



Twenty Fourth **National Convention of Electrochemists**

Date :
April 27 & 28, 2026

Venue :
Amrita Vishwa Vidyapeetham, Coimbatore

NCE-24



Organized by :

**Society for Advancement of
Electrochemical Science and Technology,
Karaikudi**

in Association with

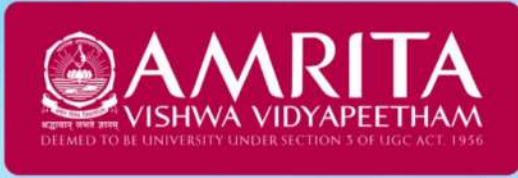


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Government of India
Ministry of Science and Technology
Department of Scientific & Industrial Research
Council of Scientific & Industrial Research

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सचिव, वैज्ञानिक और औद्योगिक अनुसंधान विभाग
महानिदेशक, वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्

Dr. (Mrs.) N. Kalaiselvi
Secretary, DSIR and Director General, CSIR



MESSAGE

I am extremely delighted to know that the Society for Advancement of Electrochemical Science and Technology (SAEST), Karaikudi is organizing the "Twenty Fourth National Convention of Electrochemists (NCE-24)" in association with CSIR-Central Electrochemical Research Institute (CECRI), Karaikudi and Amrita Vishwa Vidyapeetham, Coimbatore during April 27-28, 2026 at Amrita Vishwa Vidyapeetham, Coimbatore.

Electrochemistry is a truly multi-disciplinary science that provides sustainable solutions to many human needs including clean energy and environment, affordable healthcare, conservation of materials resources, and circular economy. I appreciate SAEST for its role as an ambassador propagating and promoting the importance of electrochemistry for a sustainable world. I am sure that this convention with its chosen experts as resource persons will discuss the recent developments in the areas of electrochemical science and technology and offer a professional brainstorming and networking opportunities. Such an effort is essential in promoting next generation towards achieving Viksit Bharat@2047 goals.

I wish NCE-24 a grand success.

April 09, 2026
New Delhi

(N. Kalaiselvi)



सत्यमेव जयते
प्रो. अभय करंदीकर
Prof. Abhay Karandikar



सचिव
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विज्ञान एवं प्रौद्योगिकी विभाग
Secretary
Government of India
Ministry of Science and Technology
Department of Science and Technology

21st April, 2026



MESSAGE

It gives me great pleasure to know that the Society for Advancement of Electrochemical Science and Technology (SAEST), Karaikudi, in association with CSIR–Central Electrochemical Research Institute (CECRI), Karaikudi, and Amrita Vishwa Vidyapeetham, Coimbatore, is organizing the National Convention of Electrochemists (NCE-24) during April 27–28, 2026.

Electrochemistry continues to play a crucial role in addressing key global challenges, particularly in clean energy, environmental protection, and healthcare diagnostics. Platforms such as NCE-24 provide valuable opportunities for researchers, academicians, industry experts, and young scholars to exchange ideas, nurture collaborations, and advance innovative solutions.

The collaboration between academia and a premier research institute in organizing this convention is highly commendable and will greatly benefit the scientific community, especially budding researchers.

I extend my heartfelt best wishes for the grand success of NCE-24 and hope it proves to be a highly enriching and inspiring event for all participants.

(Abhay Karandikar)

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Director

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MESSAGE

It gives me multifold pleasure in writing this message at various capacities as Director, CSIR-Central Electrochemical Research Institute (CECRI), President, Society for Advancement of Electrochemical Science and Technology (SAEST) and Patron, Twenty Fourth National Convention of Electrochemists (NCE-24). SAEST, Karaikudi in association with CSIR-CECRI, Karaikudi and Amrita Vishwa Vidyapeetham, Coimbatore is organizing the Twenty Fourth National Convention of Electrochemists (NCE-24) during April 27 & 28, 2026 at Amrita Vishwa Vidyapeetham, Coimbatore. This convention aims to provide a platform for vibrant discussions onto the latest developments in the fields of electrochemical science and technologies, and allied areas. I am glad to present this Abstract Souvenir Book which not only contains the brief abstracts of work from various participants but also their enthusiasm and eagerness to participate and enrich their knowledge.

SAEST has been playing a pivotal role in disseminating the knowledge on electrochemical science and technology over the past six decades. On behalf of CSIR-CECRI & SAEST, I extend a warm welcome to all the distinguished delegates and participants both from Academia and Industry, and research scholars. Your participation in this two-day convention will provide an opportunity for mutual interactions and also benefit the aspiring young researchers and students to broaden their knowledge. I envisage that the knowledge and experience to be shared by experts will definitely motivate the next generation to venture into the dynamic field of electrochemical science and technology. This would fulfil the objective of NCE-24 and pave way for the collaboration among the participants and institutions towards the Viksit Bharat@2047 and NET Zero goals.

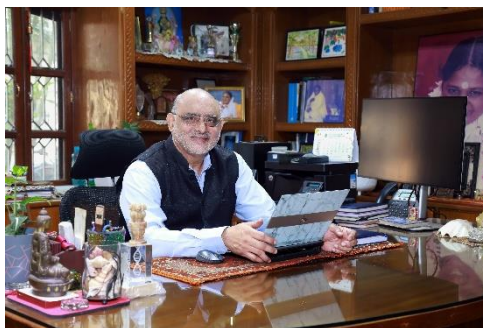
Together, let us make NCE-24 a grand success!


K. Ramesha

April 06, 2026
Karaikudi

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MESSAGE



Dr. Bipin Nair
Registrar
Amrita Vishwa Vidyapeetham

It is a matter of great pride and pleasure for Amrita University to be associated with the Society of Advancement of Electrochemical Science and Technology and to host the National Convention of Electrochemists -24 in collaboration with CSIR-Central Electrochemical Research Institute (CECRI), Karaikudi. This prestigious gathering provides an excellent platform for academicians, researchers, and industry experts to exchange knowledge, discuss emerging trends, and foster collaborations in the field of electrochemistry.

Electrochemistry continues to play a pivotal role in addressing global challenges, particularly in energy storage, sustainability, and environmental protection. Events such as this convention significantly contribute to advancing research and innovation by bringing together diverse perspectives and expertise.

On behalf of Amrita University, I extend my best wishes for the success of the convention. I am confident that the deliberations and interactions during this event will inspire new ideas and pave the way for impactful scientific contributions.

My best wishes for the grand success of this NCE-24.

Best Regards,
Bipin

MESSAGE



**Dr. Sasangan Ramanathan, Dean Academics
Amrita Vishwa Vidyapeetham, Coimbatore**

It gives me immense pleasure to welcome all delegates, researchers, academicians, industry experts, and students to the 24th edition of the National Convention of Electrochemists (NCE-24), organized by the Society for Advancement of Electrochemical Science and Technology (SAEST), in association with CSIR-Central Electrochemical Research Institute and Amrita Vishwa Vidyapeetham.

Electrochemistry is a vital branch of science and engineering that seamlessly connects chemistry, materials science, and electrical phenomena. Its significance in contemporary society is profound, underpinning advancements in energy storage systems, corrosion mitigation, environmental sustainability, sensors, and the development of advanced materials through cleaner and more efficient processes. In recent years, the boundaries between conventional disciplines have increasingly converged, making interdisciplinary collaboration essential for innovation and progress. Specialized conferences such as NCE-24 provide an excellent platform for the exchange of ideas, dissemination of cutting-edge research, and meaningful interaction among scientists, engineers, scholars, and students. I commend SAEST, along with CSIR-Central Electrochemical Research Institute and Amrita Vishwa Vidyapeetham, for jointly organizing this important convention at a time when scientific advancements and sustainable technologies are of paramount importance. I am confident that the deliberations and discussions during this conference will enhance knowledge, address emerging challenges, and motivate participants to explore rewarding research and career opportunities in the broad and dynamic field of electrochemistry.

I extend my warm greetings and sincere appreciation to the conveners, organizing committee, speakers, and participants for their dedicated efforts and enthusiastic participation.

I convey my best wishes for the grand success of NCE-24.

Warm regards,

A handwritten signature in green ink, appearing to read 'Sasangan Ramanathan', written in a cursive style.



The Society for Advancement of Electrochemical Science and Technology

The Society for Advancement of Electrochemical Science & Technology (SAEST) headquartered at CSIR-Central Electrochemical Research Institute (CSIR-CECRI) Campus, Karaikudi was founded on 14th November 1964 as a registered professional society. The prime objective of SAEST is to provide a common forum for industrialists, technologists, scientists, students, and others to meet and foster the advancement of electrochemistry, electrochemical science & technology and allied fields. The SAEST is managed by a team of office bearers elected once in two years. Today, SAEST is a society with 1200 members across the nation composed of students, researchers, scientists, professors, R&D personnel, executives from both government and private organizations, consultants and industrialists.

