2ND INTERNATIONAL CONFERENCE

2025

SWATTS UP!

Lastest Trends in Energy Storage Research

BOOK OF ABSTRACTS

CSIC Consejo Superior de Investigaciones Científicas

ICTP Instituto de Ciencia y Tecnología de Polímeros

BioLogic

KIT Karlsruher Institut für Technologie

ECS Madrid UCM Student Chapter

Scientific Program:

Sessions & Topics:

Oral Session 1 (O1):

Advanced Methods for energy storage electrodes

Oral Session 2 (O2):

Recent developments on post-Li batteries

Oral Session 3 (O3):

Redesigning Li usage: from recovery to efficiency

Poster Session Topics:

Li and post-Lithium batteries

Battery assembly, prototyping and recycling

Advanced characterization techniques (from ex-situ to operando)

Liquid and Solid Electrolytes

Supercapacitors

CONTENT:

Keynote 1:

Current state and challenges in LCA and carbon foot printing of batteries

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The talk will give an outline of the current state of knowledge and remaining gaps in the field of sustainability assessment of batteries, particularly lithium-ion and post-lithium batteries. It delves into the role of batteries for decarbonising the energy system, their environmental and social sustainability and the main drivers of environmental impacts. Furthermore, it will explain the regulatory framework under the EU Batteries Regulation and the methodology that is to be used for quantifying the carbon footprint of batteries that will soon become mandatory for new batteries placed on the marked in the EU.

As such, it will be of interest to both LCA practitioners and to battery technology or material developers, advancing knowledge and consciousness about potential sustainability implications on different TRL.

O1: Advanced Methods for Energy Storage Electrodes

Biomass-Derived Electrode Materials for Sustainable Energy Storage Applications

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Abstract

The rapid growth of the energy sector has increased interest in batteries and supercapacitors, especially those that meet sustainability goals. Traditional industrial batteries often depend on metal-based compounds, which present significant environmental issues during their extraction and processing. As the supply chain seeks greener options, biomass waste emerges as a promising, low-impact material for developing electrode components.

This work explores the valorization of Iberian agricultural and industrial biomass wastes—specifically olive pits, orange peels, and cork powder—used as precursors for carbon-based electrodes. Each biomass type was subjected to customized treatment routes based on its inherent properties. Olive pits underwent hydrothermal pre-treatment followed by pyrolysis at temperatures from 900°C to 1200°C. Orange peels were cleaned through ethanol washing and then dried before being pyrolyzed at 1200°C an alternative hydrothermal method was also investigated. Cork powder was compressed into pellets and pyrolyzed at 1200°C to produce a self-standing electrode.

The resulting carbons exhibited diverse morphologies and electrochemical profiles, suitable for a variety of energy storage applications. Olive pit-derived carbon achieved high surface area and capacitive behavior, with ~150 mAh g^{-1} for sodium-ion and ~300 mAh g^{-1} for lithium-ion batteries at 1C. Orange peel-based materials provided stable performance in sodium systems (~80 mAh g^{-1}), while cork-derived carbon, although lower in capacity (around 50 mAh g^{-1}), showed strong structural integrity and ease of synthesis.

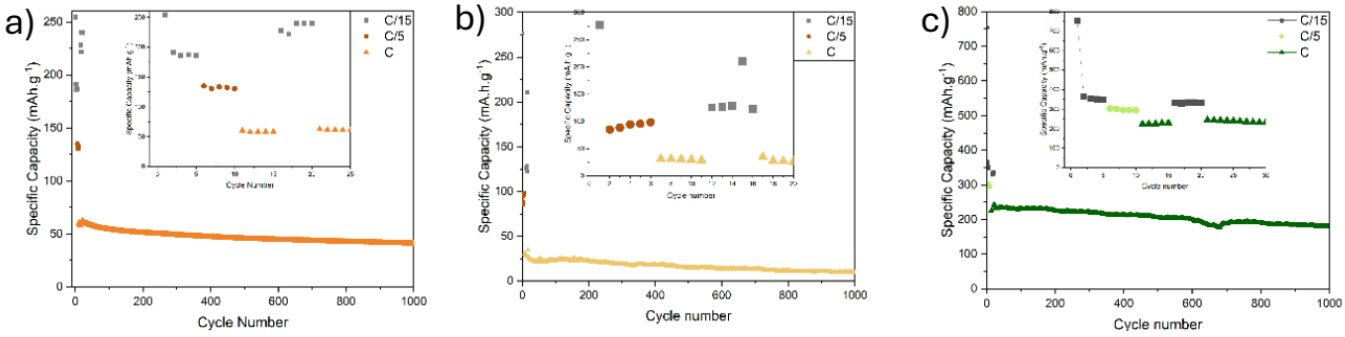

Figure 1: Electrochemical characterization of a biomass-based HC as anodes with either lithium or sodium as counter electrodes in 1M $LiFP_6$ EC:DME and 1 M $NaFP_6$ EC:PC, respectively tested between 0.001 and 2 V: a) GA charge-discharge with orange peels as a precursor vs sodium b) GA charge-discharge with cork powder as a precursor vs lithium c) GA charge discharge with olive pits as a precursor vs sodium.

