT). Isabel Seguro is thankful for her PhD grant (2022.12344.BD, doi: 10.54499/2022/12344/BD) funded by FCT and ESF (European Social Fund) through POCH (Programa Operacional Capital Humano). The authors are also grateful to the project BioReset (BiodivRestore-406 / DivRestore/0002/2020, DOI: 10.54499/DivRestore/0002/2020) funded through the 2020-2021 Biodiversa+ and Water JPI joint call for research projects, under the BiodivRestore ERA-NET Cofund (GA N°101003777), by the EU and FCT.

References

[1] N.V. Hidayati, A.D. Syakti, L. Asia, et al., *Sci. Total Environ.* **2021**, 773, 145057.
[2] Directive (EU) 2024/3019 of the European Parliament and of the Council of 27 November **2024**. http://data.europa.eu/eli/C/2023/250/oj
[3] W.A. Thompson, M.M. Vijayan, *Chemosphere* **2020**, 259, 127437.

[PP13]

Development of a potentiometric sensor to monitor urease as a biomarker of *Helicobacter pylori*

Maria Célia Tavares[1]*, Célia G. Amorim[2], Alberto A. Araújo[2], Josué C. C. Santos[3],
Maria C.B.S.M. Montenegro[2]

[1]Instituto Federal de Alagoas, Campus Arapiraca, Alagoas, Brazil
[2]REQUIMTE/LAQV, Faculdade de Farmácia, Universidade do Porto, Porto, Portugal
[3]Instituto de Química e Biotecnologia, Universidade Federal de Alagoas, Maceió, Alagoas, Brazil
*celia.tavares@ifal.edu.br

Urease is a nickel-dependent enzyme that catalyses the hydrolysis of urea into ammonia and carbon dioxide. Its activity may be clinically relevant due to its association with ureolytic bacteria, such as *Helicobacter pylori*, *Proteus mirabilis* and others involved in urinary tract infections, gastric disorders and biofilm formation [1,2]. The determination of urease activity can be done in different ways, the simplest being the one that indicates the presence of pathogens in their active form, by determining the product of urease hydrolysis, which is essential both for the development of diagnostic tools and for the evaluation of enzyme inhibitors with therapeutic potential [3]. This study aims, in its initial phase, to employ an ion-selective membrane (ISM) for the potentiometric detection of ammonium ions (NH_4^+), a product of urea hydrolysis, as an indirect method to quantify urease activity. A pencil graphite working electrode (2 mm in diameter) coated with a membrane composed of copper hexacyanoferrate (CuHCF, 20 mg/mL) and polyvinyl chloride (PVC, 1 mg/mL) in N-methyl-2-pyrrolidone (NMP) was prepared. The synthesis of CuHCF and preparation of the electrode were performed according to a methodology adapted from Xu et al. (2022) [4]. Thus, 3 µL of the suspension was deposited on the electrode and dried overnight in an oven. The potentiometric system consisted of this modified electrode and an Ag/AgCl reference electrode. Initially, calibration curves were obtained with ammonium ions (NH_4^+) to validate the membrane response, followed by assays with urea at a fixed concentration and increasing additions of urease. The ion-selective membrane electrode showed a linear and reproducible response for the NH_4^+ ion, with mean slopes of 48.9 ± 1.2 mV and detection limits of 11 ± 2 µM. In the urease assays, an increase in potential was observed as a function of enzyme concentration, reaching the plateau characteristic of Michaelis-Menten kinetics. These results confirm the feasibility of the system for monitoring urease activity potentiometrically, employing reduced reagent volumes and accessible instrumentation. The proposed method demonstrated potential as a promising analytical approach for determining urease activity, suggesting its future application as a supporting technique in the indirect diagnosis of *H. pylori* infection. Future studies should focus on obtaining the method's parameters of merit and applying the system to complex biological matrices, as well as miniaturizing the device for point-of-care analysis.

Funding
This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements
We thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico of Brazil (CNPq - process nº. 200357/2025-5), the Instituto Federal de Alagoas (IFAL - process nº. 2304.016602/2024.83) and Porto University.

References

[1] B. Krajewska, *J. Mol. Catal. B Enzym*. **2009**, 59, 9-21.
[2] K. Saxena, N. Chauhan, U. Jain, *Anal. Biochem.* **2021**, 630, 114325.
[3] D. Mora, S. Arioli, *PLoS Pathog.* **2014**, 10, e1004472.
[4] L. Xu, L. Zhong, Y. Tang, et al., *Anal. Chem.* **2022**, 94(29), 10487-10496.

[PP14]

Electrochemical biosensing approach for cystatin C: towards improved chronic kidney disease diagnostics

Maria Freitas*, Cristina Delerue-Matos, Henri P.A. Nouws
REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
*mccfs@isep.ipp.pt

Chronic kidney disease (CKD) is a significant public health concern in Portugal, underscoring the need for rapid and reliable diagnostic tools to support early detection and effective management. Biomarkers, such as Creatinine or Cystatin C, are essential to identify kidney dysfunction, tracking disease progression, and evaluating treatment responses. Clinically, Cystatin C is recognized as a highly sensitive and reliable indicator of renal function [1]. However, conventional methods for its detection are often time-consuming, costly, and dependent on centralized laboratory infrastructure. In contrast, biosensors present a promising alternative, offering faster, more accessible, and cost-effective solutions that could enable earlier intervention and lead to better patient outcomes [2].

A non-competitive electrochemical immunosensor for the detection of Cystatin C was developed, with a total assay time of 1h30min. The sensor is based on a sandwich-type immunoassay performed on miniaturized Screen-Printed Electrodes. Chronoamperometric detection was achieved using an enzymatic reaction involving horseradish peroxidase (HRP) and the enzymatic substrate 3,3',5,5'-tetramethylbenzidine (TMB) with hydrogen peroxide (H_2O_2). Under optimized conditions, the method demonstrated high precision, with a coefficient of variation below 8%, which is critical for reliable biomarker quantification in patient serum samples. The quantification range varied between 50 and 2000 ng/mL, with a limit of detection of 50 ng/mL. The results highlight the potential of the developed approach as a complementary tool or a promising alternative to conventional diagnostic methods for CKD.

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements

Maria Freitas is thankful for her contract (2022.00490.CEECIND/CP1724/CT0007, DOI: 10.54499/2022.00490.CEECIND/CP1724/CT0007) financed by FCT/MCTES-CEEC Individual Program Contract.

References

[1] I. Lousa, F. Reis, I. Beirão, et al., *Int. J. Mol. Sci.* **2021**, 22, 1-37.
[2] P. Lopes, E. Costa-Rama, I. Beirão, et al., *Talanta* **2019**, 201, 211-216.

[PP15]

A novel electrochemical genosensor platform for early detection of *Candida albicans*

Michelle Castanheira[1,2,3,4], Stephanie L. Morais[1], Luís Lima[3], Marlene Santos[2],
M. Fátima Barroso[1]*

[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]REQUIMTE/LAQV, Escola Superior de Saúde, Instituto Politécnico do Porto, Porto, Portugal
[3]Research Center, Portuguese Institute of Oncology of Porto Francisco Gentil, E.P.E., Porto, Portugal
[4]FCUP-Department of Chemistry, Faculty of Sciences, University of Porto, Porto, Portugal

*mfb@isep.ipp.pt

Considering major advances in the prevention and treatment of fungal illnesses, invasive fungi continue to be a leading cause of morbidity and mortality [1]. Global Action Fund Infections refers that about 300 million individuals contract a fungal infection each year, and over 1.5 million of them pass away. *Candida albicans* is one of the most significant fungal 66 opportunistic pathogen, which can result in invasive or superficial infections [1,2]. The most relevant and high-risk target group are those undergoing high-dose chemotherapy for acute leukaemia and those receiving allogeneic stem cell transplants, because their immune systems are suppressed throughout the transplant procedure [3,4]. Diagnosing systemic fungal infections continues to be a challenge. This study developed a simple, quick, and precise approach for detecting *Candida albicans* by developing a electrochemical nanogenosensor. Gold SPGE electrodes were chosen due to their excellent conductivity, biocompatibility, and ability to form self-assembled monolayers. A sandwich hybridization reaction was used to enhance the sensitivity of the electrochemical signal. According to preliminary results it was obtained a linear range between 0,03 nM to 1,0 nM of *C. albicans* synthetic DNA target. Although these results, efforts are proceeding to optimize the nanogenosensor for the quantification of this fungus. Future developments will address the application in a hospital setting regarding sensitivity, accuracy, promptness of response, problems, and potential.

Acknowledgements

This project is part of the CYTED-rede Ibero-Americana project (GENOPSYSEN-ref:223RT0141). MFB and JP are grateful for the FCT Investigator: 2020.03107.CEECIND-DOI: 10.54499/2020.03107.CEECIND/CP1596/CT0005 and 2023.07458.CEECIND, respectively. Michelle Castanheira (2023.05159.BDANA) and Stephanie Morais (2023.028929.BD) are grateful to FCT and the European Union (EU) for their grants financed by POPH-QREN-Tipologia 4.1-Formação Avançada, funded by Fundo Social Europeu (FSE) and Ministério da Ciência, Tecnologia e Ensino Superior (MCTES).

References

[1] A. Mendonça, H. Santos, R. Franco-Duarte, et al., *Res. Microbiol. J.* **2022**, 173, 103915.
[2] R. Frare e Silva, *J. Bras. Pneumol.* **2010**, 36, 142-147.
[3] Z. Bhatti, A. Shaukat, N.G. Almyroudis, et al., *Mycopathologia* **2006**, 162(1), 1-15.
[4] S. Bretagne, J.M. Costa, *FEMS Immunol. Med. Microbiol.* **2005**, 45, 361-368.

[PP16]

Paper-based electrochemical genosensors: a new approach for *Candida* spp. detection

Michelle Castanheira[1,2,3,4], Stephanie L. Morais[1], Isabel Seguro[1], João G. Pacheco[1], Luís Lima[3],
Marlene Santos[2], M. Fátima Barroso[1]*

[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]REQUIMTE/LAQV, Escola Superior de Saúde, Instituto Politécnico do Porto, Porto, Portugal
[3]Research Center, Portuguese Institute of Oncology of Porto Francisco Gentil, E.P.E., Porto, Portugal
[4]FCUP-Department of Chemistry, Faculty of Sciences, University of Porto, Porto, Portugal

*mfb@isep.ipp.pt

Invasive fungal infections have become more prevalent and widespread, particularly among hospitalized patients with serious underlying conditions or those with weakened immune systems [1,2]. Prompt recognition and timely initiation of antifungal treatment are vital to improving patient survival. Diagnostic approaches such as histopathological examination of tissue, serological assays, and culture techniques are commonly employed for the detection of candidiasis, yet they are often labour-intensive, time-consuming, and may lack accuracy or sensitivity [3]. Blood culture is regarded as the "gold standard" for diagnosing Candida spp. bloodstream infections. However, its diagnostic sensitivity is limited, as it yields positive results in fewer than half of the patients with chronic disseminated candidiasis [4]. In addition, culture methods are inherently slow, with certain Candida spp. requiring up to a week to grow an unacceptable delay before initiating appropriate treatment. An electrochemical DNA-based biosensor was developed to detect Candida albicans. The sensor self-assembles in an electronic paper device (ePAD) to be applied to Point-of-care for a prompt and simple detection of those species. The principle of the approach is a hybridization reaction involving two complementary single stranded DNA sequences. Early research suggested that this DNA-based sensor might detect Candida spp. in synthetic DNA samples. Despite these findings, attempts are underway to improve the sensor for assessing Candida albicans, this methodology will be validated by subsequent research. Future developments will focus on medical applications, including sensitivity, accuracy, response time, obstacles, and potential.

Acknowledgements
This work received financial support from national funds through the PaperSenseMIP project (PTDC/QUI-QAN/3899/2021, DOI: 10.54499/PTDC/QUI-QAN/3899/2021). This project is part of the CYTED-rede Ibero-Americana project (GENOPSYSEN-ref:223RT0141). This work received financial support from the project "NeuroDevice", funded by FEDER funds (COMPETE 2030) and national funds by FCT/MECI, operation no. 15875, with reference COMPETE2030-FEDER-00699000. MFB and JP are grateful for the FCT Investigator: 2020.03107.CEECIND-DOI:10.54499/2020.03107.CEECIND/CP1596/CT0005 and 2023.07458.CEECIND, respectively. Michelle Castanheira (2023.05159.BDANA), Stephanie Morais (2023.028929.BD) and Isabel Seguro (2022.12344.BD) are grateful to FCT and the European Union (EU) for their grants financed by POPH-QREN-Tipologia 4.1-Formação Avançada, funded by Fundo Social Europeu (FSE) and Ministério da Ciência, Tecnologia e Ensino Superior (MCTES).