Since its inception in 1964, SAEST has been periodically organizing National Conventions, Workshops, and International Conferences to disseminate the knowledge on electrochemical science and technology by bringing together researchers from academia and industry to interact and learn about the advancements made in the field. These events are being organized in association with CSIR-CECRI and Premier Institutions with special relevance to their contribution in the field of electrochemical science and technologies. So far, SAEST has organized 16 International Conferences/Symposia including three conferences on Electrochemical Power Systems, 71 National Seminars / Workshops, and 23 National Convention of Electrochemists (NCEs). With Michael Faraday Memorial Private Trust, Karaikudi, SAEST organizes the “Michael Faraday Medal Lecture” with a prime aim of fostering the innate spirit of Faraday's scientific pursuit and to promote scientific temper by arranging the scientific lectures by eminent researchers and experts in this area across the globe. In memory of Prof. Allen J. Bard, a pioneer in the field of electrochemistry, SAEST introduced “SAEST – A. J. Bard Memorial Lecture” during the iSAEST-13.

In this series, NCE-24 is being organized by SAEST in association with CSIR-Central Electrochemical Research Institute, Karaikudi, and Amrita Vishwa Vidyapeetham, Coimbatore during April 27 & 28, 2026 at Amrita Vishwa Vidyapeetham, Coimbatore. It is customary to have Memorial Lectures in the NCE in the name of Prof. K. S. G. Doss, Prof. S. K. Rangarajan and Prof. S. Sathyanarayana, who have pioneered different aspects of electrochemistry. Scientists and Professors bestowed with outstanding contributions in electrochemistry will be invited to deliver Memorial Lectures and interact with the participants that include students, scholars, scientists, researchers, academia and technocrats from industries. A number of awards and prizes are given in all the conferences to encourage the best oral and poster presentations.

SAEST, with the active participation by its members and success in the past, continues its journey in organizing NCE-24 and many more events in the years to come.



CSIR-Central Electrochemical Research Institute

The CSIR-Central Electrochemical Research Institute (CSIR-CECRI), a premier and largest research establishment mainly for electrochemistry in South Asia, founded on July 25, 1948, has its roots in the patriotic fervour of “Padma Bhushan” Dr. RM. Alagappa Chettiar, Pandit Jawaharlal Nehru the first Prime Minister of India, and Dr. Shanti Swarup Bhatnagar, who conceived the idea of establishing a dedicated research center of electrochemistry in order to cater the demands and needs of society. In his address on the occasion of laying the foundation stone of the institute, Pandit Nehru said, “....I believe that by such undertaking and by taking science to public good we can advance a lot of the people of India enormously”. In translating those words into action, CSIR-CECRI has blossomed into a launching pad for a multitude of technologies for the Indian electrochemical industries. Naturally, reflecting on the fact that the inimitable Dr. Alagappa Chettiar donated 300 acres of land and Rs.15 lakhs as cash in 1948 to establish a national laboratory devoted solely to Electrochemistry at a time when Electrochemistry was relegated to the flip-side of Physical Chemistry syllabi in universities, one cannot miss the rare philanthropy and foresightedness of this great visionary.

On January 14, 1953, CSIR-CECRI became a physical reality when Dr. S. Radhakrishnan dedicated CECRI as the twelfth national laboratory under the CSIR umbrella to the nation. CECRI today is a proud family of more than 300 employees, including more than 100 scientists and other staff members. Headquartered at Karaikudi, CECRI has its extension centres at Chennai and Mandapam. The CECRI campus has a rich biodiversity of flora and fauna, and is an ample green and serene environment making it an apt ambience for R&D work.

Completing 77 years of its foundation, CSIR-CECRI works on a gamut of problems covering all facets of electrochemical science and technology: viz., Corrosion & Materials Protection, Electrochemical Power Sources, Electroplating & Metal Finishing, Electrodicts & Electrocatalysis, Electrochemical Process Engineering and Electro-organic & Materials Electrochemistry. The institute provides a single and unique canopy under which all aspects of electrochemistry and related areas are investigated in all their dimensions. The activities of CSIR-CECRI are directed towards the development of new and improved products and processes as well as innovations in electrochemical science and technology. CSIR-CECRI undertakes several R&D projects in collaboration with laboratories and private companies within and outside India. The 750 patents, 250 processes, 800 sponsored and grant-in-aid projects (in the last five years), 550 licenses and 6,500 research papers in peer-reviewed national and international journals that the institute boasts of are ample testimony to its leadership in nation building.

CSIR-CECRI assists Indian industries by conducting surveys and undertaking consultancy projects. The institute has developed and transferred several technologies to industries and strategic sectors. Lithium-ion battery electrode materials and its fabrication, Supercapacitors, Fuel Cells, Redox flow battery, CO₂ adsorption under flue gas condition, CO₂ utilization to value-added products like adipic acid, oxalic acid, polyurethane, etc., Mg technology, solar powered PEM electrolyser to generate green hydrogen,

Electrowinning of rare earth metals and alloys, Extraction of metals from secondary sources, Trivalent hard chromium coating, Thermal barrier coatings and specialized anticorrosive coatings, etc., are the significant recent technologies of CSIR-CECRI.

The institute also conducts short-term refresher courses and Tailor-made courses for the benefit of industries and academia as a part of skill development activities. As a part of its human resource development programme, CSIR-CECRI runs Anna University's B.Tech. Course in Chemical & Electrochemical Engineering as well as Ph.D. course of Academy of Scientific and Innovative Research (AcSIR) established by CSIR. The institute is equipped with an excellent library as well as the state-of-the-art analytical and characterization facilities. CSIR-CECRI also organizes national and international conferences for dissemination of scientific knowledge through its professional non-profit society viz., Society for Advancement of Electrochemical Science and Technology (SAEST) and National Corrosion Council of India (NCCI), which are functioning at CSIR-CECRI Campus. CSIR-CECRI is alive to societal obligations and participates in the activities such as 'Entrepreneur Development' and CSIR's Integrated Skill Development Initiatives and Jigyasa programme. The institute has been bestowed with several prestigious national and international awards and recognitions.

In a nutshell, CSIR-CECRI is the mainstay of electrochemical industries in India.



Amrita Vishwa Vidyapeetham, Coimbatore

Accredited 'A++' by NAAC, Amrita Vishwa Vidyapeetham is a multidisciplinary research university having ten campuses spread across six states in India: Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Haryana and Uttarakhand. The university's headquarters is situated at Ettimadai, Coimbatore, Tamil Nadu. Amrita is a multi-disciplinary, research-intensive private university with a student strength of over 30,000, supported by more than 2,000 faculty members. It offers over 250 undergraduate, postgraduate, and doctoral programs spanning diverse fields, including Engineering, Management, Medical Sciences, Ayurveda, Life Sciences, Physical and Agricultural Sciences, Law, Arts & Humanities, and Social & Behavioral Sciences.

Amrita's vision and progress are inspired by its founding Chancellor, Sri Mata Amritanandamayi Devi (Amma), a world-renowned humanitarian leader. Amma's profound mission of providing education for life, and emphasis on compassion driven research, has shaped Amrita as a unique institution that provides education for a living and also education for life. Studying to become a professional is education for a living, while education for life requires an understanding of the essential human values. Education and research here are focused on beneficial returns to society. It is no wonder that at Amrita, motivation to pursue research is focused on alleviating major global problems related to poverty, starvation, sickness, environmental pollution, and contamination.

In the Times Higher Education (THE) University Impact Rankings 2025, which evaluates universities worldwide for their contributions to social and economic sustainability, Amrita has been placed among the Top 50 globally. The university is recognized as one of the fastest-growing institutions of higher learning in India, having established over 180 collaborations with top 500 world-ranked universities within just 18 years.