Cost, Stability, and Scale: Progressing Polyimide Electrodes from Lab to Pouch Cell Integration

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Abstract

In recent years, lithium-ion batteries (LIBs) have become central to powering our modern world, from smartphones to electric vehicles. Much of this success is due to breakthroughs in inorganic materials. Yet, as the demand for safer, more sustainable, and cost-effective technologies grows, there's a clear push to look beyond conventional solutions.[1]

This has brought organic electrode materials into the spotlight.[2] Thanks to their wide availability, flexible design options, and potential for greener processing, they're seen as promising candidates for the next generation of energy storage. Among these, redox-active polymers stand out – but so far, their use has been held back by practical limitations, such as low electrode mass loading and high reliance on conductive additives.[3–5]

In my talk, I will present a new approach to overcome these challenges using a polyimide derived from naphthalene-tetracarboxylic dianhydride. We processed this into a buckypaper-style electrode – completely free of binders and current collectors, which allowed us to reach very high mass loadings (up to 99 mg/cm²) while keeping the carbon content low (only 10%).[6] The results are impressive. Our electrodes achieved high capacities across all metrics: 155 mAh/g (gravimetric), 8.5 mAh/cm² (areal), and 129 mAh/cm³ (volumetric), with solid rate capability even at 5C. To our knowledge, these values are among the best ever reported for organic electrodes in LIBs. To demonstrate real-world viability, we assembled full cells in several configurations, including Li_graphite||PI and PI||LFP – in both coin and pouch formats. We evaluated their energy and power densities, as well as preliminary cost metrics for practical applications. With energy outputs of 185 $Wh/kg_{electrodes}$ and projected costs of just $70 per kWh, these materials offer a compelling case for practical (semi-)organic battery systems. [7]

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Redox-Active Metal-Anilate Frameworks as Sustainable Cathodes for High Energy Batteries

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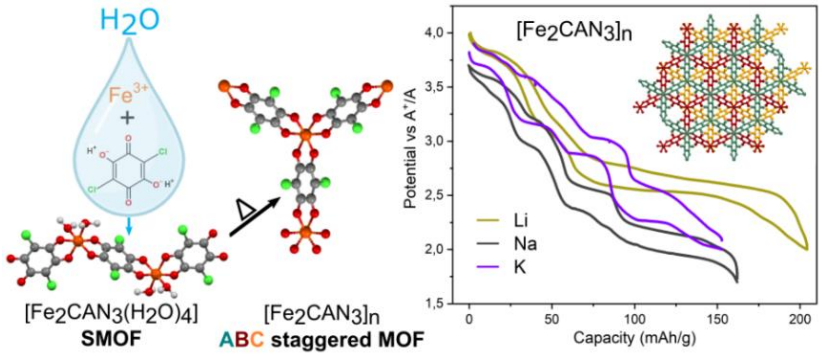
Abstract:

Achieving high battery performance from low-cost, easily synthesisable electrode materials is crucial for advancing energy storage technologies.[1] Metal organic frameworks (MOFs) combining inexpensive transition metals and organic ligands are promising candidates for high-capacity cathodes.[2] Iron-chloranilate frameworks are herein reported to be produced in aqueous media under mild conditions. Lattice water removal from known $[Fe_2(CAN)_3(H_2O)_4]\cdot 4H_2O$ yields a new supramolecular metal-organic framework (SMOF), $[Fe_2(CAN)_3(H_2O)_4]$. Further removing of coordination waters forms a new 2D honeycomb-like MOF, $Fe_2(CAN)_3$, stable without counterions or solvent.[3] This MOF adopts the unusual ABC layer-stacking, as determined using a combination of *ab initio* random structure searching, electron diffraction, and Rietveld refinement of powder XRD data. Magnetometry, Mossbauer and Raman spectroscopy confirm that all three $[Fe_2(CAN)_3(H_2O)_x]\cdot yH_2O$ phases contain HS-Fe^{3+} and CAN^{2-}. $[Fe_2(CAN)_3(H_2O)_4]$ has a reversible specific capacity for lithium (de)insertion of 112 mAh/g after 300 cycles at 1C (89% of its initial capacity due to insertion of >4Li^+/f.u.) at average 2.59 V vs Li^+/Li, while the MOF $Fe_2(CAN)_3$ shows a reversible capacity for lithium (de)insertion of 146 mAh/g, retaining 74% of its initial capacity under the same conditions at average 2.76 V vs Li^+/Li. $[Fe_2(CAN)_3]$ thus achieving high specific energy (563 Wh/kg) and high specific power (446 W/kg) values in Li half-cells, competitive with those of conventional $LiFePO_4$ (~580 Wh/kg and ~450 W/kg). For Na and K half-cells, $[Fe_2(CAN)_3]$ delivers specific energies as high as 394 Wh/kg and 421 Wh/kg, respectively, making it an affordable cathode material for sustainable alkali-ion batteries.



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Bifunctional OER/ORR Electrocatalysts Based on LDH Nanodots Confined in Fe–N–C Frameworks for High-Performance Seawater Batteries

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Abstract

The advancement of energy conversion and storage technologies, such as seawater batteries, fuel cells, and metal-air batteries, is crucial to meeting growing energy demands [1]. In these systems, electrocatalysts with bifunctional oxygen evolution (OER) and oxygen reduction (ORR) activity play a key role (Figure 1A) [2]. Current state-of-the-art catalysts include precious metals and oxides like Pt, IrO_2, and RuO_2. These materials are expensive, scarce, and lack sufficient durability for practical use [3]. Thus, low-cost, earth-abundant electrocatalysts are crucial for widespread adoption of OER/ORR-based devices.

Layered double hydroxides (LDHs) are known for their excellent OER performance in alkaline media and are considered benchmark non-precious catalysts. However, their low conductivity and tendency to aggregate limit practical use [4]. In this study, we address these limitations by confining LDH nanodots within a mesoporous iron-nitrogen-carbon matrix, improving both conductivity and active surface area (Figure 1B). The catalyst was then tested at the cathode of a seawater battery, showing enhanced stability and a reduced voltage gap compared to state-of-the-art catalysts.