References

[1] P. Sampaio, M. Santos, A. Correia, et al., *PloS one* **2010**, 5(4), e10155.
[2] R. Frare e Silva, *J. Bras. Pneumol.* **2010**, 36, 142-147.
[3] T.M. Pryce, I.D. Kay, S. Palladino, et al., *Diagn. Microbiol. Infect. Dis.* **2003**, 47, 487-496.
[4] S. Bretagne, J.M. Costa, *FEMS Immunol. Med. Microbiol.* **2005**, 45, 361-368.

[PP17]

An electrochemical sensor for gemfibrozil based on electrodeposited iron metal-organic framework

Miguel Tavares*, Álvaro Torrinha, Cristina Delerue-Matos, Simone Morais
REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
*maltr@isep.ipp.pt

Gemfibrozil (GEM), a lipid-lowering pharmaceutical drug commonly prescribed to reduce triglyceride and cholesterol levels, has been raising significant concern due to its widespread detection in the aquatic environment and documented toxicological effects [1]. In this work, we developed an electrochemical sensor capable of sensing GEM in environmental matrices such as environmental water and fish samples. Carbon paper (CP) was selected as transducer material due to its low-cost, easy miniaturization, and attractive electrochemical performance. An aqueous suspension of iron-based metal-organic framework (Fe-BTC), previously synthesized at room conditions instead of the traditional solvothermal processes, was used for the fast deposition of Fe-BTC MOF onto the CP surface by chronoamperometry. Scanning electron microscopy analysis confirmed the attachment of Fe-BTC to the carbon fibres, while X-ray photoelectron spectroscopy results showed the dominance of iron III ions in the core structure of the electrodeposited MOF in comparison to the mix-valence iron in the synthetized MOF powder. The voltammetric results showed a pronounce anodic GEM peak at + 1.2 V after electrochemical activation of the sensor. The optimized sensor was subsequently evaluated in complex matrices (e.g. fish and wastewater samples) to address its applicability for GEM environmental monitoring.

Funding

The authors are grateful for financial support from the project NATURIST 2022.07089.PTDC (doi: 10.54499/2022.07089.PTDC) funded by Portuguese national funds (FCT/MCTES, Fundação para a Ciência e a Tecnologia and Ministério da Ciência, Tecnologia e Ensino Superior).

Acknowledgements

This work also received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos. Miguel Tavares is grateful to FCT for his PhD grant (2022.13624.BD). Álvaro Torrinha thanks FCT for funding through the Scientific Employment Stimulus-Individual Call with ref. 2022.04357.CEECIND (https://doi.org/10.54499/2022.04357.CEECIND/CP1724/CT0015).

References

[1] M. Oliveira, L. Franco, J.C. Balasch, et al., *Ecol. Ind.* **2018**, 95, 1100-1107.

[PP18]

CYTED network - GenoPsySEn: Development of genosensors for pharmacogenomic targets in the central nervous system

Stephanie L. Morais[1,2], Michelle Castanheira[1,2], Clara Grosso[1], Miguel L. Prieto[3], Juan David Chamorro Cañon[4], Patricia G. Molina[4], Giovanny R. Pinto[5], Cristian C. Villa[6], Gloria Serra[7], Iris A. Feria-Romero[8], Ovidio Solano[9], Pilar Villaverde Souto[10], Fausto N. Comba[11], M. Fátima Barroso[1]*

[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]Departamento de Química, Faculdade de Ciências, Universidade do Porto, Porto, Portugal
[3]Universidade de Vigo, Department of Analytical and Food Chemistry, Faculty of Science, Ourense, Spain
[4]Universidad Nacional de Río Cuarto, Facultad de Ciencias Exactas, Río Cuarto, Argentina
[5]Laboratory of Genetics and Molecular Biology, Parnaiba Delta Federal University, Parnaíba, PI, Brazil
[6]Programa de Química, Facultad de Ciencias Básicas y Tecnologías, Universidad del Quindío, Quindío, Colombia
[7]Universidad de la República, Facultad de Química, Montevideo, Uruguay
[8]Unidad de Investigación Médica en Enfermedades Neurológicas, Hospital de Especialidades, Centro Médico Nacional Siglo XXI, Instituto Mexicano del Seguro Social, Ciudad de México, México
[9]Department of Neurology, Salvadorian Institute of Social Security, San Salvador, El Salvador
[10]FADEMGA, Plena Inclusion Galicia, Santiago de Compostela, Spain
[11]NOVOSENS, Cordoba, Argentina

*mfb@isep.ipp.pt

The GenoPsySEn thematic project by the CYTED network (REF. 223RT0141) involves institutions, investigators and biotech and social companies from Argentina, Brazil, Colombia, El Salvador, Mexico, Spain, Paraguay, Portugal, and Uruguay. Through mechanisms of cooperation that seek scientific and technological results, transferable to the Ibero-American Public Health Systems, this network aims to incorporate the consortium's expertise in electronics, electrochemistry, nanomaterials, pharmacogenomics, cell lines, molecular biology, and neurosciences, and develop successful genosensors devices for the detection of genetic variations that affect drug response in neuropsychiatric diseases. The GenoPsySEn project's specific goals are i) genotyping the most relevant allelic variants, such as CYP2D6 (CYP2D6*10) in the Ibero-American populations; ii) establish a pharmacogenomic database for the populations; iii) develop genosensors to quickly evaluate the gene variants at the doctor appointment; and iv) compare the results of this genotyping with those obtained by the molecular biology method. This network will also contribute to improve the social perception of mental health in the involved countries and promote the active participation of businesses in the innovation process of building sensor platforms for pharmacogenomic targets.

Funding

This work received financial support from the project "NeuroDevice: Challenging the Analytical Diagnosis of Neurodevelopmental Disorders: Pioneering Neurochemical Devices", funded by FEDER funds (COMPETE 2030) and national funds by FCT/MECI (Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação), operation no. 15875, with reference COMPETE2030-FEDER-00699000. This work also received financial support from Portuguese national funds (FCT/MECI) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos, and was partially supported by Programa Iberoamericano de Ciencia y Tecnología para el Desarrollo (CYTED) (through Red 223RT141).

Acknowledgements

MFB is grateful for the FCT Investigator: 2020.03107.CEECIND-DOI:10.54499/2020.03107.CEECIND/CP1596/CT0005. Michelle Castanheira (2023.05159.BDANA) and Stephanie Morais (2023.028929.BD) are grateful to FCT and the European Union (EU) for their grants financed by POPH-QREN-Tipologia 4.1-Formação Avançada, funded by Fundo Social Europeu (FSE) and Ministério da Ciência, Tecnologia e Ensino Superior (MCTES).

[PP19]

Carbon fibre paper sensor with and without functionalization with zeolitic-imidazole framework for detection of bisphenol A in fish sample

Vitória Dibo*, Cristina Delerue-Matos, Simone Morais, Álvaro Torrinha
REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
*vdibo@isep.ipp.pt

Given the hazardous and toxic potential effects of bisphenol A (BPA) in the aquatic ecosystems and consequently in human health, due to its endocrine-disruptive capacity [1], the European Commission has banned the addition of BPA to food packaging. Nevertheless, BPA is still being released into the aquatic environment and therefore, there is an urgent need for novel BPA monitoring approaches in the environment. This work consisted in the development of two carbon-fibre paper sensors to meet the necessity of novel and eco-friendly sensing platforms for detecting BPA in fish samples. The first approach relies on modifying the carbon fibre paper transducer with a leaf-like zeolitic imidazolate framework (CP/ZIF-L), obtained through a water-based synthesis at room temperature. The second uses a bare carbon paper, activated by cyclic voltammetry with sulfuric acid (CPP). Both sensors were thoroughly characterised by scanning electron microscopy, Fourier transform infrared spectroscopy, X-ray photoelectron spectroscopy, energy-dispersive X-ray spectroscopy, and X-ray diffraction and the electrochemical behaviours were investigated by cyclic voltammetry and differential pulse voltammetry. Using the latter method, crucial parameters responsible for the improvement of the analytical sensitivity, namely electrolyte pH, the technique parameters (step potential, modulation amplitude and time) and the analyte pre-concentration onto the sensor surface (deposition potential and time) were optimised. In the optimised conditions for each sensor, they achieved detection limits and linear range of BPA corresponding to 15 nM and 0.045 – 1 µM for CP/ZIF-L; 86 nM and 0.258 – 2 µM for CPP. These results show higher sensitivity for the ZIF-based sensor, indicating a better performance for the BPA detection. Further experiments exhibited good repeatability and reproducibility, and no significant interference for several organic and inorganic compounds tested. The analysis of fish samples at three spiking levels (0.5, 1.0 and 1.5 µM), CP/ZIF-L and CPP showed excellent accuracy. Additionally, their environmental performance/impact were further assessed through GAPI, Eco-scale, and AGREE metrics and compared with a standard chromatographic method, revealing greener profiles. Overall, the results emphasise the potential applicability of the bare and the ZIF-based CP transducer for BPA monitoring in complex matrices.

Funding

The authors are grateful for financial support from the project NATURIST 2022.07089.PTDC (doi: 10.54499/2022.07089.PTDC) funded by Portuguese national funds (FCT/MCTES, Fundação para a Ciência e a Tecnologia and Ministério da Ciência, Tecnologia e Ensino Superior).

Acknowledgements

This work also received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos. Álvaro Torrinha thanks FCT for funding through the Scientific Employment Stimulus- Individual Calls (DOI: 10.54499/2022.04357.CEECIND/CP1724/CT0015). Vitória Dibo thanks FCT/MCTES for her PhD grant (2023.04202.BD).

References

[1] J. Michałowicz, *Environ. Toxicol. Pharmacol.* **2014**, 37, 738-758.

[PP20]

Inkjet-printed paper electrode modified with a covalent organic framework for the detection of pharmaceutical pollutants

Vitória Dibo[1]*, Sunny Freitas[2], Isabel Seguro[1], João G. Pacheco[1], Cristina Delerue-Matos[1],
Luis Branco[2], Maria João Nunes[2], Álvaro Torrinha[1], Simone Morais[1]

[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]REQUIMTE/LAQV, Chemistry Department, NOVA School of Science and Technology, NOVA University of Lisbon,
2829-516 Caparica, Portugal

*vdibo@isep.ipp.pt

Covalent organic frameworks (COFs) are a new type of crystalline porous material composed only of organic monomers that bond to form a polymeric chain with promising properties and characteristics, such as precise structured shape and size porosity, high physical-chemical stability, large surface area and high organic functionalities [1]. Due to these advantageous properties, COFs are widely used as adsorbent materials to capture and remove pollutants from environmental samples. Given the excessive use of antibiotics and their incorrect disposal and/or treatment, they end up in the environment, making their screening critical. Once bioaccumulated by soil organisms or ingested by aquatic and non-aquatic animals, they can threaten human health. This work proposes an electrochemical paper-based sensor functionalised with COFs, specifically, a reticular innovative framework (RIO-55) that has promising results for adsorption/removal of ciprofloxacin (CPX) (a broad-spectrum antibiotic) from river water [2]. RIO-55 is an amine-based COF with high porosity and surface area. To overcome the poor electrical conductivity of the selected COF, single wall carbon nanotubes (SWCNT) were incorporated to improve not only the charge-transfer but also the number of electroactive sites. The composite COF-SWCNT was drop-casted onto a carbon transducer of an inkjet-printed paper electrode (IPPCE/COF-SWCNT). The constructed sensor was electrochemically characterised by cyclic voltammetry and square wave voltammetry, which confirmed a better analytical performance for the composite than IPPCE/COF or IPPCE/SWCNT. The following measures comprised optimisation steps to increase CPX signal such as electrolyte pH, operational parameters (amplitude, frequency and scan rate) and the CPX pre-concentration onto the electrode surface by applying deposition potential and time. The sensor calibration was then performed in the optimised conditions revealing adequate sensitivity to be applied as an environmental sensor for CPX.

Funding

The authors are grateful for financial support from the project NATURIST 2022.07089.PTDC (doi: 10.54499/2022.07089.PTDC) funded by Portuguese national funds (FCT/MCTES, Fundação para a Ciência e a Tecnologia and Ministério da Ciência, Tecnologia e Ensino Superior).

Acknowledgements

This work also received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos, and the project PaperSenseMIP PTDC/QUI-QAN/3899/2021 (DOI: 10.54499/PTDC/QUI-QAN/3899/2021) from FCT/MCTES. Álvaro Torrinha thanks FCT for funding through the Scientific Employment Stimulus-Individual Call (DOI: 10.54499/2022.04357.CEECIND/CP1724/CT0015). Vitória Dibo thanks FCT/MCTES for her PhD grant (2023.04202.BD). Isabel Seguro thanks FCT and ESF (European Social Fund) through POCH (Programa Operacional Capital Humano) for her PhD grant (2022.12344.BD).