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Twenty Fourth National Convention of Electrochemists (NCE-24)
Society for Advancement of Electrochemical Science and Technology (SAEST)

in association with

CSIR-Central Electrochemical Research Institute (CECRI), Karaikudi &
Amrita Vishwa Vidyapeetham, Coimbatore

April 27-28, 2026

TECHNICAL PROGRAMME

DAY-1: 27th April 2026 (Monday)

Time (Hours)	Event	
08:15 – 09:30	Registration	
09:30 – 10:15	Inauguration (Venue: Amriteshwari Hall, First Floor)	
10:15 – 11:00	Prof. K. S. G. Doss Memorial Lecture: Prof. U. Kamachi Mudali Vice Chancellor, Homi Bhabha National Institute (HBNI), Mumbai	
11:00 – 11:15	Opening of Exhibition Stalls / TEA BREAK	
11:15 – 12:00	Prof. S. K. Rangarajan Memorial Lecture: Dr. Sagar Mitra Professor, Indian Institute of Technology, Bombay	
12:00 – 12:30	Invited Lecture 1 (IL-1) Dr. S. Ningshen , Scientific Officer/H, IGCAR, Kalpakkam	
12:30 – 13:00	Invited Lecture 2 (IL-2) Dr. M. Shaneeth , Group Director, Energy Systems Group, Vikram Sarabhai Space Centre (VSSC), Indian Space Research Organisation (ISRO), Thiruvananthapuram	
13:00 – 14:00	LUNCH (Venue: First Year B.Tech., Mess Hall Building)	
	Amriteshwari Hall (First Floor)	Sudhamani Hall (Second Floor)
14:00 – 14:30	Invited Lecture 3 (IL-3) Dr. Muhammed Musthafa Professor, Indian Institute of Science Education and Research, Pune	Invited Lecture 5 (IL-5) Dr. Amit Paul Professor, Indian Institute of Science Education and Research, Bhopal

14:30 – 15:00	Invited Lecture 4 (IL-4) Dr. Urmimala Maitra Assistant Professor, Indian Association for the Cultivation of Science, Kolkata	Invited Lecture 6 (IL-6) Dr. Haritosh Mishra Associate Vice President - R&D Grauer & Weil (I) Limited, Mumbai
15:00 – 16:00	Oral Presentations (OP-01 to OP-06)	Oral Presentations (OP-34 to OP-39)
16:00 – 16:15	TEA BREAK	
16:15 – 17:15	Oral Presentations (OP-07 to OP-12)	Oral Presentations (OP-40 to OP-45)
17:15 – 18:15	Poster Presentations (PP-01 to PP-100) Venue: Seminar Hall I & II (Third Floor)	
18:15 – 19:15	Cultural Programme	
19:30-21:00	Dinner	

DAY-2: 28th April 2026 (Tuesday)

08:50 – 11:00	Oral Presentations (OP-13 to OP-25) Venue: Amriteshwari Hall (First Floor)	Oral Presentations (OP-26 to OP-33, OP-46 to OP-50) Venue: Sudhamani Hall (Second Floor)
11:00 – 11:15	TEA BREAK	
	Venue: Amriteshwari Hall, First Floor	
11:15 – 12:00	Prof. S. Sathyanarayana Memorial Lecture: Dr. C. Retna Raj, Professor, Indian Institute of Technology, Kharagpur	
	Amriteshwari Hall (First Floor)	Sudhamani Hall (Second Floor)
12:00 – 12:30	Invited Lecture 7 (IL-7) Dr. Saikat Adhikari Metals & Mining Research Group, Aditya Birla Science & Technology Company Pvt. Ltd., Raigad	Invited Lecture 9 (IL-9) Dr. Dhamodaran Santhanagopalan Professor, School of Nanosciences and Molecular Medicine, Amrita Vishwa Vidyapeetham Coimbatore
12:30 – 13:00	Invited Lecture 8 (IL-8) Prof. Sai Gautam Gopalakrishnan Associate Professor Department of Materials Engineering Indian Institute of Science, Bengaluru	Invited Lecture 10 (IL-10) Dr. Jegatha Nambi Krishnan Associate Professor, BITS Pilani, KK Birla Goa Campus, Zuarinagar
13:00 – 13:30	LUNCH (Venue: First Year B.Tech., Mess Hall Building)	

13:30 – 14:30	Poster Presentation (PP-101 to PP-185)	
14:30 – 15:00	Invited Lecture 11 (IL-11) Dr. Harshal Agarwal Scientist-E, CSIR-CECRI Chennai Unit, Taramani, Chennai	Invited Lecture 12 (IL-12) Prof. T. G. Satheesh Babu Professor and Research Head, Amrita School of Physical Sciences, Amrita Vishwa Vidyapeetham Coimbatore
15:30 – 16:00	TEA BREAK	
16:00 – 16:30	PRESENTATION BY SPONSORS	
16:00 – 17:30	Valedictory Function	

MEMORIAL LECTURE

Prof. K. S. G. Doss Memorial Lecture
Industrial Application of Electrochemical Processes in Closing the Nuclear Fuel Cycle



U. Kamachi Mudali

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Electrochemical processes and techniques have a myriad of applications in the nuclear industry. Nuclear systems typically involve corrosive environments, radiation fields, prolonged operation and storage. Use of innovative and advanced electrochemical methods and high-performance materials and coatings are essential for the realization of these systems to perform for extended service. Today a large number of electrochemical techniques of specific interest to the nuclear industry have been developed for application in the nuclear industry. Electrochemical materials science gained a bigger role in the development of processes for treating effluents and waste in nuclear fuel reprocessing. Corrosion is a major problem in the nuclear industry leading to the destruction of many useful components, and this can be assessed and controlled by innovative electrochemical methods. The present lecture concentrates on the electrochemical applications in nuclear technology, particularly for fast breeder reactors and associated spent fuel reprocessing plants. An attempt is made to highlight the various electrochemical processes and techniques used in the nuclear industry, and also the materials development and process improvements including corrosion science and engineering.

Prof. S. K. Rangarajan Memorial Lecture

Strategies for Enhancing the Durability of Low-Cost Cathode Materials for Lithium-ion Batteries



Sagar Mitra

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Manganese-based spinels, such as LiMn_2O_4 (LMO) and $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$ (LNMO), are compelling candidates for next-generation lithium-ion batteries due to their low cost, high operating voltage, and energy densities reaching 690 Wh/kg. However, their commercial viability is limited by structural instability and capacity fading. In LMO, Mn^{3+} disproportionation and Jahn-Teller distortion trigger manganese dissolution and irreversible phase transitions. Meanwhile, LNMO suffers from severe electrolyte decomposition and surface corrosion at high-voltage operation (>4.7 V).

This seminar presents three synergistic strategies to mitigate these degradations:

- ❖ Surface Engineering of LMO: We demonstrate the application of Li-ion permeable NMC coatings on Li-rich LiMn_2O_4 to provide a physical barrier against acid-induced corrosion and suppress structural transitions.
- ❖ Atomic Layer Deposition (ALD) for LNMO: To stabilize the high-voltage LNMO interface, niobium oxyfluoride (NbOF) coatings were deposited via ALD. This nanolayer effectively scavenges HF and mitigates surface side reactions, significantly enhancing cycling stability.
- ❖ Electrolyte Additive Engineering: We investigate LiBF_4 as a sacrificial additive to facilitate the formation of a robust Cathode Electrolyte Interphase (CEI). This interphase suppresses dendritic growth and improves Coulombic efficiency, particularly in lithium-metal configurations.

Here, we will discuss how the experimental and theoretical results confirm that these interfacial modifications collectively resolve the long-standing stability issues of manganese-based spinels, paving the way for high-performance, cost-effective energy storage.

Prof. Sathyanarayana Memorial Lecture

Toward High-Performance Aqueous Rechargeable Batteries: Interfacial Engineering of Electrode and Electrolyte

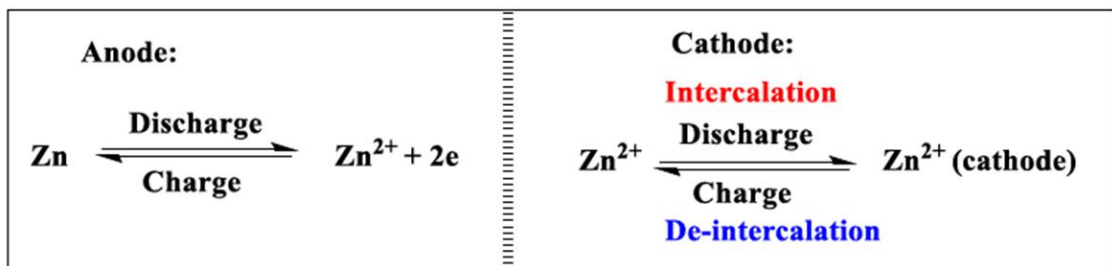
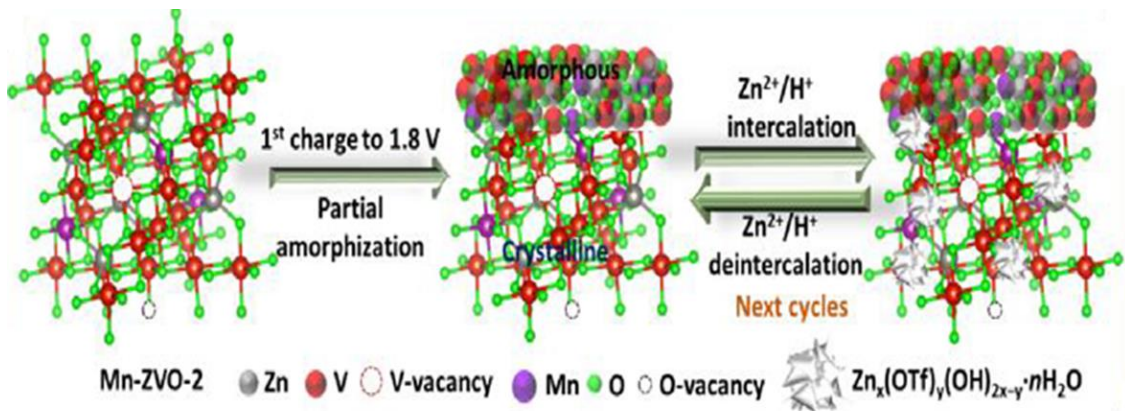