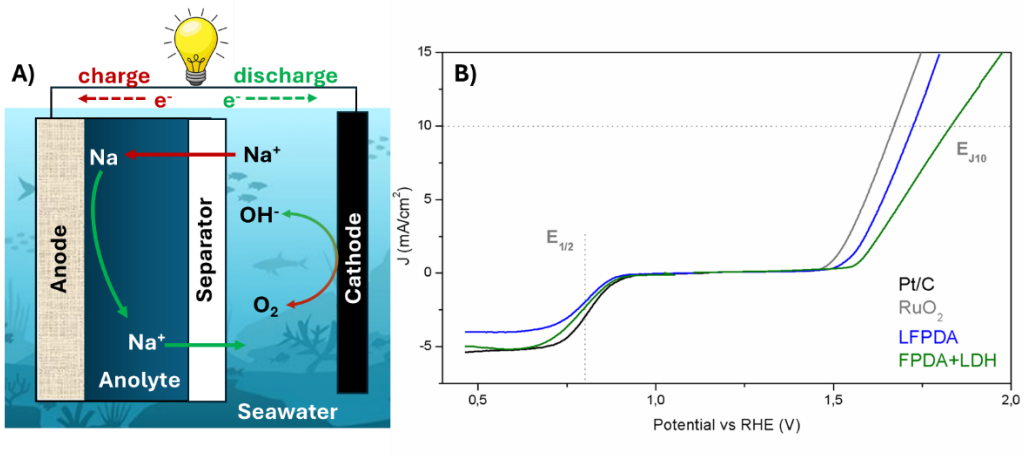

Figure 1. A) Schematic illustration of a secondary seawater battery. B) OER and ORR polarization curves in 0.1 M KOH and a 10 mVs^{-1} scan rate of Pt/C-RuO_2 as state-of-the-art catalysts (black and grey), carbon support with LDH (green) and LDH nanodots anchored on the support (blue).

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O2: Recent Developments on Post-Lithium Batteries

Studying the plating/stripping capacity of zinc ion on ionic liquid/zinc salts mixtures for applications on zinc ion batteries.

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Abstract

The intermittent character of renewable energy makes necessary the development of new energy storage technologies. Zinc-ion batteries (ZIBs) have gathered attraction as promising candidates thanks to their high energy density, cost-effectiveness and enhanced safety (1). However, the conventional electrolytes, based on organic solvents, present safety and stability problems derived from their flammability and volatility. Ionic liquids (ILs) have emerged as alternative electrolyte solvents to overcome these issues due to their negligible vapor pressure and high resistance to flammability (2).

Here, the plating/stripping of zinc ion was studied on mixtures of ILs with zinc salts to be used as potential electrolytes for ZIBs. 6 different mixtures of an IL with a zinc salt sharing the same anion (1 mol of salt per kg of solution) were prepared with the ILs [Emim][OAc], [Bmim][OAc], [Ch][OAc], [Bmim]Cl, [Amim]Cl and [OHEtMim]Cl. The rheological properties of these mixtures at different temperatures, their electrochemistry (PEIS, LSV, CV), thermal properties (TGA and DSC) and the interactions between IL and salt (FTIR-ATR) were studied. Conductivities were in the range of 0.07-6.31 mS/cm at temperatures between 25-65 ºC; viscosities were in the range of 208.25-0.04 Pa·s (between 25-55 ºC) and electrochemical windows were between 0.99-2.44 V. [Emim][OAc] and [OHEtMim]Cl mixtures could perform plating/stripping of zinc. Furthermore, the mixture based on the IL [Emim][OAc] displayed the highest electrochemical window (2.41 V), the lowest viscosity (0.20 Pa·s at 25 ºC) and the highest conductivities (0.367 mS/cm at 25 ºC) among the 6 mixtures tested.

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Sustainable Design of Prussian Blue Analogues as Cathodes Materials for Na-Ion Batteries

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Abstract:

As the demand for sustainable and cost-effective energy storage technologies continues to rise, sodium ion batteries (NIBs) are emerging as a promising alternative to lithium-based systems, particularly for stationary applications. Among the various cathode candidates, Prussian blue analogues (PBA) particularly interesting thanks to their open framework, rapid Na+ diffusion kinetics, and cost-effective synthesis [1]. This study offers a detailed investigation of iron and manganese-based PBAs synthesised by various methods, with particular emphasis on a near-solvent-free mechanochemical approach through ball milling [2,3].

In comparison to traditional wet chemical methods (co-precipitation and hydrothermal), mechanosynthesis markedly reduces solvent consumption and energy use, adhering to green chemistry principles [4]. To quantitatively evaluate the environmental impact of the different synthesis methods, we utilized the Green Chemistry Eco-Scale assessment [5]. The mechanochemical route, which achieved the highest ecoscore, underscores the potential of this strategy in not only designing high-performance cathode materials but also in facilitating greener synthetic pathways in accordance with circular energy principles.

The synthesized materials were characterised by X-ray diffraction, scanning electron microscopy, thermogravimetric analysis, Mössbauer spectroscopy, and inductively coupled plasma mass spectroscopy and test in half-cells to link the characteristics of structures and morphologies to their electrochemical performance. Moreover, operando infrared spectroscopy was applied during cycling to observe dynamic structural changes, providing real-time information on the redox mechanism and material stability [4]. The results obtained in this study confirm the potential of PBA as an efficient and adjustable cathode for future NIBs [1].

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Arene-amino acid hybrids for their application as electrodes in potassium ion batteries.

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Abstract

Potassium-ion batteries (KIBs) are a promising alternative to lithium-ion batteries (LIBs). Potassium presents several advantages, such as more abundancy in earth's crust, lower cost and reduced environmental impact, while having similar electrochemical properties to lithium. Current day LIBs components contain toxic and highly polluting elements such as cobalt and nickel. The substitution of these inorganic electrodes for organic molecules, ideally made from abundant compounds with low price, low toxicity and zero environmental impact is highly important for the future development of sustainable energy storage devices[1,2.]

Arene-amino acids hybrids are compounds made of an aromatic fragment linked to an amino acid through an amide bond[3]. The arene works as a mold, giving rigidity to the molecule and favouring intramolecular and intermolecular interactions. If the arene presents electrochemical active groups (quinone derivatives, carboxylates, imides, etc)[4] they pose a promising future as electrode materials due to their ability to complex metal cations, structural diversity and environmental sustainability.