References

[1] R. Paz, H. Viltres, N.K. Gupta, et al., *Chemosphere* **2023**, 342, 140145.
[2] S. Freitas, et al., *RCS Sustainability* **2025**, *Advance Article*.

[PP21]

Electrochemical detection of melatonin in biological and pharmaceutical samples

K. Bahend[1,2]*, N. K. Bakirhan[3], M. El Fazdoune[1,2], A. El Asri[4], E. A. Bazzaoui[5], M. Bazzaoui[1,2]

[1]Laboratory of Materials and Environment, Faculty of Sciences, Ibn Zohr University, Morocco
[2]Cité of Innovation Souss Massa, Agadir, Morocco
[3]Department of Analytical Chemistry, Gulhane Faculty of Pharmacy, University of Health Sciences, Ankara, Turkey
[4]Physical Chemistry and Environment Team, Ibn Zohr University, Agadir, Morocco
[5]Faculty of Sciences, Department of Chemistry, Mohammed First University, Oujda, Morocco

*khadija.bahend@edu.uiz.ac.ma

Melatonin (MT) is a crucial hormone for biological rhythms that influences sleep-wake cycles. The therapeutic value of MT in neurological disorders highlights the need for precise detection. However, challenges like low concentrations in biological samples and complex matrix interferences persist, necessitating rapid and precise analytical techniques. This study presents the novelty of designing a novel sensor that combines a molecularly imprinted polymer with polytoluidine blue O (PTBO) and multi-walled carbon nanotubes on a glassy carbon electrode for MT detection and the study of the interaction between MT and the proposed sensor using density functional theory (DFT). DFT showed that MT has a high nucleophilic character and low electrophilicity compared to TBO, which is a strong electrophile. This supports electron transfer from MT to TBO/PTBO, as indicated by the electronic chemical potentials and molecular electrostatic potentials. Scanning electron microscopy was used to see the morphology. Electrochemical measurements using differential pulse voltammetry demonstrated enhanced sensitivity and selectivity. Under optimized conditions, the sensor exhibited a linear response ranging from 1 to 1000 μM with a limit of detection and limit of quantification of 0.027 μM and 0.092 μM respectively. The performance of the sensor was evaluated in pharmaceutical tablets and human serum. Validation experiments confirmed the reliability of the sensor, with recovery rates of 97.5% for serum and 98.0% for pharmaceutical tablets, alongside low relative standard deviations indicating good precision. Interference studies showed minimal effects from coexisting substances, highlighting the selectivity of the proposed sensor. Comparative analysis with existing sensors showed superior performance [1].

References

[1] K. Bahend, N.K. Bakirhan, M. El Fazdoune, et al., *Synth. Met.* **2024**, 309, 117750.

[PP22]

New Insights into the conductivity and microstructure of EHPO and YHPO proton electrolytes

Carlos M.R. Almeida[1,2]*, Anatoly F. Selevich[3], Francisco J.A. Loureiro[1,2], Duncan P. Fagg[1,2]
[1]Department of Mechanical Engineering, TEMA - Centre for Mechanical Technology and Automation, Portugal
[2]LASI - Intelligent Systems Associate Laboratory, Portugal
[3]Research Institute for Physical Chemical Problems of the Belarusian State University, Belarus
*carlos.almeida@ua.pt

The growing interest in metal phosphate frameworks as proton-conducting materials stems from their flexible chemistries and adaptable structures [1]. This study explores two previously unreported trivalent metal phosphates, $Er_3H_5P_6O_{22}$ (EHPO) and $Y_3H_5P_6O_{22}$ (YHPO), to evaluate their viability as solid-state proton-conducting electrolytes.

Both compounds were synthesized via the thin layer technique (TLT) [2] and structurally characterized using powder X-ray diffraction (PXRD), confirming their crystallization in a tetragonal phase. Attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR) in the mid-infrared region (400–4000 cm^{-1}) was employed to identify the presence of both phosphate (PO_4^{3-}) and pyrophosphate ($P_2O_7^{4-}$) species, which are central to proton transport mechanisms. Simultaneous thermal analysis (STA) under nitrogen revealed thermal stability for both compounds up to approximately 400 °C, above which dehydration occurs.

The powders were compacted into dense pellets using the cold sintering process (CSP) at 180ºC [3], followed by morphological analysis through scanning electron microscopy (SEM). YHPO exhibited coarser grains ranging from 4 to 35 μm, whereas EHPO showed finer grains between 0.8 and 5 μm. Electrochemical impedance spectroscopy (EIS) was performed under controlled nitrogen environments with varied humidity levels (p_{H2O} = 0.033 atm and ~10^{-5} atm) to assess electrical performance.

The conductivity of both materials increased by nearly an order of magnitude under humidified conditions at ~140 °C, highlighting their water-dependent proton conduction. EHPO consistently outperformed YHPO in wet conditions, likely due to its favourable O-O distances between adjacent phosphate units, enhancing hydrogen-bonded pathways conducive to efficient proton transport.

These findings underscore the promise of EHPO and YHPO as new entrants in the field of solid-state proton conductors, with clear potential for integration into next-generation energy conversion systems.

Funding

This research was funded by Fundação para a Ciência e a Tecnologia (FCT), with the grants/projects 2020.02797.CEECIND/CP1589/CT0030 (https://doi.org/10.54499/2020.02797.CEECIND/CP1589/CT0030), 2022.09319.PTDC (https://doi.org/10.54499/2022.09319.PTDC), 2022.02498.PTDC (https://doi.org/10.54499/2022.02498.PTDC), COMPETE2030-FEDER-00770000, UIDB/00481/2020 (https://doi.org/10.54499/UIDB/00481/2020), and 2022.12057.BD (https://doi.org/10.54499/2022.12057.BD). SSR Program of Belarus 2021-2025, project Himreagent-2.1.07.2.

References

[1] R.M.P. Colodrero, P. Olivera-Pastor, A. Cabeza, et al., *Materials* **2022**, 15(4), 1292.
[2] A.F. Selevich, A.I. Lesnikovich, *Russ. J. Inorg. Chem.* **1994**, 39, 1322.
[3] B.M.G. Melo, F.J.A. Loureiro, S.M. Mikhalev, et al., *Int. J. Hydrogen Energy* **2024**, 73, 736.

[PP23]

MnO_2 - ecological electrode material for recycling and reuse

R. Boukoureshtlieva[1], P. Nedyalkova[2], G. Ivanova[3], B. Banov[1]*
[1]Institute of Electrochemistry and Energy Systems, 1113 Sofia, 1, “Acad. G. Bonchev” str., Bl.10, Bulgaria
[2]Defense Institute, 1784, Sofia, 2, bul. “Prof. Cv. Lazarov”, Bulgaria
[3]National Military University, “V. Levski”, 5000, V. Tarnovo, 76, bul. “Balgaria”, Bulgaria
*bbanov@iees.bas.bg

The lithium manganese dioxide (Li/MnO_2) electrochemical system is high energy but low power, which determines its main application - only for consumers requiring long discharge rates - over 50 or more hours. Since the system is easy to manufacture, uses cheap ecological active electrode materials (AEM), and is subject to high automation, it is of deserved interest to the industry. Unfortunately, the latter is "primary", which mainly determines its limited application. It is of great interest to transform this electrochemical system into a "secondary" reversible, or in other words – accumulator.

The aim of this study is to determine the most influencing factors as well as the limits of possible transformations of the physicochemical characteristics and determine their influence on the electrochemical behaviour of manganese dioxide reversible AEM.

Studies have been conducted, the electrochemical characteristics of standard international MnO_2 samples have been compared, and the key physicochemical parameters and their influence on the electrochemical characteristics of AEMs have been determined. Samples of reversible AEMs based on MnO_2 have been successfully synthesized, tested and their electrochemical characteristics have been determined, as reversible AEMs for environmentally friendly high-efficiency energy storage systems from renewable energy sources (RES).

Based on preliminary theoretical estimates, a reversible cathode material has been developed for application in a lithium-ion cell capable of operating reversibly at high charge/discharge rates of 4C.

After the end of its life cycle, the created AEM can be recycled 100%. A "green technology" has been successfully developed and laboratory-tested for its recycling without the formation of any waste, air or water pollution because it works in a completely closed cycle. The AEM obtained after recycling process is 100% suitable for reuse in a new lithium-ion cell, thus achieving a 100% circular economy.

Acknowledgements
The authors thank the financial support of the project National Scientific Program "Security and Defence" NNPSO funded by the Ministry of Education and Science of the Republic of Bulgaria in implementation of Council of Ministers Decision MC No. 731/21.10.21 and Agreement No. Д01-74/19.05.2022.

[PP24]

Turning tides: converting invasive water milfoil into green energy electrocatalysts

Daniela Alves, Inês S. Marques, Diana M. Fernandes*
REQUIMTE/LAQV, Dep. Chemistry and Biochemistry, Faculty of Science, University of Porto, Porto, Portugal
*diana.fernandes@fc.up.pt

The current global energy crisis, reflected in the depletion of fossil fuels and growth of environmental pollution has stimulated the development of novel renewable energy storage and conversion technologies as well as of effective and greener catalytic processes for the preparation of important molecules. Electrocatalysis plays a central role enabling several sustainable processes for future technologies. Oxygen reduction and evolution reactions (ORR and OER) are two of the crucial energy-related processes in fuel cell and electrolyser systems [1]. For this reason, regarding the real implementation of these technologies, efficient electrocatalysis of these processes is required, stimulating the quest for new, non-expensive, and highly active electrocatalysts during the last years.
Future alternatives may include biochar, a porous carbon-rich solid material produced by the thermochemical degradation of biomass. These materials have attracted increasing interest due to their tuneable physical-chemical properties, renewable feedstock, and low production cost [2].
Water milfoil (*Myriophyllum*), a poisonous and dreadful aquatic invasive weed, is also a valuable renewable and sustainable source of biomass. Their absorbent capacities depleting the water bodies of oxygen and nutrients may be advantageous for the preparation of biochar.
Herein, we prepared different nitrogen-doped supported metal electrocatalysts using melamine as nitrogen precursor [3]. Then, wet impregnation was used for metal functionalization (Co, Fe). Activation under chemical/physical experimental conditions resulted in high surface areas (some $A_{BET} > 1000$ m^2/g). The successful preparation of electrocatalysts was confirmed by XPS, XRD, Raman and SEM/EDS. The ORR and OER electrocatalytic properties were evaluated in an alkaline medium and the results showed good performance towards the reactions envisaged.

Funding
This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements
I.S.M. thanks FCT for PhD fellowship 2022.10224.BD. D.M.F. thanks FCT for funding through the Individual Call to Scientific Employment Stimulus (Ref. 2021.00771.CEECIND/CP1662/CT0007).

References

[1] R. Ramos, V.K. Abdelkader-Fernández, R. Matos, et al., *Catalysts* **2022**, 12, 207.
[2] D.M. Fernandes, P. Mathumba, A.J.S. Fernandes, et al., *Electrochim. Acta* **2019**, 319, 72.
[3] I.S. Marques, B. Jarrais, R. Ramos, et al., *Catal. Today* **2023**, 418, 114080.

[PP25]

Electrochemical characterizations of the W-dependent formate dehydrogenase FdhAB from *Desulfovibrio vulgaris* Hildenborough

Francesca Rizzo[1]*, Guilherme Martins[1], Anna Lielpetere[2], Wolfgang Schuhmann[2],
Inês A.C. Pereira[1], Felipe Conzuelo[1]

[1]Instituto de Tecnologia Química e Biológica Antonio Xavier, Universidade Nova de Lisboa, Portugal
[2]Analytical Chemistry – Center for Electrochemical Sciences (CES), Faculty of Chemistry and Biochemistry, Ruhr University Bochum, Germany

*francesca.rizzo@itqb.unl.pt

Reducing CO_2 emissions is a critical challenge in mitigating the impacts of global warming and climate change. Among emerging strategies, electrochemical CO_2 reduction using redox enzymes as catalysts offers a promising approach due to their ability to catalyse the selective and reversible conversion of CO_2. Formate dehydrogenases (FDHs) are redox enzymes capable of catalysing the two-electron interconversion between CO_2 and formate under relatively mild conditions [1]. In particular, the W-dependent FDH from *Desulfovibrio vulgaris* Hildenborough (*Dv*FdhAB) has been reported as one of the most active enzymes for CO_2 reduction [2], making it a valuable candidate for the development of biotechnological applications. Therefore, there is growing interest in conducting detailed research on the catalytic activity of *Dv*FdhAB performing electrocatalytic conversions under controlled conditions.