C. Retna Raj

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Aqueous rechargeable zinc batteries (ARZBs) have emerged as promising candidates for safe, low-cost, and sustainable energy storage, owing to their intrinsic non-flammability, high ionic conductivity, and environmental compatibility. However, their practical deployment is hindered by interfacial challenges at the electrode–electrolyte boundary, including limited electrochemical stability windows, parasitic reactions, electrode corrosion, dendrite formation, and sluggish charge-transfer kinetics. Our group is actively developing aqueous rechargeable zinc–air and zinc–ion batteries by engineering anodes, cathodes, and electrolytes. This work presents our recent findings on advancing zinc–ion batteries (ZIBs) *via* rational engineering strategies, including electrode surface tailoring via nanostructuring, surface coatings, and substitutional doping, as well as electrolyte modulation. These approaches enhance active-site accessibility, suppress side reactions, and improve structural stability during cycling. Defect engineering of vanadium-based cathodes, surface modification of the anode with zincophilic polymers, and electrolyte modulation using polyelectrolytes have a profound impact on device performance. The synergistic optimization of the electrode–electrolyte interface is shown to significantly boost the overall performance of ZIBs. In particular, our anode engineering strategies reduce nucleation overpotential and suppress the undesired growth of zinc dendrites. As a result, outstanding rate capability, extended cycling stability, and high capacity have been achieved.



INVITED LECTURE

High Temperature Molten Salts Corrosion of Structural Materials and Corrosion Monitoring by Electrochemical Techniques

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Molten salts (fluorides/chlorides/nitrates/sulfates or carbonates), with exceptionally high thermal stability, economic and low-cost, wide liquid range, high thermal conductivity, large heat capacity, high boiling points, volumetric heat capacities, and efficient heat storage and transfer and higher-efficiency power cycles, making them a core alternative and cornerstone technology for sustainable and next-generation high-temperature energy system. Several recent applications highlight the importance of molten salts across various industries: Nuclear, Concentrated Solar Power (CSP), Batteries and Fuel Cells, Chemical Industry, Catalysis, Metal Production and Processing, Purification and Separation of Chemical Species, and many other industrial processes.

The challenges posed by climate change and the search for sustainable energy sources are reviving interest in nuclear energy to meet future energy demands. In recent years, the adoption of molten salt technology has seen a renewed interest as a key enabling technology for Gen-IV nuclear systems, including molten salt reactors (MSRs), fluoride-salt-cooled reactors (FHRs), and extraction media for pyrochemical reprocessing systems, tritium production for fusion reactors, as it offers numerous safeties, proliferation resistance, efficiency, economic and flexibility benefits. Despite these operational advantages, molten salts are highly corrosive at high temperatures and pose significant engineering challenges for long-term service, as well as concerns for the deployment of molten salt technologies. To overcome the corrosion degradation of structural materials in the highly aggressive molten chloride and fluoride salts environment at high temperature, active research on corrosion protection and monitoring methods, advanced materials, and advanced coating technology for handling molten salts has been initiated in our Lab at IGCAR. Recent achievements on ceramic coatings and pyrolytic graphite coatings on HDG crucibles, process vessels and components for metal fuel fabrication and Gen-IV reactors for handling molten salts. Results on the qualification of candidate structural materials (SS 316L, Sanicro-25, 2.25Cr-1Mo, SS 410 410, 9Cr-1Mo steel, etc.) in molten salts (LiCl-KCl, CeCl₃-LiCl-KCl, UCl₃-LiCl-KCl, LiCl + 1% Li₂O salt, FLiNaK salt, etc.) will be presented. Corrosion sensing using electrochemical methods as an online tool to monitor and safeguard the health of materials in molten salts, particularly in advanced nuclear energy systems and pyrochemical processing facilities, will also be highlighted.

IL-02

Electrochemical Energy Systems for Space Applications: Achievements and Experiences at VSSC-ISRO

M. Shaneeth

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Space missions involve one way and two way transportation to space, Space based observations, expeditions to extra terrestrial bodies, space habitation etc. These are accomplished without the crew or with crew. In this regard, Space Transportation Systems are the most visible elements and they consist of rockets, launch vehicles, satellites, spacecrafts, space probes, landers, rovers etc. Almost always, these systems operate autonomously and they require their own standalone energy sources onboard for station management, perform mission operations and for various payloads to function. Depending on the types of operation involved, power level, standby duration, recharge feasibility, duty cycle etc. vary. While harnessing solar energy is the most preferred method, secondary energy storage and distribution are essential in many cases. In addition, in specific cases, primary onboard energy sources other than solar energy are also necessary. The talk intends to provide an overview of different types of energy systems employed to meet the onboard electrical energy demand in space missions. The talk will also touch upon various achievements made at VSSC-ISRO in this regard and valuable experiences gained therein.

Ligand Isomerism-assisted Electrochemical Process Modulation

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While the central metal ion in molecular systems has conventionally been regarded as the primary driver of electrochemical activity, emerging evidence highlights the critical role of ligand nature and, notably, ligand isomerism in modulating electrochemical kinetics, mechanisms, and energy storage. In this talk, I will discuss how molecular-scale structural variations in ligands influence interfacial dynamics and reaction pathways, often rivaling or surpassing metal centered effects. These findings challenge conventional design strategies and emphasize the importance of considering ligand architecture as equally vital as the metal ion in molecular electrochemistry. A deeper understanding of these ligands effect will guide the development of highly efficient and tunable molecular platforms, enabling precise control over electrochemical processes and driving transformative breakthroughs across energy, catalysis, and materials science [1-5].

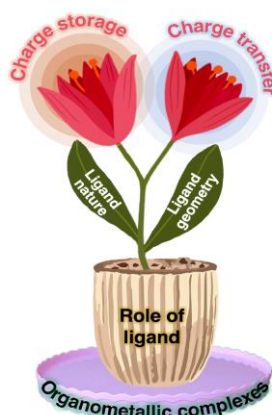


Figure 1. Electrochemical process switching through ligand isomerization.

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IL-04

Fe-Mn based Cathode for Na-ion Cathodes as Sustainable Alternative for Current Li-ion Technology

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Batteries, especially Li-ion battery technology, have revolutionized the way we store energy *vis-a-vis* electrons. Our mobile phones, laptops, and electric cars all the way up to batteries that store the renewable energy at solar and wind farms are products of this revolution. Several chemical challenges plague the further development of currently used Li-ion battery technology specially to make them compatible with the renewable future that we all envisage. Cost and sustainability of battery technology is the driving factor. The high abundance of Na and the competitive energy densities of Na insertion host materials compared to Li make Na-ion batteries the technology of choice. Low-cost Fe and Mn based cathode materials free from expensive elements such as Co, Ni are of primary interest. Unfortunately, even after five decades of research the development of practical Na-Fe-Mn-O based layered oxide cathodes remains elusive. This is due to their intrinsic large volume change, accompanied by in-plane and out-of-plane TM migrations during charging and discharging, which lead to capacity fading. A distinctive strategy would entail the elimination of certain transition metals, which are costly and heavy, in favour of less expensive non-redox-active elements such as Li/Mg/Zn. This approach involves the systematic introduction of disorder within the system. A disordered cathode is devoid of any driving force for TM migrations, thereby rendering the charge-discharge process reversible. This creates the possibility of achieving a long cycle life and inexpensive next-generation cathode materials.

Graphene-based Materials for Supercapacitor Application

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Renewable energy applications became an important area of research because of environmental concerns and limited fossil fuel resources. In this regard, electrochemical supercapacitor research is crucial due to its role in the short-term power supply, portable electronics etc. In this presentation, first, I will discuss a new quick graphene synthesis methodology developed in our laboratory by employing formic acid intercalation, which results in oxygen-functionalised graphene (OFG) [1]. OFG revealed excellent supercapacitor performance due to excellent electrical conductivity [1]. Thereafter, I will demonstrate by increasing oxygen functionalities, supercapacitor performance can be improved due to increased wettability [2]. Then, hydroxyl-rich few-layer graphene (HRFG) and nitrogen-oxygen functionalized grapheme (NOFG) will be demonstrated for three-electrode and two-electrode supercapacitor applications [3-4]. These examples will reveal the resolution of some of the key concerns for supercapacitor applications such as (a) ion accumulation inside the nanopores, (b) electrical conductivity, (c) ion diffusion, and (d) wettability towards the improvement of specific capacitance and energy density [1-4].