In this communication we will present the synthesis, structural and compositional characterization, as well as the electrochemical performance for K insertion of a series of arene-amino acid hybrids. For all the compounds prepared, spectroscopy characterization (^{1}H-NMR, ^{13}C-NMR, IR, MS-ESI), powder X-ray diffraction, polarimetry and melting point were conducted. Electrochemical properties were obtained via the measurement of charge and discharge capacities in galvanostatic mode in various electrolytes. With the data obtained we discussed the viability of these compounds as electrodes for KIBs.

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Hazelnut Shells-Derived Sustainable Hard Carbon Anodes for K-ion Batteries

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Abstract

The intermittency of electricity generation from renewable energy sources requires the development of energy storage devices. Although lithium-ion batteries have been widely used, their non-uniform geographical distribution and low abundance have prompted the emergence of potassium-ion batteries as a promising alternative, owing to their low-cost (K abundance), high energy (low redox K^+/K potential) and high power (high K^+ diffusion in liquid) density. [1,2]

Carbon-based materials have emerged as promising candidates for anode development and can be classified into three categories: graphite, hard carbon and soft carbon, which differ in their degree of graphitization. Their microstructure depends on the type of precursors and the annealing temperature. Among them, hard carbon, a non-graphitizable carbon with a highly disordered structure, offers excellent cycling stability. Its abundance and lower cost make it attractive for energy storage. [1]

In this work, hazelnut shells-derived hard carbon anode materials have been synthesized via two approaches: direct pyrolysis and three-step synthesis, i.e., prepyrolysis, acid washing, and pyrolysis at 1100 °C. These materials were characterized using X-ray diffraction, scanning electron microscopy, energy-dispersive X-ray spectroscopy and Raman spectroscopy. Additionally, they were electrochemically tested in half-cells using 2 M KFSI in TEP as electrolyte. The water-washed hazelnut-derived hard carbon delivered a specific capacity of 200 $mAh \cdot g^{-1}$ at 0.1C. However, its performance was improved by washing it with 2 M HCl to remove impurities, significantly increasing the specific capacity to 240 $mAh \cdot g^{-1}$. These results clearly demonstrate the crucial role of the pre-treatment parameters on the electrochemical properties of the hard carbon anode materials.

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Development of Hollandite-Type Structure Titanium Oxides as Electrode Materials in Rechargeable Potassium-Ion Batteries

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Abstract

The growing demand for alternative electrochemical energy storage systems beyond lithium-ion batteries (LIBs) has increased interest in potassium-ion batteries (KIBs), owing to potassium's greater natural abundance and lower cost. A critical challenge lies in identifying electrode materials capable of reversibly accommodating large K^+ ions without inducing detrimental volumetric expansion.[1] Hollandite-type oxides ($A_yB_xTi_{8-x}O_{16}$, where A = alkali metal, B = transition metal) are promising due to their (2×2) tunnel structures formed by TiO_6 octahedral chains, which facilitate the stable insertion/extraction of K^+ ions and mitigate structural degradation[2].

In this work[3], a series of hollandite-type materials with the general formula $K_yV_xTi_{8-x}O_{16}$ ($0.25 \leq x \leq 2$) were synthesized via the citrate route and evaluated as KIBs electrode candidates. Neutron Powder Diffraction (NPD) confirmed an undistorted *I4/m* crystalline structure across all compositions, with consistent potassium content ($1.4 \leq x \leq 1.6$). Advanced Transmission Electron Microscopy (TEM) techniques, including SAED, ABF and HAADF-STEM, revealed potassium/vacancy short-range ordering along the c-axis, with disorder between tunnels. Magnetic measurements indicated predominantly paramagnetic behaviour down to 2 K, with antiferromagnetic interactions at low temperatures, except for x = 0.25, which showed ferromagnetic tendencies. The magnetic moment analysis pointed to a low Ti^{3+} content, with differences at x = 1.25.

Electrochemical performance was assessed via galvanostatic cycling in 2.5 M KFSI (TEP). At C/10, materials enabled reversible insertion/extraction of 2 K^+ /f.u. Notably, x = 0.75 maintained stable insertion of 1 K^+/f.u. at C/5, highlighting its potential as a viable electrode for KIBs.

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Keynote 2:

Ionic Liquid-Based Additives for the Protection of High-Voltage Cathodes

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Ionic liquids (ILs) have traditionally been employed as thermally stable electrolytes in lithium-ion batteries, offering a safer alternative to carbonate-based systems. Some ILs, particularly those containing oxalatoborate anions, can form a protective cathode electrolyte interphase (CEI) on high-voltage cathodes such as LiNi 0.5 Mn 1.5 O 4 (LNMO).

We recently introduced a novel approach by incorporating bis(oxalato)borate-based ILs (BOB-ILs) directly into the cathode, rather than the electrolyte. LNMO electrodes containing 3 wt% BOB-IL exhibited stable capacity above 120 mAh/g and high Coulombic efficiency over 200 cycles.

In contrast, IL-free electrodes demonstrated comparable initial capacity but failed after 109 cycles. While adding BOB-ILs to the electrolyte also enhanced cycle life, it resulted in lower capacity, likely due to reduced ionic conductivity. Post- cycling XPS and XRD analyses, conducted at the NanoTerasu Synchrotron Light Source, confirmed CEI formation derived from the IL within the cathode. This study demonstrates a new application of IL electrode additives, enabling effective stabilization of high-voltage cathodes.

O3: Redesigning Li usage: from recovery to efficiency

Efficient recovery of strategic materials from spent lithium-ion batteries through hydro and biohydrometallurgy

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Abstract

The recovery of Critical Raw Materials (CRM) has been targeted by the European Union as a priority, in order to meet sustainable development goals. CRMs such as cobalt, lithium, nickel, manganese, and graphite, which are present in the manufacture of lithium-ion batteries, which are essential for the development of electric vehicles, can be recovered from this type of e-waste.