In this study, we present the electrochemical characterization of *Dv*FdhAB embedded in a redox polymer film [3], which ensures a mediated electron transfer configuration to enhance the electron transfer rate between the immobilized enzyme and a carbon-based electrode. The enzymatic activity is studied for both formate oxidation and CO_2 reduction, allowing the influence of reaction conditions on catalytic efficiency to be evaluated, including the pH of the electrolyte, the ionic strength, and the presence of varying substrate/product concentrations in the reaction medium. In addition, with a view to potentially optimizing the biocatalyzed conversion for sustained activity over time, the enzyme-modified electrodes are also integrated into a flow-cell reactor for their comparative investigation under stationary and forced flow conditions.

Funding

This research was funded by FCT – Fundação para a Ciência e a Tecnologia, I.P., grant number 2022.07024.PTDC; UIDB/04612/2020 and UIDP/04612/2020 (MOSTMICRO-ITQB R&D Unit); and LA/P/0087/2020 (LS4FUTURE Associated Laboratory).

References

[1] J.Y. Yang, T.A. Kerr, X.S. Wang, et al., *J. Am. Chem. Soc.* **2020**, 142, 19438.
[2] A.R. Oliveira, C. Mota, C. Mourato, et al. *ACS Catal.* **2020**, 10, 3844.
[3] A. Ruff, *Curr. Opin. Electrochem.* **2017**, 5, 66.

[PP26]

Coupling glycerol oxidation on Au-In foam anodes with gas-phase CO_2 electroreduction for continuous co-valorisation

Pieter-Jan B. Baert[1], Eli A. Annaert[1], Marti Molera[2], Guillermo Díaz-Sainz[1]*, Angel Irabien[1], Jose Solla-Gullón[3], Teresa Andreu[2], Manuel Álvarez-Guerra[1]

[1]Departamento de Ingenierías Química y Biomolecular, Universidad de Cantabria, Avda. Los Castros, 39005 Santander, Spain

[2]Department of Materials Science and Physical Chemistry, Universitat de Barcelona, Martí i Franquès, 1-11, 08028 Barcelona, Spain

[3]Instituto de Electroquímica, Universidad de Alicante, Apdo. 99, E-03080 Alicante, Spain

*diazsg@unican.es

Electrochemical conversion of CO_2 provides a versatile strategy to today's global challenges by simultaneously enabling carbon capture, renewable energy storage, and the production of value-added chemicals such as formic acid or formate [1]. Continuous gas-phase CO_2 electroreduction allows for the efficient generation of concentrated formate at the cathode [2], and its performance can be further improved by coupling it with anodic reactions that are more useful than the conventionally employed oxygen evolution reaction (OER). Among the alternatives, glycerol, a low-cost and abundant by-product of biodiesel production, is particularly attractive, as its oxidation not only yields high-value products but also lowers the anodic potential, thereby enhancing the overall energy efficiency of the electrochemical cell.

In this work, glycerol oxidation is successfully coupled with CO_2 reduction to formate using Au–In foam anodes, which have previously shown promising performance [3]. As the cathode, a 10 cm² gas diffusion electrode (GDE) is employed, spray-coated with Bi/C nanoparticles at a catalyst loading of 0.75 mg/cm². The objective of the study is to analyse both cathodic and anodic efficiencies under different operating conditions. Preliminary results indicate promising cathodic performance, with a Faradaic efficiency toward formate of 58.31 ± 1.60% under a current density of 45 mA/cm², an anolyte flow rate of 2.28 mL/cm²·min, and a cathodic CO_2 flow rate of 200 mL/min containing 2 g/h H_2O (1 atm, 65 °C). On the anodic side, Au–In foam favours selectivity toward glyceraldehyde and dihydroxyacetone (DHA), both valuable oxidation products. These findings are preliminary, and further investigation into anodic efficiency and product distribution is necessary, as controlling these processes remains a significant challenge.

Funding

The authors gratefully acknowledge support through coordinated project CO2GLY (PID2022–138491OB-C33, PID2022–138491OB-C32, PID2022–138491OB-C31) funded by MICIU/AEI/10.13039/ 501100011033 and ERDF/EU and the Complementary Plan in the area of "Energy and Renewable Hydrogen" (funded by Autonomous Community of Cantabria, Spain, and the European Union Next GenerationEU/PRTR).

References

[1] Y. Ma, R. Xu, X. Wu, et al., *Top. Curr. Chem.* **2025**, 383, 2.
[2] G. Díaz-Sainz, M. Alvarez-Guerra, B. Avila-Bolívar, et al., *Chem. Eng. J.* **2021**, 405, 126965.
[3] M. Molera, K. Fernández-Caso, M. Amazian, et al., *ChemSusChem* **2025**, 18, e202402378.

[PP27]

Sustainable amines from biomass: biochars driving electrochemical reductive amination

Inês S. Marques*, Andreia F. Peixoto, Diana M. Fernandes
REQUIMTE/LAQV, Dep. Chemistry and Biochemistry, Faculty of Science, University of Porto, Porto, Portugal
*up201608306@fc.up.pt

The chemical industry is a driving force in the transition from conventional fossil resources to renewable biomass in chemical production, in order to address the challenge of a 2030 world that is increasingly concerned with societal issues surrounding climate change [1]. Amines are nitrogen-containing chemical compounds that play an integral role in the synthesis of a diverse range of products, including agrochemicals, pharmaceuticals, and polymers. At present, the industrial production of amines from petrochemical resources relies on the use of hazardous and/or costly chemicals. The objective of this work is to advance the development of Electrochemical Reductive Amination (ERA), a clean, safe, affordable, and scalable catalytic process for the production of bioamines from renewable resources. ERA represents a substitute for traditional chemical reductive animation, whereby only protons and electrons are employed in place of molecular hydrogen derived from fossil fuels [2].

Within carbon materials, biochars obtained from biowaste feedstocks are emerging as a promising class of sustainable carbon materials with potential applications in diverse fields. Their favourable surface chemistry and porosity, coupled with the use of renewable feedstocks and low production costs, make them an attractive option for various applications [3].

In the present study, agroforestry waste or shrimp shells were subjected to pyrolysis under a range of conditions to produce porous biochars, which were then doped with nitrogen using either ball milling or wet impregnation. Furthermore, various transition metals were employed to functionalize the doped biochars. The chemical and physical experimental conditions enabled the production of biochars with high surface areas through activation. The success of all functionalization was confirmed using XPS, XRD, Raman and SEM/EDS. The XPS results demonstrated the presence of N-functionalization, while SEM revealed the formation of highly porous structures [4]. The biochars produced have the potential to enhance the effectiveness of the ERA process. The discussion will focus on the electrocatalytic results and the performance of the catalysts, with reference to the characterization results.

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos.

Acknowledgements

I.S.M. thanks FCT for PhD fellowship 2022.10224.BD. D.M.F. and A.F.P. thank FCT for funding through the Individual Call to Scientific Employment Stimulus (Ref. 2021.00771.CEECIND/CP1662/CT0007 and through the Institutional Call – Laboratórios Associados (Ref. CEECINSTLA/00029/2022), respectively.

References

[1] M.C. Gaspar, C.V.T. Mendes, S.R. Pinela, et al., *ACS Sustain. Chem. Eng.* **2019**, 7(20), 17154-17165.
[2] V. Froidevaux, C. Negrell, S. Caillol, et al., *Chem. Rev.* **2016**, 116(22), 14181-14224.
[3] R. Ramos, V.K. Abdelkader-Fernández, R. Matos, et al., *Catalysts* **2022**, 12, 207.
[4] I.S. Marques, B. Jarrais, R. Ramos, et al., *Catal. Today* **2023**, 418, 114080.

[PP28]

Impact of catalyst deposition method on PEM fuel cell performance

J. Isidro*, A.B Megias, M.A. García, J. Rodríguez, R. Campana
Centro Nacional de Experimentación en Tecnologías de Hidrógeno y Pilas de Combustible, Prolongación
Fernando el Santo s/n, 13500 Puertollano, Ciudad Real, Spain
*julia.isidro@cnh2.es

Proton Exchange Membrane Fuel Cells (PEMFCs) are clean energy devices that directly convert hydrogen into electricity, producing water and heat as the only by-products. Their high energy efficiency, compact design, and rapid dynamic response have enabled implementation in transport, stationary power, and portable systems [1]. The growing availability of renewable hydrogen further strengthens their role as a sustainable energy technology. However, challenges remain in terms of platinum group metal (PGM) costs, membrane durability, and the environmental impact of fluorinated binders, which limit large-scale adoption [2].

This work investigates the influence of catalyst deposition techniques on the performance of low-temperature PEMFCs, focusing on reducing platinum usage while maintaining efficiency. Four deposition methods were compared: automatic ultrasonic spraying, manual airbrush spraying, electrospraying, and spin coating. Catalyst ink was prepared using 40 wt% Pt/C, 5 wt% Nafion™, and ethanol, in a 50:50 Pt/C:Nafion mass ratio, and applied onto gas diffusion layers at 0.10 mgPt/cm^2 (cathode) and 0.05 mgPt·cm^2 (anode), with Nafion® 211 membranes used for MEA fabrication. Electrochemical characterization included a 20-h activation protocol, polarization curves for power density evaluation, and electrochemical impedance spectroscopy (EIS). Post-mortem scanning electron microscopy (SEM) assessed catalyst distribution, surface morphology, and layer thickness. Results demonstrate that spraying techniques, both automatic and manual, provide superior electrochemical performance, more uniform catalyst distribution, and improved layer integrity compared to spin coating. Differences between spraying methods were minor, yet both significantly outperformed spin coating in efficiency and deposition quality. These findings support prioritizing spraying techniques for MEA fabrication. Future work should optimize electrospraying, explore PGM-free catalysts, and replace fluorinated membranes to improve sustainability, cost-effectiveness, and compliance with environmental regulations.

Funding

This work was carried out within the Renewable Energy and Hydrogen Program, included in the Complementary R&D&I Plans of the MICIN, and funded by the European Union NextGenerationEU within the framework of Component 17 of the Recovery, Transformation and Resilience Plan (C17.I01.P01), and as part of the E3Tech-Plus Network funded by the Ministry of Science and Innovation (Government of Spain).

Acknowledgements

"Programa primera Experiencia Profesional", grant number 2022-C23.I01.P02.S0020-0000295, funded by the MICIN and "Programa INVESTIGO", grant number PINVE-13-0011/2024 funded by the European Union.

References

[1] E.M. Khetabi, K. Bouziane, X. François, et al., *Int. J. Hydrogen Energy* **2024**, 56, 1257-1272.
[2] H. Kahraman, Y. Akın, *Energy Convers. Manag.* **2024**, 304, 118244.

[PP29]

Towards integrated carbon valorisation: advanced oxidation and CO_2 electroreduction with reticulated electrodes

Sandra Maldonado[1,2]*, Gabriela Roa-Morales[1], Reyna Natividad[1], Manuel A. Rodrigo-Rodrigo[2]
[1]Joint Research Centre in Sustainable Chemistry (CCIQS) UAEM-UNAM, highway Km. 14.5, Unit San Cayetano, Toluca - Atlacomulco, 50200 Toluca de Lerdo, Mexico
[2]Department of Chemical Engineering, University of Castilla-La Mancha, Ciudad Real, Spain
*sandramaria.maldonado@alu.uclm.es

The increasing concentration of atmospheric CO_2, mainly from fossil fuel combustion, has accelerated the search for technologies that simultaneously mitigate emissions and generate value-added products. Electrochemical CO_2 reduction (CO_2RR) represents a promising approach, as the selectivity and efficiency strongly depend on the electrocatalyst employed.

This work investigates copper reticulated foams modified with Sn, Ag, Pb, Sn/Ag, and Sn/Pb, aiming to optimize the production of alternative fuels, with a particular focus on methanol. Experiments were carried out in an H-type electrochemical cell using both 0.1 M $KHCO_3$ and confectionery wastewater as electrolytes. Product distribution was analysed by HPLC and GC.

Among the different electrode modifications, Ag-decorated Cu foams showed the highest activity and selectivity toward methanol, achieving concentrations between 4 and 8 mM. The superior performance of Ag is attributed to its weak binding energy, which favours C1 product formation over formate, while also enhancing the stability of the electrocatalyst during operation. Comparisons with Sn- and Pb-modified foams confirmed lower methanol selectivity, although some synergistic effects were observed in bimetallic systems.

These results demonstrate the potential of Ag-modified Cu foams as efficient electrocatalysts for methanol production from CO_2RR under ambient conditions. This strategy not only reduces CO_2 emissions but also enables the valorisation of waste streams, contributing to sustainability, decarbonization, and the development of circular economy models.

Funding

To CONACHyT for funding the research project scholarship number 841940. Citlalit Martinez Soto technical support and MSc Melina Tapia Tapia for mycoscopy tests.