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Next-Gen Electroless Nickel Plating: Poised for Global Growth through Innovation and Expanding Applications

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Electroless plating, an autocatalytic method of depositing a uniform layer of metal alloy on a substrate without an external current, is on a path for significant expansion. The future of this versatile technology lies in its ability to meet the increasing demands of high-performance industries, its role in emerging technology, and its adaptation to growing environmental concerns. Key developments in alloy composition, composite materials & coating, and the process automation, are set to unlock new potential and propel its adoption across a wider range of applications. The market for electroless plating is projected to see steady growth, with the demand surging from key sectors such as Oil & Gas, Electronics, Automotive, Green Energy, and Aerospace. The purpose of this presentation is to look at the recent innovation in the Electroless Nickel (EN) plating technology which diversifies its applications in the emerging technology like semiconductors, Electric Vehicle (EV), 3D printing, drone technology, aerospace, defence, composite materials and green energy sectors.

In the first part of the presentation, the advantages and characteristics of EN-Polyalloy (Ni-X/Y-P/B), EN-Nanocomposite and customized multifunctional hybrid (Dual) plating are discussed in detail. The properties and performance of these coatings exceed the capability of any other plating technique alone. The second part focuses on how the unique properties of Electroless plating meet the specific requirements of emerging technology. The EN plating can achieve solid lubricity for the aerospace industry and meet the requirements for high thermal conductivity and corrosion resistance in EV, but often through specialized variations of the process. The synergy between electroless plating and 3D printing presents a transformative opportunity. The Electroless plating can be used to produce composite material by plating on granules of ceramics, graphite, diamond and other non-metallic materials, imparting conductivity, wettability, strength, and other metallic properties. The Automotive Sector is increasingly relying on electroless plating for corrosion and wear resistance on critical components like engine parts, fuel injectors, and braking systems. Similarly, the Textile and Energy sectors utilize electroless plating to enhance the durability and performance of vital parts, which are subjected to extreme conditions. All these applications have been illustrated in the paper with suitable examples. Finally, in conclusion, the future of electroless plating is bright and dynamic. Its ability to provide highly uniform and functional coatings on a wide variety of substrates, coupled with ongoing innovations in materials science and process technology, ensures its continued relevance and growth in an increasingly technologically advanced world.

Lithium-ion Battery Materials: From Molecules to Market

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Over the last several decades, rapid industrial growth and a surging global population have significantly increased the demand for energy. Our continued dependence on finite conventional sources—such as coal and crude oil—has not only raised environmental and social concerns, but also underscored the urgent need for cleaner, more sustainable alternatives. As renewable energy sources continue to expand, so does the importance of advanced energy storage solutions, with battery technology playing a central role. In this context, lithium-ion batteries (LIBs) have become the leading commercial option, valued for their high energy density, lightweight design, and cost-effectiveness. Their applications now span a wide spectrum, including portable electronics, grid-scale stationary storage, and electric vehicles (EVs). As a class of rechargeable (secondary) batteries, LIBs operate through the reversible shuttling of lithium ions between layered electrode materials, a process termed intercalation. This electrochemical mechanism underpins their advantageous high energy density and extended cycle life. The overall performance of a LIB—encompassing energy and power density, safety, and longevity—is intrinsically linked to the structural stability and synergistic function of its components: the electrode materials, electrolytes, additives, separators, and the chosen form factor. While their commercialization began in the 1990s for portable devices, the accelerating adoption of EVs has imposed a new set of rigorous standards. These include uncompromising safety, sufficient energy density for an extended driving range, fast-charging capability, durable cycle life, and a cost point that achieves parity with internal combustion engine vehicles. In response, contemporary research is dedicated to the design and development of innovative materials to meet these multifaceted requirements, paving the way for the next generation of high-performance and practically viable LIBs.

With a clear focus on innovation, sustainability, and global collaboration, Aditya Birla Group (ABG) is not just keeping pace with the evolving energy landscape, it is helping shape it. Part of ABG portfolio of global businesses, Hindalco & Birla Carbon are bringing their deep expertise to the forefront of this transformation. Our intensive R&D has produced a portfolio of advanced materials for lithium-ion batteries—from battery-grade aluminium foil and high-performance carbons to sustainable graphite solutions, structural components, bus bars, enclosures, and specialty alumina for separators. To propel this momentum further, we have commissioned a state-of-the-art fabrication and testing facility at the Aditya Birla Science and Technology Company (ABSTC), the Group's corporate R&D hub. This centre is designed to accelerate innovation by fostering deep collaboration within ABG businesses and with the broader external ecosystem, streamlining the development, evaluation, and qualification of next-generation materials, components, and assemblies. By connecting fundamental electrochemistry with real-world engineering, we demonstrate how ABG's comprehensive solutions tackle the pressing challenges of battery manufacturers, from performance optimization to strengthening domestic supply chains.

IL-08

AI Meets Electrochemistry

Sai Gautam Gopalakrishnan

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Innovation with advancement in materials is a key for several technological applications, including energy storage and energy harvesting. For example, developing better batteries is directly dependent on designing better electrode and electrolyte materials, which requires identification of new materials and/or optimisation of properties within existing materials. In this context, machine learning and artificial intelligence can play a key role in accelerating the design and discovery of materials for different applications. Hence, I will talk about some of the recent developments in machine learning, including graph neural networks and their utility in predicting materials properties accurately, modelling larger length-scale and longer time-scale phenomena within materials, and inverse design of materials. I will also use cases for each of the different advancements, which can result in practical performance improvements of devices that we use in our day-to-day application.

IL-09

Organic Frontiers: Bridging Molecular Design and Sustainable Energy Storage

Dhamodaran Santhanagopalan

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Organic materials (OMs) are gaining attention as a sustainable, transition metal-free alternative for energy storage technologies. They combine cost effectiveness with environmental compatibility, while offering moderate energy densities. In this presentation, I shall introduce the diverse ion-storage mechanisms of OMs, highlighting representative examples. At the same time, I will address critical challenges such as low operating voltage, poor electronic conductivity, solubility concerns, first charge incapability, low material loading, and short cycle life. Building on both published studies and our own research, I will focus on strategies that show promise in overcoming some of these limitations, particularly through innovative molecular design. Finally, I will present case studies that illustrate how these approaches can advance the performance of organic materials in both Li ion and Na ion storage systems.

Emerging Electrochemical R&D Areas in Batteries, Sensors, Sorting Technologies and Ion Exchange Membranes

Jegatha Nambi Krishnan

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Electrochemical engineering is the branch of engineering which describes the relationship between electrical energy and chemical change through charge transfer at electrode–electrolyte interfaces. Fundamental electrochemical techniques such as cyclic voltammetry (CV), electrochemical impedance spectroscopy (EIS), and stripping potentiometry (SP) enable characterization of redox behavior, interfacial resistance, diffusion processes, and reaction mechanisms. These techniques, together with principles of electrochemical kinetics, electrode design, and mass transport, form the foundation of electrochemical engineering and the development of controlled electrochemical systems for energy and sensing applications. During my session, our earlier studies related to various emerging electrochemical engineering R&D areas such as Lithium-Ion Batteries [1, 2], Complementary metal-oxide-semiconductor (CMOS) high density electrical impedance biosensor array for tumor cell detection [3, 4], Rapid microfluidic separation of magnetic beads through dielectrophoresis and magnetophoresis [5, 6], Microfluidic electrochemical sensor for the detection of heavy metal ions in water samples [7, 8], Fabrication and characterization of noble metal nanowires for nanogap devices [9] Au Nanoflowers for SERS substrates [10] and Amphiphilic-acid blend membranes for energy applications [11] will be discussed.

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Low Temperature PEM Fuel Cell - Fundamentals to Technology**Harshal Agarwal***CSIR-Central Electrochemical Research Institute (CECRI) Chennai Unit, Taramani, Chennai, India***E-mail: harshalagarwal.cecri@csir.res.in*

Hydrogen, the most abundant element, is key to global decarbonization. Fuel cells are electrochemical devices that efficiently convert hydrogen and oxygen into electricity, producing only water as a byproduct. This talk presents research and development work translating advanced Proton Exchange Membrane Fuel Cell (PEMFC) research into commercially viable hydrogen energy solutions. The foundational work focused on optimizing Membrane Electrode Assemblies (MEAs), an effort that has yielded a 100% improvement in fuel cell performance and a substantial 30% reduction in system costs. We detail the simulation-driven design methodologies and real-world validation techniques used to achieve these breakthroughs. Crucially, this work has successfully demonstrated technology transfer, notably of the automotive-grade LT-PEMFC to industry partners, bridging the gap between R&D and market deployment. The vision extends to accelerating the technology readiness level (TRL 6 to TRL 9), fostering robust public-private partnerships, and establishing vital accredited testing and certification infrastructure to make hydrogen a sustainable and commercially scalable solution.