In this work, we study the direct recovery of Co, Li, Ni, and Mn from the cathode of a real black sample from a computer spent battery (named as BM-C), comparing the traditional hydrometallurgy with inorganic/organic acids and biohydrometallurgy, with the bacterial strain *Acidihalobacter sp*. For bacterial experiments, we compared the one-step direct mechanism and a two-step indirect mechanism in both bacterial growth and metal dissolution.

For the leaching with chemical reagents, we chose gluconic acid for its great efficiency and for being a biodegradable, non-toxic and non-corrosive acid. After applying experimental design for optimization, leaching yields of 93 % of Co, 98 % of Li, 86 % of Ni and 97 % of Mn, at S/*L* = 10 g/L, *T* = 75 ºC, *t* = 24 h, H_2O_2 = 0.5 g/g, were achieved using 1 N gluconic acid. For bioleaching experiments, indirect mechanism proved to be more effective, with leaching efficiencies of 88% for Co^{2+}, 97% for Li^{+}, 83% for Ni^{2+}, and 68% for Mn^{2+}, due to the acidic and Fe-oxidizing conditions generated by the culture, which enhanced the chemical attack to the waste.

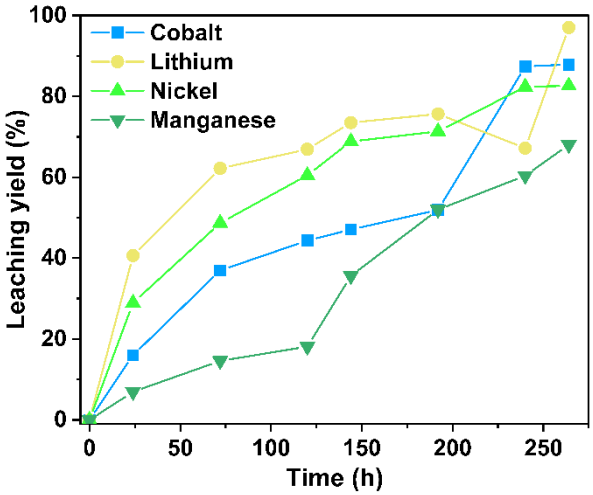

Fig 1. Results of bioleaching of black mass under an indirect mechanism.

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Influence of RF Magnetron Sputtering Deposition Parameters on the Optimization of the Physicochemical Properties of Ternary Lithiated Oxide Thin Films Deposited on Flexible Kapton Substrates

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Abstract

Rechargeable lithium-ion batteries are widely used in numerous electrical and electronic devices due to their high energy density in small volumes and weights. Flexible electronics, driven by emerging fields such as implantable devices and the Internet of Things, also demand compatible energy storage solutions. However, conventional lithium-ion battery production methods rely on rigid systems and liquid electrolytes, which reduce device safety. An alternative approach involves the fabrication of lithium-ion battery electrodes as thin films using physical deposition techniques such as sputtering. This method eliminates the need for binders and conductive additives that usually lower the battery's specific energy.

In this study, we investigated the fabrication of ternary lithiated transition metal oxide (Ni, Mn, Co) thin films optimized for electrochemical discharge capacity without the need for thermal treatments, either in situ or post-deposition, thus enabling the use of flexible substrates. A factorial design of experiments was employed with four variables (power, pressure, thickness, and oxygen percentage) at two levels plus a central point. Several characterization techniques were applied to evaluate the physical and chemical properties of the films, with particular emphasis on electrochemical discharge capacity. The optimized sample achieved a discharge capacity of 212 $mAhg^{-1}$, a 50% improvement over conventional electrodes. These findings demonstrate the feasibility of producing high-capacity thin films without thermal treatments, contributing to the advancement of flexible electronics for health and social well-being applications.

Enhancing efficiency of $LiFePO_4$ cathodes with Fe3O4 magnetic nanoparticles for lithium batteries.

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Abstract

Lithium iron phosphate ($LiFePO_4$) is a widely used cathode material in lithium-ion and lithium metal batteries due to its excellent thermal stability, long cycle life, and environmental friendliness. However, it suffers from limited electronic conductivity and polarization issues during charge/discharge cycles, which can lead to capacity loss and reduced efficiency over time. Addressing these limitations is essential for advancing high-performance energy storage systems.

This study aimed to address these issues by incorporating Fe_3O_4 magnetic nanoparticles to enhance the electrochemical performance of $LiFePO_4$-based cathodes.

The work was divided into two main phases: the synthesis of Fe_3O_4 nanoparticles and the fabrication of composite cathodes. In the first phase, Fe_3O_4 nanoparticles were synthesized via a microwave-assisted hydrothermal method in aqueous media, optimizing reaction times to achieve maximum magnetization. The nanoparticles were characterized using powder X-ray diffraction (P-XRD), infrared spectroscopy (IR), and transmission electron microscopy (TEM). Additionally, Le Bail refinement was performed with FullProf Suite to determine structural details.

In the second phase, composite cathodes with varying $Fe_3O_4/LiFePO_4$ ratios were prepared and tested in lithium metal batteries using a Neware® potentiostat. The objective was to evaluate their capacity retention, polarization behavior, and cycling stability.

Poster Session:

Advanced Ultrasonic Techniques for Non-Invasive Characterization of Lithium-Based Energy Storage Systems

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Abstract:

The development of advanced diagnostic tools is essential for understanding and improving the performance and safety of lithium-based energy storage systems. As these systems become more complex and widely used, especially in high-demand applications such as electric vehicles and grid storage, there is a growing need for methods that can reveal internal structural changes without compromising the integrity of the cell. Traditional electrochemical approaches offer valuable data but often compromise in spatial resolution or require invasive procedures. [1]

Our study investigates the application of ultrasonic non-destructive testing (NDT) for evaluating the internal structure of battery materials. The technique utilizes high-frequency through-transmission immersion measurements to monitor changes in acoustic signal behavior in relation to state of charge (SOC) and battery aging. This non-invasive method enables the identification of internal defects, such as delamination of layers, gas accumulation, or electrode degradation without the need to dismantle the cell. It shows strong potential for use in both manufacturing quality control and long-term performance monitoring. Additionally, the applicability of this approach to next-generation solid-state batteries is examined. The results demonstrate that ultrasonic NDT can serve as a valuable complement to conventional electrochemical characterization methods by providing spatially resolved insights into the internal condition of lithium-based energy storage systems.