References

[1] S. Zhao, S. Li, T. Guo, et al., *Nano-Micro Lett.* **2019**, 11(1), 62.
[2] S. Bhardwaj, A. Biswas, M. Das, et al., *Sustain. Energy Fuels* **2021**, 5(9), 2393–2414.
[3] P. Wang, H. Yang, C. Tang, et al., *Nat. Commun.* **2022**, 13(1), 3754.

[PP30]

Impact of carbon-based conductive additives on the electrochemical performance of Mo-doped Prussian blue cathodes for sodium-ion batteries

Beata Kurc[1]*, Ewelina Rudnicka[1], Karol Rytel[2], Damian Burzyński[3], Kamil Kędzierski[2], Stanisław Mikulski[3], Leszek Kasprzyk[3]

[1]Faculty of Chemical Technology, Poznan University of Technology, Poland
[2]Faculty of Materials Engineering and Technical Physics, Poznan University of Technology, Poland
[3]Faculty of Control, Robotics and Electrical Engineering, Poznan University of Technology, Poland

*beata.kurc@put.poznan.pl

Prussian Blue analogues (PBAs) are gaining attention as cathode materials for sodium-ion batteries, owing to their open framework and ability to reversibly intercalate sodium ions. Introducing transition metals such as molybdenum into the PBA structure can enhance its electrochemical activity, electrical conductivity, and structural durability [1].

In this work, a new molybdenum-doped Prussian Blue analogue with the composition $Na_xMo_yFe_z[Fe(CN)_6]\cdot nH_2O$ (Mo-PBA) was synthesized and investigated as a cathode material for Na-ion batteries. X-ray diffraction confirmed the formation of a pure cubic structure typical for PBAs, with key diffraction peaks corresponding to planes such as (200), (220), and (400). The refined lattice parameter of approximately 9.92 Å indicated successful molybdenum incorporation without compromising structural integrity.

The electrochemical behaviour of the Mo-PB cathode was assessed using a 1 M $NaClO_4$ solution in a 1:1 mixture of ethylene carbonate and dimethyl carbonate as the electrolyte. Various conductive additives—carbon black (CB), graphene nanoplatelets (GNP), graphene powder (GP), and multi-walled carbon nanotubes (MWCNT)—were tested in the composite electrode to evaluate their impact on performance. Metallic sodium served as both the counter and reference electrode in Swagelok-type cells assembled under ambient conditions.

Charge capacity tests conducted at a current density of 10 mA/g revealed strong dependence on the type of conductive additive: GP and MWCNT-based electrodes delivered the highest initial specific capacities of 215 and 165 mAh/g, respectively. In contrast, electrodes with CB and GNP showed significantly lower capacities, which is likely due to insufficient contact between the active material and conductive network. The superior performance of GP was attributed to its large flake size, offering better electrical connectivity, while MWCNTs provided a 3D conductive framework facilitating both electron and ion transport. The lower performance of GNPs was associated with their tendency to agglomerate, reducing effective conductivity.

These results underscore the critical role of conductive additive morphology in optimizing electrode architecture and performance. Two- and three-dimensional carbon structures, such as GP and MWCNTs, significantly enhance charge transport and accessibility in Prussian Blue-based cathodes for sodium-ion batteries.

Funding

This research was funded by the Ministry of Science and Higher Education, grant number 0212/SIGR/2401.

References

[1] M. Palacios-Corella, I. Echevarria, C.S. Santos, et al., *Chem. Mater.* **2025,** 37, 4203.

[PP31]

Investigation of metal sulphide-based anodes and graphene effects in sodium-ion batteries

Jakub Tomasz, Ewelina Rudnicka*, Beata Kurc, Xymena Gross
Faculty of Chemical Technology, Poznan University of Technology, Poland
*ewelina.rudnicka@put.poznan.pl

Lithium-ion cells, which are common in many daily-used electronic devices, face rising costs, prompting interest in sodium-ion cells. Na-ion technology offers similar energy storage, faster charging and improved high-temperature safety. These phenomena make this technology a promising alternative for energy storage systems [1].

Two anode materials were analysed: molybdenum and manganese sulphide. The effect of graphene on the electrochemical properties of the analysed systems was investigated as well. Carob gum powder was used as a binder, and the electrolyte consisted of 0.5 M $NaClO_4$ in EC:DMC (1:1 wt.%). Electrochemical tests were performed using cycling voltammetry in the range of 0.005–2.5 V, galvanostatic charge/discharge tests at current values of 10, 50, and 100 mA/g, and electrochemical impedance spectroscopy. For the molybdenum-sulphide anode the galvanostatic charge/discharge tests at a current of 10, 50 and 100 mA/g indicate a gravimetric capacity of 885, 783 and 518 mAh/g for the first cycle of sodium ion insertion into the anode material. After approximately 10 cycles, these values dropped to 158, 127 and 120 mAh/g. The addition of graphene resulted in a decrease in the differences between the capacitance values across successive cycles. For the graphene-modified anode, at current value of 10 mA/g the capacitance values for the first and tenth cycles are 763 and 190. Additionally, the graphene modification contributed to the stabilization of the Coulombic efficiency of the analysed systems (Fig.1). The obtained results demonstrate the high gravimetric capacity of the electrode materials used as the anode in sodium-ion cells. While the systems operate cyclically, achieving complete reversibility of the reactions remains a challenge. Results from impedance spectroscopy show similarities to Li-ion cells. The materials analysed in this study present a promising alternative for use as electrodes in electrical energy storage systems.

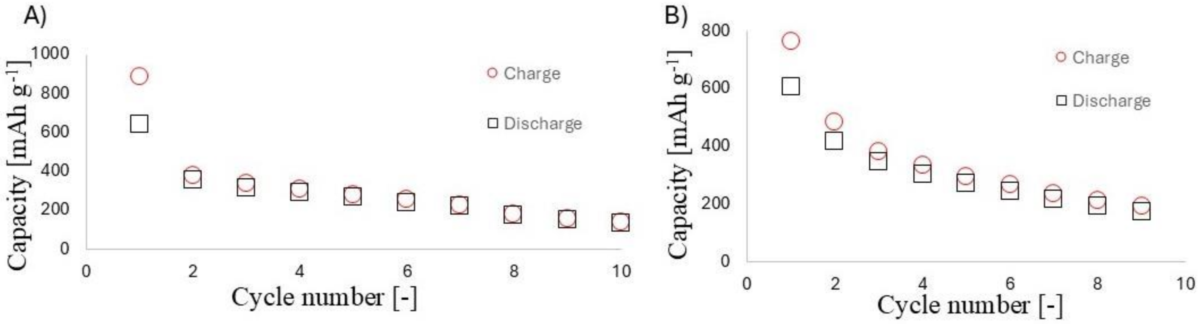


Figure 1. Capacity values of A) molybdenum-sulphide cell; B) graphene-modified molybdenum-sulphide cell. Current: 10 mA/g.

Funding
This research was funded by the Ministry of Science and Higher Education, grant number 0911/SBAD/2502.

References
[1] I. Hasa, J. Hassoun, S. Passerini, *Nano Res.* **2017**,10, 3942.

[PP32]

Influence of proton-donor and proton-acceptor additives on the electrochemical characteristics of a vanadium redox flow battery

B. Mladenova*, M. Matrakova, T. Stankulov, L. Soserov, R. Boukoureshtlieva, P. Nikolov

Institute of Electrochemistry and Energy Systems, Bulgarian Academy of Sciences, Acad. G. Bonchev Str.,10,
1113 Sofia, Bulgaria

*borislava.mladenova@iees.bas.bg

Vanadium flow batteries (VRFB) are attracting increasing attention in scientific and industrial communities due to their ability to provide reliable and scalable energy storage from renewable sources. They are characterized by high power and energy density, long service life, exceptional resistance to charge–discharge cycling, and a high degree of safety. The electrolyte in these batteries can be recycled, making them sustainable and environmentally effective solutions for large-scale energy systems.

This work presents a study of various proton-donor and proton-acceptor substances based on 2-pyrrolidone as additives to the vanadium electrolyte to improve the electrical performance of a vanadium-redox flow battery (VRFB). First, the effects of the additives were monitored in a three-electrode cell with vanadium electrolyte, using graphite electrodes and a Hg/$HgSO_4$ reference electrode. The goal was to track the influence of each additive on the electrochemical activity of the system. Additionally, tests were performed in a small laboratory-scale flow battery, where the electrical behaviour of the system, including changes in the oxidation states of the vanadium electrolyte, was analysed. The results obtained show that selected proton-donor and proton acceptor substances demonstrate a beneficial effect on the electrochemistry and overall performance of the VRFB.

Funding

This research was carried out with the financial support of the National Recovery and Resilience Plan of the Republic of Bulgaria, co-funded by the European Union, under project No. BG-RRP-2.011-0048, titled “Improved Electrolyte for Vanadium Flow Batteries”.

[PP33]

Visualization of O_2 bubble evolution in PEM electrolysis cells: an experimental and simulation study

Bruna G. Pedro[1]*, Cristina M. Cordas[2], Rui P.P.L. Ribeiro[2], Kostadin V. Petrov[1]

[1]Hylab – Green Hydrogen Collaborative Laboratory, Portugal
[2]NOVA School of Science and Technology, Portugal

*bruna.pedro@hylab.pt

Gas bubbles naturally generated in electrolysers reduce efficiency by blocking active electrode areas, increasing resistance, and hindering charge transfer. Their accumulation forms gaseous layers that isolate electrodes and slow electrochemical reactions, making bubble removal essential for performance and durability.

This work combines Optical Coherence Tomography (OCT) and COMSOL Multiphysics simulations to investigate O_2 bubble evolution in Proton Exchange Membrane (PEM) cells during water electrolysis. OCT enables real-time visualization of nucleation, growth, and detachment at the electrode/membrane interface, while simulation results provide complementary insights and allow the use of OCT data as boundary conditions in Computational Fluid Dynamics (CFD) models.

We applied this approach to a 3D-printed PEM reference cell for green hydrogen production. Results show strong agreement between OCT observations and COMSOL simulations, validating the methodology. Despite some image quality limitations due to resin impurities, the combined experimental–numerical framework enabled the analysis of bubble dynamics and multiphase flow inside the cell.

The integration of OCT with CFD simulations offers a deeper understanding of structural and flow effects, guiding electrolyser design improvements and supporting efficiency optimization.

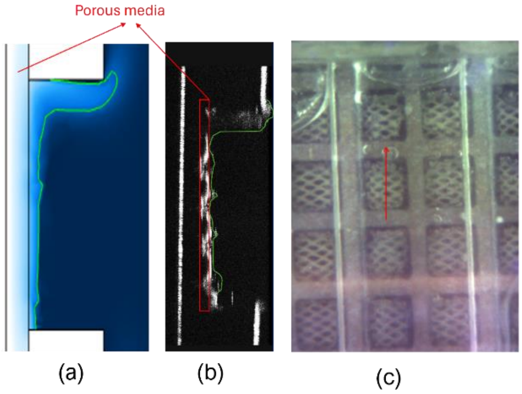


Figure 1. Comparison of OCT and COMSOL results: The phase volume fraction from simulation (a) agrees with the OCT B-scan (b). The experimental setup with scan direction is shown in (c).

Funding

This research was funded by the call RE-C05-i02 – Missão Interface N.º 01/C05-i02/2022 of the Portuguese Recovery and Resilience Plan, and the Base Funding Project of Collaborative Laboratory, managed by ANI – Agência Nacional de Inovação.

References

[1] X. Lu, C. Zhou, R.S: Delima, et al., *Nat. Chem.* **2024**, 16, 979–987.

[PP34]

Synergistic effects of vanadium and cobalt Co-doping in Prussian blue analogues for high-performance sodium-ion batteries

Ewelina Rudnicka*, Manuela Skowron, Maciej Galiński
Faculty of Chemical Technology, Poznan University of Technology, Poland
*ewelina.rudnicka@put.poznan.pl

The rapid growth of the lithium-ion battery market, driven by electromobility and stationary energy storage, raises concerns over the long-term sustainability of lithium resources, which are limited and unevenly distributed. In this context, sodium-ion batteries (Na-ion) have attracted increasing attention as a cost-effective and sustainable alternative, owing to sodium's abundance and similar electrochemical behaviour to lithium. Nevertheless, the commercialization of Na-ion technology remains hindered by the lack of cathode materials that combine high capacity, long-term stability, and facile synthesis [1,2].

Prussian Blue analogues (PBAs) are among the most promising candidates due to their open-framework structure, fast Na^+ transport, high structural stability, and compositional flexibility. To further enhance their performance, doping strategies with transition metals have been widely explored. In this study, we report the successful synthesis of a vanadium and cobalt co-doped Prussian Blue analogue (PB-VCo) using a simple co-precipitation method. Structural analysis (SEM, EDS, and XRD) confirmed the formation of a crystalline PBA lattice with homogeneous V and Co incorporation, accompanied by slight lattice distortions that indicate successful substitution within the framework.