Biosensors for Point-of-Care Applications**T. G. Satheesh Babu***Amrita Biosensor Research Lab, Amrita School of Engineering Coimbatore, Amrita Vishwa Vidyapeetham, India**Department of Chemistry, Amrita School of Physical Sciences Coimbatore, Amrita Vishwa Vidyapeetham, India**Amrita Biomedical Engineering Centre, Amrita School of Engineering Coimbatore, Amrita Vishwa Vidyapeetham, India***E-mail: tq_satheesh@cb.amrita.edu*

The growing global burden of non-communicable diseases (NCDs), cancer, and infectious pathogens demands a paradigm shift from centralized diagnostics to decentralized, patient-centric healthcare. In this talk we explore how the convergence of electrochemical sensing, lab-on-a-chip (LOC), wearable technologies, and microfluidic automation is redefining point-of-care (POC) diagnostics, particularly for resource-limited settings. The talk highlights advance in non-enzymatic electrochemical sensing strategies for clinically relevant metabolites and electrolytes enabling robust, low-cost, and multiplexed detection. Moving beyond conventional approaches, the integration of these sensors within miniaturized LOC and wearable platforms demonstrates how complex laboratory assays can be translated into portable devices capable of delivering rapid and reliable results at the patient's doorstep.

A key focus will be on the role of microfluidic components such as micromixers, microvalves, and programmable flow systems in enabling automated immunosensing, thereby minimizing user intervention while improving precision and scalability. The discussion will further extend to emerging nanomaterial enabled immunosensors for early cancer detection, achieving ultrasensitive quantification of biomarkers such as HER2 and CA125. In addition, recent breakthroughs in bacterial detection using carbon dot-based electrochemical sensors, as well as bacteriophage assisted platforms, will be presented, showcasing rapid and selective identification of clinically relevant pathogens. By bridging sensing, microfluidics, and device engineering, this talk underscores a unified vision for next-generation POC systems that are portable, affordable, and intelligent diagnostic tools. Such technologies hold transformative potential to democratize healthcare access and enable timely decision making across both rural and urban landscapes.

ORAL PRESENTATIONS

Electrochemical Power Sources

OP-01

Pulsed Potential Electrodeposition of Silver and Zinc for the Fabrication of Thin Film Rechargeable Batteries

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Printed micro-batteries are ideal for the energy demand of flexible and portable electronic applications. Silver-zinc micro-batteries have attracted research interest due to their high energy and power density, recyclability, and low self-discharge compared to other batteries. However, the major shortcoming reported is its limited cycling stability, especially due to the dissolution of zinc while testing in alkaline medium. Chronopotentiometry can be considered as the most appropriate electrodeposition technique for obtaining quality metal deposits, in which the optimized current step applied can increase the stability of the deposit. Along with this, the addition of additives to alkaline solution can restrict the dissolution of zinc by inhibiting the formation of $Zn(OH)_2$ and further increasing the stability of the device. This work presents the fabrication of a flexible electrodeposited silver-zinc battery using electrodeposited silver and zinc from suitable solutions by applying an optimised current step. The number of deposition cycles needed to obtain a stable deposit was also optimised. The battery was fabricated using electrodeposited silver and zinc as the positive and negative electrodes in which the final testing and analysis was done with PVA/KOH gel electrolyte. The incorporation of additives into the gel electrolyte helped to improve the cycling stability. The OCP of the fabricated device was 1.7 V with a high specific capacity of 102 mWh/g and a high specific energy and power density of 190 mWh/g and 32 mW/g.

OP-02

A Theoretical and Experimental Investigation of the Synergistic Effect of h-BN Nanosheets on the Enhancement of Composite Polymer Electrolyte for Lithium-ion Battery Applications

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DFT studies were carried out to understand the interaction between composite material and cation and anion utilizing Gaussian software. PVDF-HFP-PMMA based composite polymer membranes incorporating different concentrations (4-10%) of h-BN nanoparticles were fabricated via a simple solution casting technique. The fabricated membrane exhibited high tensile strength with nanopores, which aids in an ample amount of electrolyte absorption. A high ionic conductivity of $0.55 \times 10^{-4} \text{ S/cm}$ and transference number of 0.7 at room temperature were obtained with this membrane. A wide electrochemical stability window of 6 V was achieved with Li/CPE/SS cell. The fabricated $\text{LiFePO}_4/\text{CPE}/\text{Li}$ coin cell displayed a capacity of 130 mAh/g at 0.5 C rate with retention of 85% after 150 cycles. To our knowledge, a thin film (50 μm) of polymer nanocomposite of PVDF-HFP/PMMA/h-BN is fabricated as CPE for LIBs for the first time. This study demonstrates the optimized concentration of h-BN in PVDF-HFP/PMMA CPE through a simple process, achieving minimal thickness and enhanced physio- and electrochemical performance for potential application in next-generation energy storage systems.

OP-03

Enhanced Pseudocapacitive Performance of Hydrothermal Sn-engineered Bi_2O_3 for Supercapacitor Application

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A primary factor in attaining enhanced electrochemical efficiency is the advancement of a novel and sophisticated supercapacitor negative electrode. In this study, synthesis of Sn-doped α - Bi_2O_3 at different doping concentrations using an economically viable approach, namely hydrothermal technique, was assessed as a negative electrode in a hybrid supercapacitor. Structural, morphological and compositional analyses of the synthesised samples were carried out using XRD, FESEM, TEM and XPS. Their electrochemical performance was assessed in a three-electrode system employing 1 M Na_2SO_4 electrolyte within a -1.3 to 0.5 V potential window. Notably, α - Bi_2O_3 doped with 3 wt% Sn delivered a superior specific capacity. The fabricated β - MnO_2 || SB3 cell provided a remarkable specific capacity along with a capacity retention of more than 60% after 10000 GCD cycles.

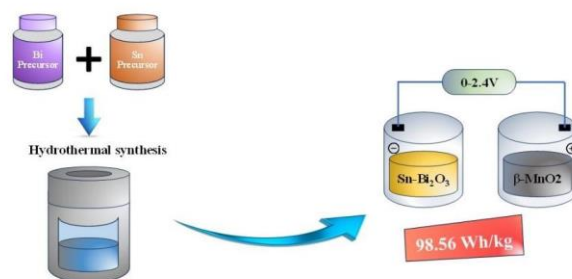


Figure 1. Schematic representation of Sn-doped α - Bi_2O_3 synthesis.

OP-04

Surfactant-regulated Bismuth–Nickel Oxide Nanomaterials for Efficient Supercapacitors

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Bismuth-nickel oxide is a prominent mixed-metal oxide electrode material (Bi_2O_3 & NiO) for electrochemical energy storage applications. The rapid evolution of energy storage technologies has elevated demand for electrode materials that ensure optimal energy density and long-term stability. In this work, three notable synthesis routes were performed to fabricate bismuth nickel oxide built on materials. In the first route, the direct synthesis of bismuth-nickel oxide (Bi_2O_3 & NiO) as a bulk material (Figure 1). Secondly, the co-reduction of metals by hexamine is used as a template agent to improve redox behaviour and charge transfer mechanisms. Thirdly, bismuth-nickel oxide was synthesised with poly(methyl methacrylate) (PMMA) as a sacrificial template, resulting in a porous structure. This electrode material exhibits an additional surface area and stability, which promotes

rapid charge-discharge cycles and high energy density. This study confirms the performance order in the three-electrode setup: bulk < hexamine < PMMA. The template controlled by hexamine significantly improved the electrochemical performance compared to the bulk material. In contrast, the PMMA-supported route achieved even higher specific capacitance and stability. This indicates template-controlled synthesis could enhance the electrochemical performance and long-term stability for next-generation energy storage devices.

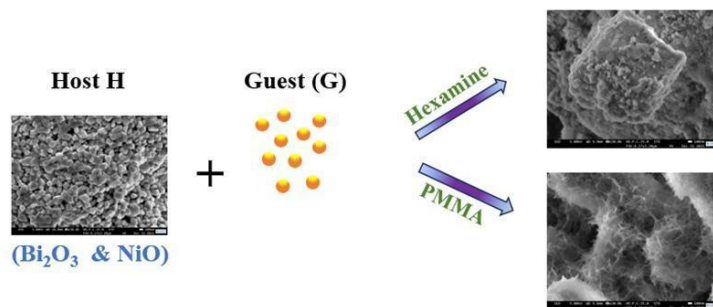


Figure 1. Schematic of template-controlled synthesis of bismuth nickel oxide.