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Post-Mortem Analysis of Degradation Mechanism in Starch-Derived Carbonaceous Electrodes

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Abstract:

This study reports the synthesis and electrochemical characterization of mesoporous carbon materials derived from renewable sources, alongside a novel post-mortem analysis of structural transformations induced by electrochemical testing. The materials were prepared from starch via the Starbon® methodology, a gelation-retrogradation process that eliminates the use of templates and hazardous chemicals used for their removal. To enhance electrical conductivity and capacitive performance, the materials were doped with graphene oxide (GO) nanoparticles. The carbonaceous nature of the materials was evaluated with microanalysis and Raman spectroscopy, while nitrogen adsorption-desorption isotherms and SEM were employed to assess their textural properties. The optimal surface area and pore volume were achieved with a minimal GO loading of 0.5 wt.%.

Subsequently, symmetrical electrochemical cells were assembled using a 2M H_2SO_4 solution electrolyte. The electrodes containing 0.5 wt.% GO exhibited superior performance, reaching specific capacitances of 200 $F \cdot g^{-1}$ and power densities up to 6000 $W \cdot kg^{-1}$. Post-mortem characterisation revealed a significant increase in BET surface area and pore volume—more than double in both cases—along with a marked enhancement in mesoporosity, as detailed in Table 1.

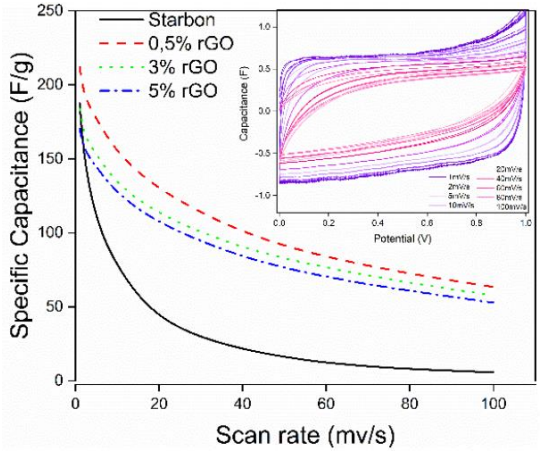

Figure 1: Variation of the specific capacitance of the carbons with scan rate. In zoom, voltammograms of 0.5% doped Starbon at different scan rates.

Table 1: Comparison of textural properties after electrochemical use

Parameter	Units	Prior-to-test (A)		Post-mortem (B)		Difference in parameters (A-B)	
		0% GO	0.5% GO	0% GO	0.5% GO	0% GO	0.5% GO
S_{BET}	m^2/g	221	284	557	446	336	162
$V_{MICRO}^{t\text{-}plot}$	m^3/g	0.07	0.09	0.25	0.2	0.19	0.11
$V_{MESO}^{t\text{-}plot}$	cm^3/g	0.3	0.35	0.85	0.9	0.55	0.55
V_{TOTAL}^{BJH}	cm^3/g	0.36	0.44	1.1	1.1	0.74	0.66

In conclusion, this work presents a sustainable and efficient route for the development of high-performance carbon-based electrodes for supercapacitors. Furthermore, we present a preliminary study of electrochemical ageing, which provides valuable insights into the structural stability of electrode materials, contributing to the development of more durable and efficient supercapacitor electrodes.

Next-Generation Energy Storage: MOF-Ionic Liquid Hybrids as Solid Electrolyte

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Abstract:

Lithium-ion batteries (LIBs) are widely used for their high energy density and long cycle life. However, the growing demand for more sustainable and cost-effective energy storage systems has increased interest in sodium-ion batteries (SIBs), which use more abundant and inexpensive materials. Despite their potential, both LIBs and SIBs face safety issues linked to the use of flammable and unstable liquid electrolytes. To address these challenges, solid electrolytes (SEs) are being explored as a safer alternative, offering improved thermal stability, structural integrity, and ion transport. This research presents the development of a novel solid electrolyte combining a Metal-Organic Framework (MOF) with an ionic liquid (IL), suitable for both LIB and SIB applications. The porous architecture of the MOF enables controlled ion diffusion, while the IL enhances overall ionic conductivity. By integrating these components, the proposed hybrid electrolyte aims to deliver improved safety, enhanced stability, and better electrochemical performance—contributing to the advancement of high-efficiency, next-generation energy storage technologies.

High performance OER catalysts derived from eutectic leachates from spent lithium-ion batteries

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Abstract:

The rise and development of electric vehicles has drawn significant attention to the recycling of lithium-ion batteries (LIBs). As LIBs reach the end of life, the heavy metals such as nickel, cobalt and manganese present in one of the most common cathodes of LIBs, $LiNi_xCo_yMn_{1-x-y}O_2$ (NMC), will flow into the environment, which will have an immeasurable impact on water and soil.

This way, recovering critical metals from NMC is equally important as challenging, particularly for nickel and cobalt, which share similar chemical properties. In this work, we propose a deep eutectic solvent (DES) for nickel separation and leaching of cobalt and manganese. Then, separation of cobalt from the leachate is performed via electrodeposition. In addition to providing a strategy for the recovery of metals from NMC, we go one step further as we study the performance towards the oxygen evolution reaction (OER) of the recovered cobalt from electrodeposition. OER is the kinetic bottleneck in the electrochemical splitting of water into hydrogen and oxygen. Since hydrogen is considered to be the cleanest source of energy in the 21st century, search for lower cost alternatives to the state-of-the-art catalysts like RuO_2 and IrO_2 is rising. In this context, transition metal species, such as Co hydroxides/oxyhydroxides, are generally good catalysts that can exhibit excellent OER properties.