Electrochemical testing revealed that PB-VCo exhibits significantly enhanced performance compared to pristine Prussian Blue (PB) and undoped Prussian Blue analogues (PBA). Cyclic voltammetry showed well-defined and stable redox peaks over multiple cycles, while charge–discharge studies demonstrated improved specific capacity, stable voltage plateaus, and superior capacity retention. Notably, PB-VCo displayed higher initial capacity and improved long-term cycling stability, attributed to the synergistic effects of V and Co co-doping, which enhance electronic conductivity, structural robustness, and ion diffusion pathways.

Overall, these results highlight PB-VCo as a promising cathode material for next-generation sodium-ion batteries. The findings contribute to the ongoing search for sustainable and scalable energy storage technologies, positioning co-doped PBAs as efficient, durable, and economically viable alternatives to conventional cathode materials.

Funding

This research was funded by the Ministry of Science and Higher Education, grant number 0911/SBAD/2502.

References

[1] M. Pasta, C.D. Wessells, N. Liu, et al., *J. Phys. Chem. C* **2015,**119, 5770.
[2] Y. Song, W. Zhang, R. Wang, et al., *SSRN Electronic J.* **2024.**

[PP35]

Development and integration of metallic interconnectors for reversible solid oxide cells

A. Moratalla[1]*, M.R. Serrano de la Cruz[1], I. Ayuso[1], A. Pardo[1], N. Díaz[1], J. Broceño[1], C. Berges[2], G. Herranz[2], C. Montes[1], R. Campana[1]

[1]Hydrogen National Centre (CNH2), Puertollano, Spain
[2]UCLM-ETSII, Ciudad Real, Spain
*angela.moratalla@cnh2.es

Solid oxide cells (SOCs), operating either as fuel cells (SOFCs) or as electrolysis cells (SOECs), represent a strategic technology for the energy transition, enabling efficient and reversible conversion between chemical and electrical energy. Their high thermodynamic efficiency, fuel flexibility (including hydrogen, biomass-derived gases and CO_2 electrolysis), and potential for integration into energy storage systems, make them ideal candidates for stationary and industrial applications [1]. However, large-scale deployment faces significant technical challenges, including material degradation under redox conditions, high operating temperatures (700–900 °C), and the complex integration of ceramic and metallic components into modular stack configurations. In particular, a critical bottleneck in SOC stack design lies in the incorporation of metallic interconnectors that must ensure proper gas distribution, transverse electrical conduction, thermal compatibility with ceramic layers, and corrosion resistance in both oxidizing and reducing atmospheres. Moreover, conventional manufacturing methods such as machining or stamping impose limitations in terms of geometry, cost, and reproducibility [1].

In this context, the objective of this work is to study metal injection molding (MIM) as an alternative method for fabricating metallic interconnectors and assess their functional integration into SOCs. To this end, interconnectors were produced using Crofer30 and Master alloys, selected for their low electrical resistivity, chemical stability, and thermal expansion coefficients compatible with ceramic materials such as yttria-stabilized zirconia (YSZ) and nickel supports. These interconnectors were then evaluated in SOCs constructed with two types of supports, one based on YSZ ceramics and the other on nickel, both fabricated via tape casting and pressing. Subsequently, functional layers were deposited by semiautomated ultrasonic airbrushing. On the YSZ support, a gadolinium-doped ceria (GDC) barrier layer was applied, followed by a nickel hydrogen electrode and a lanthanum strontium manganite (LSM) oxygen electrode, while the nickel support received sequential layers of YSZ, GDC, and LSM. After deposition and sintering, the cells were assembled into an experimental system incorporating manufactured interconnectors, ceramic sealants, electrical contacts, terminal plates, and gas feed lines, enabling electrochemical evaluation through polarization curves, electrochemical impedance spectroscopy (EIS), and constant-current operation under controlled conditions. Preliminary results indicate good densification of the interconnectors, low gas permeability, structural stability during thermal cycling, and consistent reversible performance in both SOFC and SOEC operation.

Funding

This work has been developed as part of Energy and Renewable Hydrogen Program of the Complementary R&D&I Plans of the Ministry of Science and Innovation, funded by the European Union NextGenerationEU within the Framework of Component 17 of the Recovery, Transformation and Resilience Plan (ref C17.I01.P01) and as part of PID2020-115935RA-C44 and PID2024-162053OB-C31 funded by Ministerio de Ciencia e Innovación (Gobierno de España), and Agencia Estatal de Investigación (AEI) and SBPLY/24/180225/000095 and SBPLY/21/180501/000255 (Junta de Comunidades de Castilla-La Mancha).

References

[1] C. Berges, J. Hidalgo, R. Andújar, et al., *Results Eng.* **2021**, 11, 100268.

[PP36]

Symmetric SOECs for efficient H_2O/CO_2 co-electrolysis

M. Rosario Serrano de la Cruz[1]* A. Moratalla[1], A. Pardo[1], I. Ayuso[1], N. Díaz[1], A. Iranzo[2],
F.J García-García[2], C. Montes[1], R. Campana[1]
[1]Hydrogen National Centre (CNH2), Puertollano, Spain
[2]Departamento de Ingeniería y Ciencia de los Materiales y del Transporte, Universidad de Sevilla, Spain
*rosario.serrano@cnh2.es

Green hydrogen is positioned as a strategic energy vector for the decarbonization of the industrial and energy sectors. For its production, solid oxide electrolysis cells (SOECs) can achieve efficiencies above 80% due to high-temperature operation, which reduces electrode overpotentials and allows direct integration with renewable energy or waste heat sources. In addition, co-electrolysis of H_2O and CO_2 in SOEC also provides a direct route for the production of synthesis gas, enabling the synthesis of fuels and value-added chemicals. However, their large-scale use is limited by material degradation, delamination, and the complexity of combining different anode and cathode compositions. In this context, symmetric solid oxide cells emerge as a promising alternative, as they simplify processing and mitigate chemical and mechanical incompatibility at interfaces. In this regard, mixed perovskite materials, such as PBMO ($PrBaMn_2O_5+\delta$), LSF ($La_{1-x}Sr_xFeO_3-\delta$), LSCM ($La_{0.75}Sr_{0.25}Cr_{0.5}Mn_{0.5}O_3-\delta$), and LSCF ($La_{1-x}Sr_xFe_{1-Y}Co_YO_3-\delta$) have been investigated due to their high ionic and electronic conductivity, redox tolerance, and catalytic activity for H_2O and CO_2 redox reactions. Particularly, PBMO exhibits near-complete reversibility between its reduced and oxidized phases under oxygen partial pressure cycles, maintaining thermal and chemical stability even at high temperatures [1]. LSCM and LSCF offer excellent chemical stability, fast oxygen-ion transport, and high activity for CO_2 electrolysis under SOEC conditions [2]. However, further studies are needed to enhance the stability and efficiency of these materials supported in cells.

With this background, mixed perovskites such as PBMO ($PrBaMn_2O_5+\delta$), LSCM ($La_{0.75}Sr_{0.25}Cr_{0.5}Mn_{0.5}O_3-\delta$), and LSCF ($La_{1-x}Sr_xFe_{1-Y}Co_YO_3-\delta$) were synthesized and systematically compared in this work. PBMO was prepared via direct mechanochemical milling, while LSCM and LSCF were obtained using different techniques including mechanosynthesis, electrospinning, and solution combustion. The synthesized powders were first characterized to determine their phase composition, microstructure, and surface area using X-ray diffraction (XRD), scanning electron microscopy (SEM), and BET analysis. Afterwards, the powders were deposited as electrodes in symmetrical flat cells supported by yttria-stabilized zirconia (YSZ), incorporating a gadolinium-doped ceria (GDC) barrier layer on both sides to prevent chemical interaction. The electrochemical performance of the cells was evaluated under electrolysis and co-electrolysis conditions. Reversibility and redox switching were assessed by alternating electrode polarity and gas composition. Finally, post-mortem SEM characterization was conducted to correlate microstructural changes with the electrochemical behaviour of each material.

Funding

This work has been developed as part of Energy and Renewable Hydrogen Program of the Complementary R&D&I Plans of the Ministry of Science and Innovation, funded by the European Union NextGenerationEU within the Framework of Component 17 of the Recovery, Transformation and Resilience Plan (ref C17.I01.P01) and as part of PID2020-115935RA-C44 and PID2024-162053OB-C31 funded by Ministerio de Ciencia e Innovación (Gobierno de España), and Agencia Estatal de Investigación (AEI) and SBPLY/24/180225/000095 (Junta de Comunidades de Castilla-La Mancha).

References

[1] F.J. Garcia-Garcia, M.J. Sayagués, F.J. Gotor, et al., *Nanomaterials* **2021**, 11(2), 380.
[2] M. Wang, J. Wang, J. Du, *J. Power Sources* **2024**, 610, 234742.

[PP37]

Evaluation of cobalt ion release from metal alloys and strategies to minimize its toxicity in biomedical applications

Victor Lobo[1]*, Esmeraldo Salote[1], Ana Ribeiro[1], Artur Valente[1], Sonia Fangaia[1,2]
[1]CQC-IMS, Departamento de Química, Universidade de Coimbra, 3004-535 Coimbra, Portugal
[2]Faculdade de Medicina, CIROS, Instituto de Implantologia e Prótese Dentária, Universidade de Coimbra, Av. Bissaya Barreto, Blocos de Celas, 3000-075 Coimbra, Portugal
*vlobo@ci.uc.pt

Cobalt and chromium are constituents of metal alloys for biomedical use, including dental prostheses (Fig.1). The typical composition of Co-Cr alloys is approximately 60% by mass of cobalt and 30% of chromium, and may also include smaller percentages of other elements such as molybdenum, aluminium, manganese and silicon. Thus, the release of these ions in the human body can lead to harmful biological effects. The interaction of metal ions with carbohydrates might have information on the role of mouthwashes in preventing these effects. In our work we are mainly focused on the release of cobalt ions from metal alloys. Thus, after immersion of dental alloys in different physiological media, the samples were analysed for mass variation. The evaluation of cobalt ion release from metal alloys was made by using ICP-OES and electrical conductivity techniques. The interaction between Co^{2+} and the carbohydrate β-cyclodextrin (β-CD) has been studied in aqueous solutions (pH approximate 6.0), 298.15 K, using multinuclear NMR spectroscopy and coupled with measurements of diffusion coefficients. The transport properties of cobalt ion solutions are markedly influenced by the presence of β-CD. Data from NMR spectroscopy show that these effects are due to interactions between this carbohydrate macrocycle and cobalt due to formation of 1:1 (β-CD: Co^{2+}) complexes. The formation of such 1:1 complex is also supported by diffusion measurements. The significant decrease in the diffusion coefficient of $CoCl_2$ solutions in the presence of β-CD leads us to assume the presence of supramolecular complexes between these species. From the analysis of these data, it was possible to calculate the 1:1 complexation constant, resulting in the value $K = 30\ M^{-1}$.

This work will contribute to unveiling the mechanisms responsible for transport by diffusion in aqueous solutions, and, therefore, mitigating the potential toxicity inherent to those metal ions.

Figure 1. Example of a dental prosthesis made with a Co-Cr metal alloy [1].

Funding

This research was funded by Coimbra Chemistry Centre (CQC-IMS), supported by Fundação para a Ciência e a Tecnologia (FCT, Portugal) through the programs UIDB/00313/2025 and UIDP/00313/2025.

Acknowledgements

E. Salote acknowledges the support given by the Angolan government.

References

[1] A. Vaicelyte, C. Janssen, M. Le Borgne, et al., *Crystals* **2020,** 10(12), 1151.