OP-05

Ag₂MnO₂ as the Electrode Material for the Fabrication of High-performance Flexible Symmetric Supercapacitors

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The rapid advancement of wearable electronics has led to an increased demand for energy storage devices that are efficient, lightweight, compact and flexible. In this regard, high performance microsupercapacitors, whose performance remains unaffected when subject to mechanical deformations, have emerged as a compelling solution for powering these devices. Bimetallic layered oxides are an important class of electrode materials in the energy storage field due to the high structural integrity, increased redox active sites and the synergistic effect of the two metals to enhance the overall electrochemical performance of the device. Ag₂MnO₂ is such a layered bimetallic

oxide with Ag bilayers in between the MnO₂ slabs. This work presents the facile synthesis of Ag₂MnO₂ using urea hydrolysis method and its use as the electrode material in the fabrication of flexible symmetric supercapacitors. The material was thoroughly characterized and tested for its electrochemical performance. The fabricated supercapacitor consists of a screen-printed interdigitated electrode array with PVA-KOH as the gel electrolyte. A high areal capacitance of 403 mF cm⁻² was obtained at a current density of 1.5 mA cm⁻². The device exhibited a high energy density of 81 μWh cm⁻² at a power density of 0.9 mW cm⁻², while maintaining an energy density of 30.4 μWh cm⁻² at a high-power density of 3 mW cm⁻². The supercapacitor exhibited good capacitance retention even after 5000 charge-discharge cycles. The supercapacitor was tested for its flexibility at different bent positions and maintained its performance even under flexed conditions. These results indicate the viability of the microsupercapacitor for powering next-generation wearable devices.

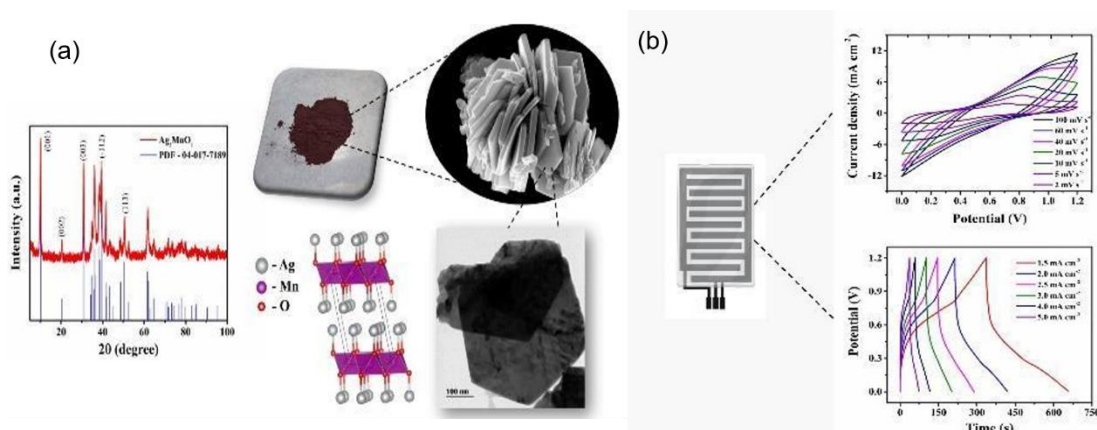


Figure 1. (a) Material characterization of Ag₂MnO₂. (b) Electrochemical characterization of the fabricated microsupercapacitor.

OP-06

Mechanically Reinforced Vanadium Hexacyanoferrate–PMMA Nanocomposite Electrodes for Stable and High-performance Supercapacitors

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Vanadium hexacyanoferrate (VHCF) is an emerging pseudocapacitive material; however, its practical application is often limited by poor mechanical stability and structural degradation during prolonged cycling. To overcome this limitation, a mechanically reinforced VHCF–PMMA nanocomposite electrode is developed, in which polymethyl methacrylate (PMMA) functions as a structural supporting matrix rather than a conventional binder. VHCF–PMMA composites with different

compositions were prepared and systematically investigated to establish the structure–composition–performance relationship. XRD, FESEM and HRTEM analyses confirm the successful incorporation and uniform confinement of VHCF nanocrystals within the PMMA framework, forming an interconnected composite architecture with high surface area and mesoporous characteristics. Electrochemical performance was evaluated in a three-electrode configuration using 1 M KOH electrolyte (Figure 1). Among the investigated compositions, the VHCF–PMMA (80:20) electrode exhibits the best pseudocapacitive behaviour, delivering a high specific capacitance of 575 F g⁻¹ at 10 mV s⁻¹ and 455 F g⁻¹ at 0.5 A g⁻¹, along with a low internal resistance and reversible redox response. The optimized electrode retains 72% of its initial capacitance after 5000 cycles, indicating improved cycling durability. Furthermore, a symmetric supercapacitor device fabricated using the optimized electrodes delivers a specific capacitance of 119 F g⁻¹ and shows 67% capacitance retention after long-term cycling. The device achieves a maximum energy density of 24 Wh kg⁻¹ and a high-power density of 3015 W kg⁻¹. The improved electrochemical performance is mainly attributed to the mechanically robust PMMA network, which suppresses structural degradation of VHCF and preserves electrochemically active sites during repeated redox cycling.

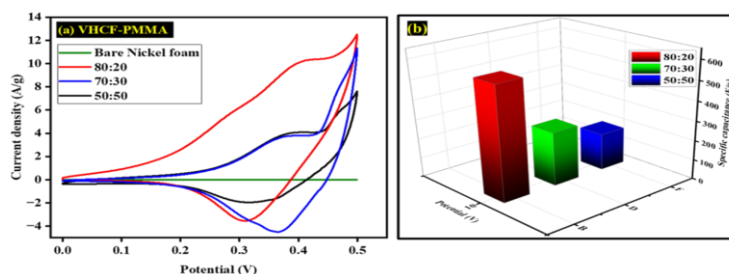


Figure 1. (a) CV curves of VHCF-PMMA nanocomposites. (b) Specific capacitance values of VHCF-PMMA electrodes evaluated at a scan rate of 10 mV/s.

OP-07

Synthesis and Electrochemical Performance of a Novel CuCoTe_x/Mn₃O₄/MXene Ternary Nanocomposite Electrode for Hybrid-supercapacitor

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The increasing global shift towards renewable energy emphasizes the urgent need for improved energy storage technologies, particularly in supercapacitors, where the advanced electrode materials can significantly enhance the performance. The rise of metal chalcogenides as electrode material in supercapacitors offers promising electrochemical conductivity with abundant electroactive sites.

However, the traditional metal chalcogenides cannot meet the requirements for high energy density due to their inherent low conductivity and slower ionic diffusion channels which is necessary for commercial viability due to their inherent low conductivity and slower ionic diffusion channels. Among the different metal chalcogenide materials being studied, bimetallic copper-cobalt telluride (CuCoTe_x) is gaining attention due to its high specific capacitance, excellent conductivity, and strong electrochemical stability. Despite these promising properties, the application of CuCoTe_x as an electrode material in supercapacitors remains relatively underexplored. In this study, a novel ternary nanocomposite consisting of copper cobalt telluride (CuCoTe_x), manganese oxide (Mn_3O_4), and titanium carbide ($\text{Ti}_3\text{C}_2\text{T}_x$) MXene was synthesized via a one-pot method for the first time as an electrode material for supercapacitors (Figure 1). This new nanocomposite leverages the strengths of each constituent: CuCoTe_x provides superior conductivity and electrochemical reactivity, Mn_3O_4 offers rich redox chemistry and high theoretical capacitance, and $\text{Ti}_3\text{C}_2\text{T}_x$ MXene delivers exceptional conductivity and mechanical stability. The ternary nanocomposite achieved a specific capacitance of 127 F/g at 1 mA/cm², surpassing the 100 F/g of CuCoTe_x alone, and demonstrated an energy density of 6.2 Wh/kg and power density of 54 W/kg. It also exhibited excellent cyclic stability with 91 % retention after 2500 cycles. The incorporation of MXene further optimizes charge transport and enhances the structural integrity of the nanocomposite, addressing the conductivity limitations of Mn_3O_4 . These findings represent the first successful integration of CuCoTe_x , Mn_3O_4 , and MXene in a single hybrid electrode and offer a scalable pathway towards high-performance, durable energy storage systems for renewable energy applications.