Hydrogel Electrolytes for Supercapacitors with High Energy Density and Long Cyclability

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Abstract:

Supercapacitors are energy storage devices known for their high-power density, rapid charge/discharge capabilities and exceptional long cycle life compared to conventional batteries. However, one of the main challenges in their development is optimizing the electrolytes, a key component that impacts both energy efficiency and operational stability. In this context, hydrogel electrolytes have attracted significant attention as a promising alternative due to their unique combination of properties.
Hydrogels possess mechanical flexibility similar to that of solid elastomers, which allows them to conform to various shapes and support mechanical stress without compromising their structural integrity. At the same time, hydrogels exhibit high ionic conductivity analogous to liquid electrolytes, ensuring efficient ion transport during the charging and discharging processes. Importantly, hydrogels minimize the risk of liquid leakage, a common problem in liquid-based systems, making them particularly attractive for applications requiring enhanced safety and reliability, such as wearable electronics and flexible energy devices. This makes them a highly suitable option for electrolytes in advanced energy applications.

In this work, we explore the design and optimization of a hydrogel based on polyvinyl alcohol (PVA), agarose and polyethylene glycol (PEG) synthesized through a freeze-thaw process and functionalized as an electrolyte for supercapacitors by soaking it in various salt solutions. This hydrogel forms a polymeric network that can absorb large quantities of water, creating an ideal environment for ion mobility while maintaining a solid-like structure. Supercapacitors devices were tested using commercial carbon electrodes and the prepared hydrogel electrolytes having different salt contents. The optimized gel showed a remarkable electrochemical stability window demonstrating a significant improvement in specific capacitance and an excellent cyclability, with minimal degradation over ten thousand charge/discharge cycles. The results position this material as a viable alternative for the next generation of high-performance flexible supercapacitors.

Speeding Up Battery Research Through Usage Pattern Modeling

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Abstract:

One of the most pressing challenges of our time is the development of clean and sustainable energy systems. Renewable energy sources are central to this transition; however, their intermittent nature presents a critical challenge: the need for efficient energy storage solutions [1]. Among the available technologies, lithium-ion batteries have emerged as a leading option thanks to their high energy density and adaptability. Nonetheless, enhancing battery performance and prolonging their lifespan remain key research priorities. A major hurdle in this area is the considerable time and resources required for battery cycling tests, which are vital for assessing long-term performance. These procedures often span several months, creating a significant bottleneck for innovation.

To overcome this limitation, researchers are turning to alternative approaches—among them, machine learning stands out as a particularly promising tool. By utilizing datasets from previously tested batteries, it is possible to train predictive models that estimate critical metrics such as long-term state of health [2]. This study centers on the theoretical modelling of lithium-ion battery behavior using machine learning techniques, specifically Random Forest and Multivariant Linear Regression. The objective is to predict the optimal slurry composition for nickel-rich cathodes.

The analysis investigates how variations in components—such as the proportion of active material, carbon black, and other additives—impact battery performance. Rather than directly extending battery lifespan, this research aims to elucidate the relationships among these parameters and identify configurations that could lead to improved overall performance.

Figure 1. Machine Learning Workflow for Optimizing Battery Slurry Composition

References:

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Poster Presentation

From Biowaste to Battery: Sustainable hard carbon anodes for sodium-ion batteries via hydrothermal treatment

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Abstract:

This study explores the use of biomass waste (pineapple residue from juice production and sunflower seed shells) as alternative precursors for hard carbon (HC) production. It is focused in the effect of different variables on the electrochemical performance of hard carbon produced from biowaste, with special attention to the hydrothermal treatment (HTC), the heating ramp during pyrolysis, and the ageing of the material after its synthesis. In addition, the compatibility of these HCs with aqueous binders as an environmentally friendly alternative to traditional organic solvents is analyzed.

A two-step synthesis route was employed to prepare the biowaste-derived HCs: hydrothermal carbonization conducted at 250 ^{o}C for 24h under autogenous pressure to reduce the inorganic impurities and increase the carbon content, followed by a pyrolysis process at 1200 ^{o}C for 2h using two different heating rates: 5 ^{o}Cmin^{-1} and 10 ^{o}Cmin^{-1}. The physicochemical characterization showed the structural, morphological and compositional features of the prepared HCs. Electrochemical performance was evaluated in half cell through galvanostatic charge-discharge, revealing promising performance. The results indicate that HTC appears to enhance the electrochemical performance of both biomass-derived carbons; however, its effectiveness depends on the type of feedstock. In addition, a slower heating rate during pyrolysis seems to improve the electrochemical performance. The use of a water-based binder system was also investigated, showing comparable capacities to those obtained with conventional binders.

Finally, it was observed that the aging of the already-produced hard carbon tends to reduce its electrochemical performance.

Poster Presentation

From 21GRD01 OpMetBat to 24GRD09 HyMetBat, traceable metrology applied to batteries

Arcangelo Celeste[1], Sergio Brutti, Anita Scipioni, Valentina Migliorati, Stefano Stranges, Stefano Passerini, Marco Agostini*

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Abstract:

Batteries play a crucial role in modern society and are essential to meeting net-zero ambitions. However, rising demand combined with limited EU-based supply of critical raw materials is leading to concerns over a potential shortage of battery commodities. Furthermore, there is a pressing need to improve the environmental sustainability of batteries and battery production. New chemistries and processing strategies are emerging to address these issues, but these introduce further complexity and are poorly understood. New metrology is critical to accelerate the development of the next generation sustainable battery materials systems.
A battery materials metrology framework exists based on benchmark Li-ion batteries (LIBs) but its extension to new chemistries is non-trivial owing to the wider diversity of elemental combinations, structures, and interactions. It is necessary to ensure that existing best practice can be reliably extended to emerging, more sustainable materials systems such as sodium-ion batteries (SIBs), while broadening the range of techniques to include properties such as thermal characteristics. Recycling of battery materials offers a route to de-risking the supply chain, but the process introduces impurities, so there is a need for traceable analytical techniques and calibration materials to reliably quantify and understand the impact of elements in recycled electrodes. The complexity of battery electrode composites makes them highly challenging to characterize reliably, particularly during charge-discharge cycling. Operando methods offer a solution to this, but improved confidence in these measurements requires their hybrid combination; there is a need to develop instrumentation to enable multiple independent and simultaneous measurements of singular and related quantities to minimize uncertainty.
The OpMetBat and Hymetbat projects have received funding from the European Partmership on Metrology Participating States and from the European Union's Horizon 2020 research and innovation programme.