[PP38]

Microbial electrolysis cell electrochemical response to increasing ethanol concentration

Ana Baía[1]*, Alonso I. Arroyo-Escoto[2,3,4], Maria C. Fernandes[2,3], Annabel Fernandes[1]

[1]FibEnTech-UBI, Department of Chemistry, Universidade da Beira Interior, 6201-001 Covilhã, Portugal
[2]Alentejo Biotechnology Center for Agriculture and Agro-Food (CEBAL), Polytechnical Institute of Beja (IPBeja), Apartado 6158, 7801-908 Beja, Portugal
[3]MED – Mediterranean Institute for Agriculture, Environment and Development & CHANGE – Global Change and Sustainability Institute, CEBAL, 7801-908 Beja, Portugal
[4]Department of Environmental Engineering, Technical University of Denmark (DTU), Bygningstorvet, 115, 214, 2800 Kgs. Lyngby, Denmark

*ana.isabel.mota.baia@ubi.pt

Microbial electrolysis cells (MECs) are bioelectrochemical systems that use electroactive microorganisms to oxidize organic compounds, generating electrons that are transferred to an anode. With the application of a small external voltage, these electrons move towards the cathode, driving reduction reactions that produce valuable compounds such as hydrogen gas. Electrochemical impedance spectroscopy (EIS) plays a fundamental role in advancing bioelectrochemical systems through its ability to analyse and quantify essential electrochemical processes. This technique enables the characterization of charge transfer resistance, double-layer capacitance, and mass transport phenomena, which are critical for understanding the dynamics at the biofilm electrode interface. In this study, EIS was used to provide mechanistic insights into charge transfer and biofilm development in a dual-chamber MEC system operating with an anaerobic microbial consortium for winery wastewater degradation and subjected to increasing ethanol concentration. The obtained results showed significant changes in charge transfer resistance and diffusive elements with the increase of ethanol concentration, suggesting changes in biofilm performance. The data suggest that increased ethanol exposure induces morphological and electrochemical changes in the biofilm, reducing the rate of hydrogen production. The integration of advanced equivalent circuit models, such as multiple constant phase elements and Warburg diffusion components, has proven essential for accurately capturing the complex phenomena associated with biofilm and extracellular polymeric substances.

Funding

This research was funded by Fundação para a Ciência e a Tecnologia (FCT), R&D Units FibEnTech-UBI (https://doi.org/10.54499/UIDB/00195/2020), CHANGE (https://doi.org/10.54499/LA/P/0121/2020), and MED (https://doi.org/10.54499/UIDB/05183/2020, https://doi.org/10.54499/UIDP/05183/2020); project 2022.02566.PTDC–Wine4H2 (https://doi.org/10.54499/2022.02566.PTDC); PhD grants 2022.11077.BD (A. Baía) and UI/BD/153579/2022 (A.I. Arroyo-Escoto); research contract awarded to A. Fernandes under the scope of the CEEC Institutional 2021 (https://doi.org/10.54499/CEECINST/00016/2021/CP2828/CT0006).

Acknowledgements

The authors wish to praise the guidance and helpful collaboration of Prof. Ana Lopes, who recently passed away, in this research work and, simultaneously, pay tribute to her for her dedication to the FibEnTech-UBI and Wine4H2 project. A. Baía and A. Fernandes acknowledge the support granted by the Research Unit of Fiber Materials and Environmental Technologies (FibEnTech-UBI), through the Project reference UIDB/00195/2020, funded by FCT, IP/MCTES through national funds (PIDDAC). M.C. Fernandes thanks Project "BioAlenTec - Transfer of Knowledge and Technology for a Sustainable, Circular and Resilient Bioeconomy in Alentejo (ALT2030-FEDER-01951700)" co-financed by the Regional Programme ALENTEJO2030 through the ERDF - European Regional Development Fund.

References

[1] A. Baía, A.I. Arroyo-Escoto, N. Ramos, et al., *Energies* **2025**, 18, 3043.

[PP39]

Electrochemical oxidation of textile effluents: towards cleaner processes and water reuse

Milena B. Espinosa[1], Bárbara Saraiva[1], Davide Vione[2], Annabel Fernandes[1]*

[1]Fiber Materials and Environmental Technologies (FibEnTech-UBI), Department of Chemistry, Universidade da Beira Interior, Covilhã, Portugal
[2]Dipartimento di Chimica, Università di Torino, Torino, Italy

* annabelf@ubi.pt

Textile dyeing processes generate effluents with high organic load and recalcitrant compounds, representing a critical environmental challenge for water treatment and reuse. This study investigates the efficiency of electrochemical oxidation for the degradation of organic matter in real dyeing effluents. The effluent was subjected to electrochemical treatment using three anodic materials: boron-doped diamond (BDD), Ti/RuO_2-TiO_2, and Ti/IrO_2-RuO_2, under varying current intensities and electrolyte concentrations. Results demonstrated that BDD consistently exhibited the highest current efficiency, achieving up to 89% COD removal. Particularly, operation at low applied currents provided the most favourable balance between efficiency and energy demand (16 kWh/kg COD). Among the mixed metal oxide electrodes, Ti/IrO_2-RuO_2 outperformed Ti/RuO_2-TiO_2, especially under extended operation, reaching 73% COD removal. Additional experiments with auxiliary dyeing agents and dye solutions revealed that certain additives displayed high resistance to mineralization, even under BDD treatment. The reuse of treated wastewater in subsequent dyeing processes proved effective, showing no notable deviations in colorimetric values or fastness when compared to dyeings carried out with fresh water. These results highlight the potential of electrochemical oxidation, particularly with BDD anodes, for organic load reduction in textile effluents, supporting the feasibility of effluent reuse in new dyeing baths and aligning with industrial water reuse practices.

Acknowledgements

This research was funded by the Lusitano project 01/C05-i09/2024.PC644933224-00000043, financed by the Recovery and Resilience Plan. The authors are very grateful for the support granted by the Research Unit of Fiber Materials and Environmental Technologies (FibEnTech-UBI), through the Project reference UIDB/00195/2020, funded by the Fundação para a Ciência e a Tecnologia (FCT), IP/MCTES through national funds (PIDDAC), and DOI: 10.54499/UIDB/00195/2020 (https://doi.org/10.54499/UIDB/00195/2020). Annabel Fernandes acknowledges FCT and the University of Beira Interior for the research contract CEECINST/00016/2021/CP2828/CT0006 under the scope of the CEEC Institutional 2021, funded by FCT (https://doi.org/10.54499/CEECINST/00016/2021/CP2828/CT0006). Milena B. Espinosa acknowledges FCT for the PhD grant PRT/BD/154710/2023 (https://doi.org/10.54499/PRT/BD/154710/2023).

[PP40]

Design and evaluation of waste-derived biochar for the treatment of polluted water

Antón Puga*, Manuela Moreira, Cristina Soares, Cristina Delerue-Matos
REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
*anton@isep.ipp.pt

The conversion of agricultural residues into advanced water treatment materials represents a promising route toward sustainable and circular solutions. In this work, waste from basil (*Ocimum basilicum*) processing was valorised into a carbon-rich biochar, designed to function as a catalyst support for the degradation of pirimicarb - a widely applied carbamate pesticide frequently detected in surface waters and municipal wastewater effluents [1]. The treatment approach relied on the electro-Fenton (EF) process, first optimized in batch mode and later scaled to continuous flow conditions simulating a municipal wastewater treatment plant (WWTP).

In this study, different amounts of biochar were evaluated as a catalytic support in the EF reaction, comparing the results with degradation experiments conducted without biochar to confirm its catalytic effect. Once the optimal process parameters were established, several continuous-flow experiments were carried out at different flow rates to approximate operation under conditions more representative of a real water treatment system. The results were very promising, achieving nearly complete pesticide removal (98%) in batch experiments and approximately 70% removal in continuous-flow trials.

Therefore, this work highlights the potential of repurposing basil agro-industrial residues as sustainable catalyst supports for EF-based degradation of persistent organic micropollutants, such as pesticides. Demonstrating efficient operation under WWTP-relevant continuous conditions, the approach supports decentralized or tertiary treatment applications [2]. Overall, the process aligns with the principles of green chemistry and advances circular economy strategies in wastewater management [3].

Funding

This work also received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos, and EXPL/BII-BIO/0436/2021 financed by FCT/Ministério da Ciência, Tecnologia e Ensino Superior (MCTES). The authors are also grateful to the project BioReset (BiodivRestore-406 / DivRestore/0002/2020, DOI: 10.54499/DivRestore/0002/2020) funded through the 2020-2021 Biodiversa+ and Water JPI joint call for research projects, under the BiodivRestore ERA-NET Cofund (GA N°101003777), by the EU and FCT, and Project PCI2022-132941 cofunding by MCIN/AEI/10.13039/501100011033. Furthermore, this work was funded by the U.Porto innovation agency through the BIP PROOF 2024/2025 call. A. Puga acknowledges FCT for his grant (2021.08888.BD) and Manuela M. Moreira is thankful for her contract (2023.05993.CEECIND) financed by FCT/MCTES—CEEC Individual Program Contract.

References

[1] I. Meffe, I. de Bustamante, *Sci. Total Environ.* **2016**, 401, 280-289.
[2] M. Pacheco-Álvarez, J.A. Reyes-Merino, *J. Water Process Eng.* **2022**, 45, 102485.
[3] P. Pandey, P. Shukla, *J. Environ. Manage.* **2022**, 303, 114144.

[PP41]

Electrooxidation and electrocoagulation processes for the treatment of raw textile wastewater

César Afonso[1,2]*, André Rodrigues[2], Bárbara Saraiva[1,2], Annabel Fernandes[1,2]

[1]Fiber Materials and Environmental Technologies (FibEnTech-UBI), Universidade da Beira Interior, 6201-001 Covilhã, Portugal
[2]Department of Chemistry, Universidade da Beira Interior, 6201-001 Covilhã, Portugal

*cesar.afonso@ubi.pt

The textile industry is one of the largest consumers of water, discharging nearly all of it as wastewater [1]. In the context of increasing water scarcity, efficient treatment technologies enabling wastewater reuse are urgently needed [2]. Electrochemical processes have emerged as promising solutions due to their versatility and environmental compatibility [3]. In this study, two electrochemical approaches, electrooxidation (EO) and electrocoagulation (EC), were comparatively evaluated using a raw textile wastewater with a chemical oxygen demand (COD) above 1000 mg/L. EO was assessed using boron-doped diamond (BDD) and mixed metal oxide (MMO) anodes, both in batch reactors and in a recirculating cell. BDD consistently outperformed MMO, reaching up to 63% COD and 50% total organic carbon (TOC) removal in 6 h of batch treatment, while MMO achieved less than 20% COD and 5% TOC removal under similar conditions. In the larger-scale recirculating cell, BDD maintained its efficiency, attaining 63% COD reduction in only 4.5 h. EC was studied with iron and aluminium anodes under different potentials, treatment times, and mixing conditions. The iron anode provided the highest performance, with 75% COD removal at 2 V for 2 h, combined with lower sludge generation and improved separation under agitation. Aluminium electrodes performed less efficiently, achieving 52% COD removal at 2 V for 3 h. The results demonstrate that EO with BDD and EC with iron represent the most effective operational configurations. Both processes show strong potential as viable technologies for textile wastewater remediation, contributing to sustainable water management in the textile sector.

Funding

This research was funded by Fundação para a Ciência e a Tecnologia (FCT), project UIDB/00195/2020 (https://doi.org/10.54499/UIDB/00195/2020) and research contract CEECINST/00016/2021/CP2828/CT0006 (https://doi.org/10.54499/CEECINST/00016/2021/CP2828/CT0006) awarded to Annabel Fernandes under the scope of the CEEC Institutional 2021, and by the Lusitano project 01/C05-i09/2024.PC644933224-00000043, financed by the Recovery and Resilience Plan.

References

[1] S. Vajnhandl, J.V. Valh, *J. Environ. Manage.* **2014**, 141, 29-35.
[2] N. Mohan, N. Balasubramanian, C. Basha, *J. Hazard. Mater.* **2007**, 147, 644–651.
[3] Y. Zhang, K. Shaad, D. Vollmer, et al., *Water* **2021**, 13, 3515.

[PP42]

Removal of pharmaceuticals from water combining adsorption and electrochemical treatments

Verónica Poza-Nogueiras*, Nuria Bernárdez, Bárbara Lomba, Marta Pazos, Ángeles Sanromán
CINTECX, Universidade de Vigo, Departamento de Enxeñaría Química, 36310 Vigo, Spain
*vpoza@uvigo.gal

Pharmaceuticals are detected in water environments worldwide, raising significant concerns regarding their impact on ecosystems and public health. In particular, antibiotics pose a threat due to their potential contribution to antimicrobial resistance. One of the main ways these compounds enter the environment is through discharges from wastewater treatment plants, since the conventional treatments applied there do not always achieve an effective removal of antibiotics [1]. This highlights the need to develop efficient methods for eliminating them from water. In this context, adsorption stands out as a promising alternative. However, the high cost of adsorbent materials, and the need to regenerate the spent adsorbent after the treatment hinder its practical application. To tackle this, low-cost biosorbents obtained from agri-food waste can be used [2]. Additionally, the application of electrochemical processes combined with the adsorption treatment allows the continuous regeneration of the adsorbent.

Taking this into consideration, in this study a low-cost commercial biochar obtained from forestry wastes was tested for the remediation of water polluted with the antibiotic sulfamethoxazole. Initially, adsorption tests were performed providing the adsorbent in two formats: as a powder and immobilized in an alginate matrix. Results showed that the biochar retained its adsorption capacity for the removal of sulfamethoxazole even after immobilization. Therefore, given that working with the immobilized biochar simplifies the recovery of the adsorbent, this format was selected. Afterwards, the study examined the synergistic effects of combining adsorption with anodic oxidation treatments in a 0.5 L electrochemical reactor, using a graphite anode and a nickel foam cathode. Results showed that the removal efficiency of sulfamethoxazole was significantly enhanced when both methods were employed together, compared to using either method alone. Specifically, the elimination after 2 h of treatment was boosted from a *ca.* 25% removal for adsorption or anodic oxidation treatments to a 75% when combined. This synergism is attributed to the oxidation of sulfamethoxazole, which not only aids in pollutant degradation but also contributes to the regeneration of the adsorbent. Furthermore, analysing the hydrogen peroxide availability during the electrochemical treatment, it was possible to conclude that a Fenton reaction was taking place thanks to the iron content of the biochar employed, thus contributing to the elimination of sulfamethoxazole. These findings demonstrate that the integration of adsorption and electrochemical treatments using low-cost adsorbents hold potential for the removal of pollutants from water in real-world applications.

Funding

This research was funded by MCIN/AEI/10.13039/501100011033 through the projects PCI2022-132941 and PID2023-146133NB-I00, by Xunta de Galicia GRC-ED431C 2025/47 and by Deputación Provincial de Pontevedra. Verónica Poza-Nogueiras is grateful to Xunta de Galicia (Consellería de Cultura, Educación y Universidad) for the postdoctoral fellowship financial support (ED481B-2022-077).

References

[1] A.J. dos Santos, M.S. Kronka, G.V. Fortunato, et al., *Curr. Opin. Electrochem.* **2021**, 26, 100674.
[2] S. Escudero-Curiel, V. Acevedo-García, M.A. Sanromán, et al., *Electrochim. Acta* **2021**, 389, 138694.

[PP43]

Development of a paper-based electrochemical sensor for the detection of amisulpride in water

Xoel Álvarez[1], Isabel Seguro[1], Verónica Poza-Nogueiras[1,2], Marta Pazos[2], Ángeles Sanromán[2], Cristina Delerue-Matos[1], João G. Pacheco[1]*
[1]REQUIMTE/LAQV, Instituto Superior de Engenharia do Porto, Instituto Politécnico do Porto,
Rua Dr. António Bernardino de Almeida 431, 4249-015 Porto, Portugal
[2]CINTECX, Universidade de Vigo, Departamento de Enxeñaría Química, 36310 Vigo, Spain
*jpgpa@isep.ipp.pt

The presence of pharmaceuticals in the environment has become a growing concern. Consequently, the revised Urban Wastewater Treatment Directive (EU) 2024/3019 has included some of these compounds (*e.g.* the antipsychotic drug amisulpride) as priority substances. In this context, there is an increasing need for efficient tools to detect and monitor these compounds in water. Therefore, electrochemical sensors have emerged as a promising option, given their high sensitivity, cost-efficiency, simple operation, portability and speed in obtaining results. In addition, they do not usually require complex pretreatment processes and allow on-site analysis, hence being suitable to monitor environmental pollutants [1]. In this work, a paper-based electrochemical sensor modified with a molecularly imprinted polymer (MIP) was prepared for the detection of amisulpride in water. The electrode was manufactured by inkjet-printing, depositing gold and silver conductive inks on a waterproof paper substrate. After being modified with carbon ink, the MIP layer was directly synthesized on the electrode through the electropolymerization of sulfanilic acid as the functional monomer and amisulpride as the template molecule. Using differential pulse voltammetry as the detection method, the variables influencing the synthesis of the MIP were assessed and optimized. As a result, the optimal sensor was obtained performing the following steps: i) an electropolymerization performing 15 cycles of cyclic voltammetry using 15 mM of sulfanilic acid and 10 mM of amisulpride, ii) an extraction with HCl 0.1 M during 30 min, and iii) an incubation in PBS pH 8 during 7.5 min. The developed sensor exhibited a linear response for concentrations between 2.5 and 100 µM, with a limit of detection (LOD) of 0.50 µM. Additionally, tests with other pharmaceuticals with chemical structures similar to amisulpride proved the exceptional selectivity of the sensor. Furthermore, its performance in real water matrices was demonstrated by the recoveries obtained (96-106%) in spiked river water samples. Considering the promising results obtained, the developed MIP-based sensor holds potential for monitoring amisulpride in environmental waters.

Funding

This work received financial support from Portuguese national funds (FCT/MECI, Fundação para a Ciência e a Tecnologia and Ministério da Educação, Ciência e Inovação) through the project UID/50006/2025 - Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos, and the project PaperSenseMIP PTDC/QUI-QAN/3899/2021 (DOI: 10.54499/PTDC/QUI-QAN/3899/2021) from FCT/MCTES. The authors are also grateful to the project BioReset (BiodivRestore-406 / DivRestore/0002/2020, DOI: 10.54499/DivRestore/0002/2020) funded through the 2020-2021 Biodiversa+ and Water JPI joint call for research projects, under the BiodivRestore ERA-NET Cofund (GA N°101003777), by the EU and FCT. X.Á. is thankful for his Erasmus+ Internship grant. V.P.-N. acknowledges Xunta de Galicia (Consellería de Cultura, Educación y Universidad) for her postdoctoral grant (ED481B-2022-077). I.S. is grateful to FCT for her PhD grant (2022.12344.BD) and J.G.P. is thankful for his contract (2023.07458.CEECIND/CP2842/CT0002) funded by FCT/MCTES.

References

[1] M. Madadelahi, F.O. Romero-Soto, R. Kumar, et al., *Biosens. Bioelectron.* **2025**, 272, 117099.

[PP44]

Powder-to-Powder electrochemical reduction of iron oxides: toward scalable, carbon-free iron production

Ding Ge[1,3]*, Giulia Finotello[1,3], John van der Schaaf[2,3], Niels Deen[1,3], Yali Tang[1,3]

[1]Power & Flow, Department of Mechanical Engineering, Eindhoven University of Technology, The Netherlands
[2]Sustainable Process Engineering, Department of Chemical Engineering & Chemistry, Eindhoven University of Technology, The Netherlands
[3]Eindhoven Institute for Renewable Energy Systems (EIRES), Eindhoven University of Technology, The Netherlands

*d.ge@tue.nl

The global iron and steel industry produced approximately 1.9 billion tons of steel in 2023, contributing around 7% of total anthropogenic CO_2 emissions [1]. Conventional blast furnace and direct reduction methods remain carbon-intensive and energy-demanding. Electrochemical reduction of iron oxides has emerged as a promising alternative, offering advantages such as CO_2-free, low-temperature operation, scalable and compatible with renewable energy generation, etc.. In this study, we developed a powder-to-powder electrochemical reduction process [2] using submicron iron oxide powders as feedstock. The experimental investigation spans over wide range of system parameters/conditions, include feedstock composition, current density, temperature, electrode material, solid concentration, pre-treatment, etc. High Faradaic efficiency exceeding 90% [3] has been achieved, with production of high-purity iron powders of micron sized. Quantitative characterization of the process using measurement techniques like X-ray diffraction (XRD) and UV-Visible spectroscopy revealed a combined conversion pathways of both solid-state electroreduction with Fe_3O_4 as an intermediate and dissolution-redeposition mechanism. Beyond offering a practical strategy for green ironmaking, this work enhances the fundamental understanding of electrochemical iron reduction in powder-based suspensions, which informs the design and scaling of the electrolytic iron production process, contributing to sustainable iron and steel production.

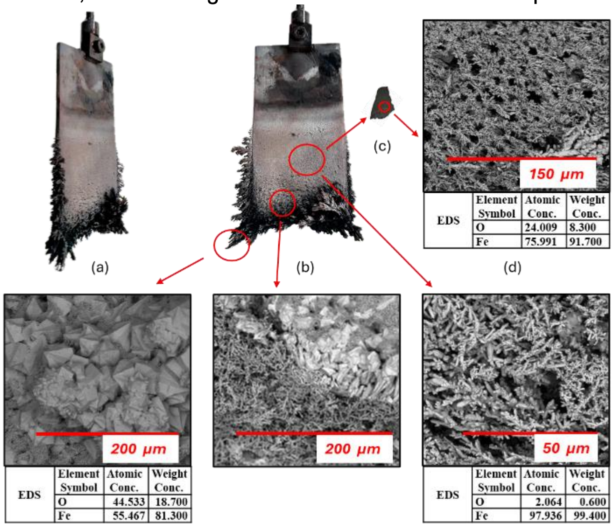


Figure 1. (a) and (b) Images of cathode with iron production in different angles. (c) Images of iron production. (d) (e) (f) (g) The SEM&EDS image of different areas (conditions: I=4000 A/m^2, solid concentration 20 wt%, T=110 degree C, stirring before reduction = 1h, reduction = 1h).

Funding
This research was funded within the EuroTech PhD program at Eindhoven University of Technology.

References

[1] World Steel Association. World Steel in Figures 2024. Brussels: World Steel Association; 2024.
[2] A.I. Majid, Y. Tang, G. Finotello, et al., "Systems and methods for continuous electrolytic production of metals." (**2023**) Patent: WO2023209544A1.
[3] A.I. Majid, G. Finotello, J. van der Schaaf, et al., *Chem. Eng. Sci.* **2024**, 291, 119931.

[PP45]

H_2O_2-assisted photoelectrocatalysis for the elimination of pharmaceuticals from surface waters

André Torres-Pinto[1]*, Manuel Peñas-Garzón[2], Maria J. Sampaio[1], Cláudia G. Silva[1], Joaquim L. Faria[1], Adrián M.T. Silva[1]

[1]LSRE-LCM, ALiCE, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
[2]Departamento de Ingeniería Química, Instituto Universitario de Materiales y Nanotecnología (IMANA), Universidad de Málaga, Campus de Teatinos, 29010 Málaga, Spain
*andretp@fe.up.pt

The increasing presence of pharmaceutically-active substances in surface waters has raised serious environmental and public health concerns. Therefore, there is a need for the development of sustainable treatment technologies, such as photoelectrocatalysis (PEC) which has emerged as a promising strategy. Graphitic carbon nitride (GCN) is a widely studied photocatalyst in this context, owing to its favourable optical and electrochemical properties, ease of synthesis and metal-free composition [1]. However, its practical application is hindered by rapid exciton recombination, which limits charge carrier availability and overall catalytic efficiency. To address this, material engineering approaches, such as heteroatom doping have been explored to tune the physicochemical properties of GCN and enhance its performance. In this work, we investigated the effect of phosphorus doping on GCN using various precursors (H_3PO_4, NaH_2PO_4, Na_2HPO_4, $NH_4H_2PO_4$) at different weight percentages for the PEC degradation of a mixture of pharmaceuticals, including atenolol (ATL), tramadol (TMD), venlafaxine (VFX), citalopram (CTP), ibuprofen (IBU), carbamazepine (CBZ), ketoprofen (KET), and diclofenac (DCF), under visible-LED illumination and under low current (2 mA), as shown in Fig.1. Also, the role of hydrogen peroxide (H_2O_2) as an added oxidant was studied with varying concentrations. Additionally, the influence of water matrix composition (including simulated mineral, estuarine, river and urban wastewater effluent) was assessed, demonstrating that the PEC removal of pharmaceuticals is efficient even in complex environments (>95% total equivalent carbon removal in 1 h).

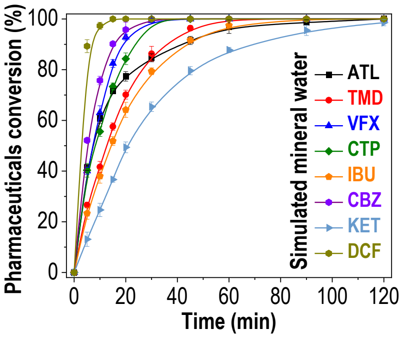


Figure 1. H_2O_2-assisted PEC removal of pharmaceuticals (5 μM each) in mixture spiked in a simulated mineral water, under optimised electrolytic conditions and using a P-doped GCN suspension photoelectrode.

Acknowledgements
This work was supported by FCT/MCTES (PIDDAC) under project DRopH2O - 2022.08738.PTDC (DOI: 10.54499/2022.08738.PTDC). This research was also supported by Fundação para a Ciência e a Tecnologia, I.P. /MCTES through national funds: LSRE-LCM, UID/50020/2025; and ALiCE, LA/P/0045/2020 (DOI: 10.54499/LA/P/0045/2020).

References
[1] Q. Zhu, Y. Shi, Y. Tao, et al., *Chem. Eng. J.* **2024**, 482, 149066.

BOOK OF ABSTRACTS

XXVI Meeting of the Portuguese Electrochemical Society

November 19–21, 2025 | Porto, Portugal

9-648-5.33-29-0