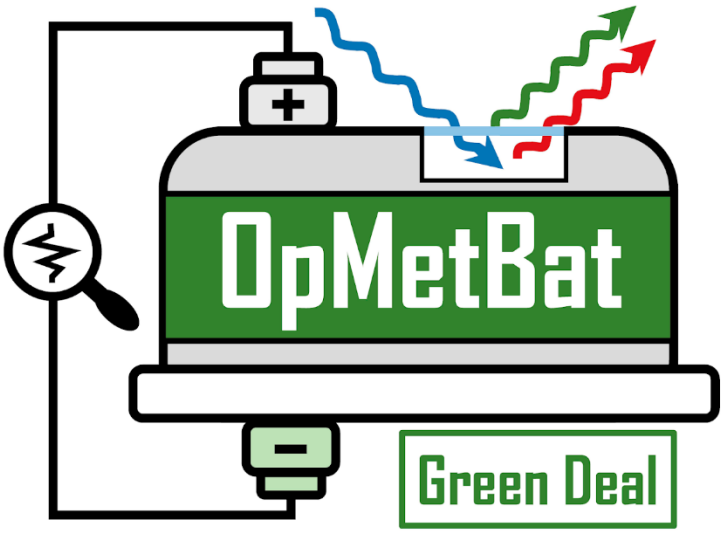

Fig. 1. Logo of the OpMetBat project

Influence of Synthesis Techniques on the Structural, Thermal, and Electrochemical Properties of $Na_{0.67}Ni_{0.25}Mn_{0.75}O_2$ Cathodes for Sodium-Ion Batteries.

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Abstract:

Sodium-ion batteries (SIBs) are emerging as promising alternatives to lithium-ion batteries (LIBs), especially for applications prioritizing cost, resource availability, and sustainability. Like LIBs, SIBs operate via similar electrochemical mechanisms but benefit from using more abundant materials, such as sodium in place of lithium and hard carbon instead of graphite. A key challenge in developing efficient and sustainable SIBs is identifying suitable cathode materials. Layered sodium transition metal oxides are strong candidates due to their structural versatility (P2, P3, O3 types), high specific capacities, and synthesis routes similar to those used for LIB cathodes. However, these materials often suffer from unwanted phase transitions during cycling, leading to reduced performance and stability. Therefore, synthesis methods and precursor selection play crucial roles in controlling phase purity and structural integrity. In this study, we compare $Na_{0.67}Ni_{0.25}Mn_{0.75}O_2$ synthesized via solid-state and sol-gel approaches. We examine how differences in precursor thermal behavior affect the resulting material properties. A detailed analysis of crystal structure, thermal characteristics, and electrochemical performance reveals that synthesis conditions significantly impact phase composition and cycling stability. These results highlight the importance of controlled synthesis in developing high-performance cathode materials for next-generation SIBs.

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[3] J. Deng, et al. Adv Energy Mater. **2018**, 8(4), 1701428.

Poster Presentation

Influence of Ion-Exchange Membranes and Controlled Iron Coordination on the Performance of All-Iron Redox Flow Batteries

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Abstract:

All-iron redox flow batteries (AIRFBs) are emerging as a promising candidate for large-scale energy storage due to their low cost, environmental friendliness, and use of abundant iron resources. The challenge of iron-based RFBs is how to design a system with high energy density, power density, and superior cycling stability. In this study, we systematically investigate the influence of ion-exchange membranes and various operating parameters on the electrochemical performance of AIRFBs. Several types of ion-exchange membranes were evaluated in terms of iron ion permeability and ion transfer efficiency. We also examine the effect of electrode compressibility on the resistance and capacity retention of AIRFBs, as well as the effect of different concentrations of electrolyte additives on the redox kinetics and the stability of iron plating/stripping. Our results show that different ion-exchange membranes have a significant impact on the Coulombic and energy efficiencies of AIRFBs, while moderate electrode compression improves the performance by improving interfacial contacts. In addition, an optimized controlled of iron coordination contributes to the suppression of side reactions and improves long-term stability. This comprehensive study provides valuable insights into the rational design and operation of high-performance AIRFBs and offers a reference for the future development of cost-effective and durable energy storage systems.

The use of metal-organic gels as anodes in lithium-ion batteries

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In recent years, the search for cleaner and more sustainable energy has become a major challenge for our society. For this reason, new renewable energy sources and energy storage systems are being developed. Within the different available storage systems batteries, especially lithium-ion batteries (LIBs), have gained much attention.

In this research work, our focus has been the anode, and our main goal is to explore alternative materials with improved properties, cheaper and more endurable. For this purpose, we propose the synthesis, characterization and application of two metal-organic materials, more specifically, a family of metal-organic gels. These materials have been chosen based on their interesting properties such as their high BET specific surface area, the electrical conductivity and, above all, the presence of redox active elements. The charge storage mechanism involves an in-situ electrochemical reduction of metal-organic materials obtaining good capacities, up to 600 mAh g^{-1}, at various current densities that range from 10 mA g^{-1} to 200 mA g^{-1}.

Poster Presentation