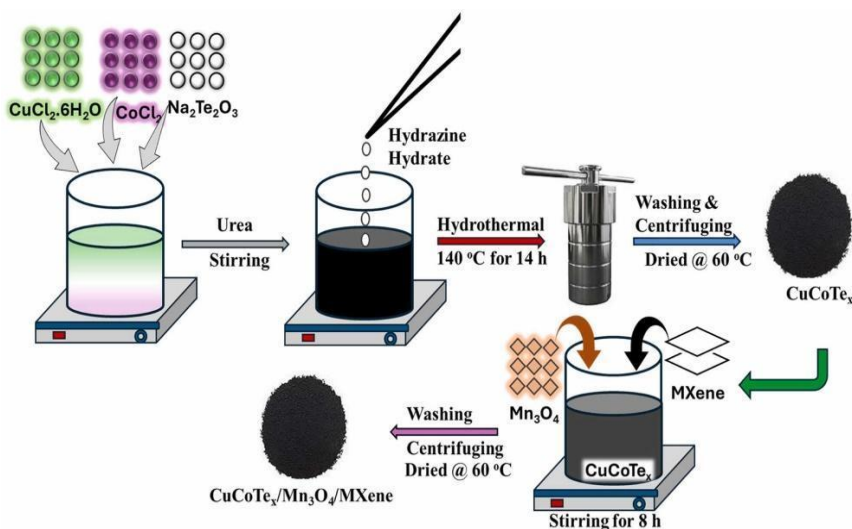


Figure 1. Schematic representation of the synthesis of MXene nanocomposites.

OP-08

Mesoporous Zinc Vanadate as a Superior Electrode for High-power-density Supercapacitors

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The escalating worldwide pursuit of sustainable energy storage solutions is driving the development of next-generation electrode materials with superior electrochemical performance and environmental compatibility. This study presents the optimized hydrothermal synthesis of zinc vanadate ($Zn_3V_2O_8$, ZVO) nanostructures, engineered as high-performance supercapacitor electrodes. The ZVO exhibits a hierarchical carnation-like architecture composed of densely packed nanosheets, delivering a high specific surface area ($16 \text{ m}^2 \text{ g}^{-1}$) and mesoporous networks that enhance ion transport and redox activity. Electrochemical testing in a three-electrode configuration using an eco-friendly aqueous electrolyte (3 M KOH) attained a high specific capacitance (CS) of 676 F/g at a current density of 0.5 A/g. Additionally, the fabricated symmetric supercapacitor with nano-ZVO exhibited energy and power densities of 11 Wh kg^{-1} and 400 W kg^{-1} , while $\sim 85\%$ of the capacitance was retained after 5000 charge and discharge cycles, reflecting good cyclic stability. Structural and spectroscopic analyses elucidate that oxygen vacancies and enhanced porosity support improved charge-transfer kinetics and Faradaic redox activity, providing mechanistic insights into ZVO's structure-property relationship. The practical viability of the symmetric supercapacitor is validated through consistent powering of portable low-power electronic devices. This work highlights the novelty of mesoporous nano-ZVO as a scalable, economical, and sustainable electrode material, paving the way for promising developments in next-generation supercapacitor technologies.

OP-09

Entropy-engineered Layered Double Hydroxide-derived High-entropy Alloy Cathodes for Zinc-air Batteries

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Zinc-air battery (ZAB), a battery beyond lithium-ion battery, has become the one of the leading storage technologies because of their high theoretical energy density, abundant raw materials,

environmental-friendliness, and intrinsic safety. Because of the complexity of oxygen reduction and oxygen evolution reactions during discharging and charging respectively, effective electrocatalysts are vital for energy efficient ZABs. Herein, we have developed a high-entropy layered double hydroxide (HELDH) precursor strategy to produce a high-entropy alloy (HEA) based on MnFeCoNiCu that is uniformly integrated with nitrogen-doped carbon nanotubes. The best optimized catalyst, HEA 900, showed superior bifunctional oxygen activity with a low bifunctionality index (ΔE) of 0.89 V, high stability, and exceptional durability. Outstanding metrics, such as an OCV of 1.53 V, a peak power density of 186 mW/cm², and a near-theoretical capacity of 801 mAh/g Zn, were demonstrated by HEA 900 when it was used in zinc-air batteries. More significantly, the battery maintained exceptional reversibility under extended high depth-of-discharge cycling of up to 10 h per cycle and supported more than 3300 short-cycle charge-discharge operations. This new HELDH-derived HEA method creates a new design paradigm for entropy-engineered catalysts, which allows extremely strong ZAB to work even in very difficult deep-discharge conditions.

OP-10

Flexible Solid-state Bi₂S₃//Ni₃S₂ Hybrid Supercapacitor *via* Pulsed Laser Deposition: Enabling a Wide Operating Voltage Window with High Energy Density

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The flexible solid-state hybrid supercapacitor (HSC) is fabricated by combining a battery-type bismuth sulfide (Bi₂S₃) anode with a pseudocapacitive nickel sulfide (Ni₃S₂) cathode, both deposited as thin films via pulsed laser deposition (PLD). By using PLD, it precisely controls the film thickness, uniformly thin coating onto the substrate, and tunes the nanostructures. Herein, HSC was fabricated using PVA-KOH gel electrolyte, and the device voltage reached up to 1.7 V. The higher voltage is attributed to the combination of battery type and pseudocapacitive electrodes, and the device delivers the areal capacitance of 232 mF cm⁻² at 1 mA cm⁻². Additionally, it has exhibited superior cycling stability, which is 90% of capacitance retention and 97% of coulombic efficiency over 10,000 charge-discharge cycles, showing the remarkable durability of the device. Notably, this device obtained a high specific energy of 93 mWh cm⁻² and a specific power of 2 mW cm⁻². The fabricated device demonstrates that the strategic combination of battery-type and pseudocapacitive metal sulfide electrodes provide high-energy, portable power applications and high-power flexible energy storage platforms for wearable electronics.

OP-11

2D-ZIF-L MOF and NiMo-LDH Composites for High-power Asymmetric Supercapacitors and Self-powered Systems

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Multifunctional materials capable of efficiently storing energy while harvesting mechanical energy are central to the development of self-sufficient, self-powered electronic systems. Yet, most reported materials either exhibit limited multifunctionality or rely heavily on device-level integration to achieve dual functionality. In this work, a hierarchically coupled 2D-2D Ni-Mo layered double hydroxide (LDH)/leaf-like Zn-ZIF-L heterostructure is synthesized through a simple in-situ growth approach. The leaf-like Zn-ZIF-L framework provides a porous and mechanically robust scaffold that supports the uniform growth of ultrathin NiMo-LDH nanosheets, effectively suppressing restacking and enabling continuous pathways for ion and charge transport. Owing to this architecture, the optimized NiMo-LDH/ZIF-L (0.5 g) electrode delivers a high specific capacitance of 1327 F g^{-1} , low charge-transfer resistance, and rapid ion transport governed by a mixed capacitive-diffusion process ($b \approx 0.65$, with $\sim 79\%$ capacitive contribution). When assembled into a flexible asymmetric supercapacitor with reduced graphene oxide, the device operates stably over a 1.3 V window, achieving an energy density of 22 Wh kg^{-1} at a power density of 1300 W kg^{-1} with excellent cycling durability. Beyond electrochemical storage, the same heterostructure acts as an effective tribo-positive material, generating $\sim 600 \text{ V}$, $\sim 270 \mu\text{A}$, and a peak power density of 19 W m^{-2} in a vertical contact-separation triboelectric nanogenerator. Together, these results demonstrate that LDH-MOF 2D heterojunctions can function as intrinsically multifunctional materials, providing a unified materials-level strategy for integrated energy harvesting, storage, and next-generation self-powered systems.

OP-12

Monoclinic BiVO₄ Nanosphere for High-performance Symmetric and Asymmetric Supercapacitor

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As fossil fuel resources decline, the world relies more on efficient, sustainable energy storage devices, where supercapacitors stand out among electrochemical energy storage devices. Supercapacitors are characterized by their ability to charge and discharge at ultrafast rates, making them highly suitable

for applications that demand quick energy delivery. A facile one step hydrothermal method was employed to synthesize BiVO₄ nanoparticles. The designed BiVO₄ demonstrated enhanced specific capacitance, attributed to the enhanced conductivity and optimized nanostructures. The observed decrease in R_{ct} value from 3.3 Ω in pristine BiVO₄ to 2.2 Ω upon Co-BiVO₄ demonstrates improved electrical conductivity and faster charge transfer. This enhancement is directly associated with the increased specific capacitance of the Co-doped BiVO₄ electrode. The electrode achieved a high specific capacitance of 825 F/g at a current density of 1 A g⁻¹, retaining 89% capacitance after 5,000 cycles at 10 A g⁻¹ in a three-electrode system. Asymmetric supercapacitors were fabricated using carbon as the negative electrode and BiVO₄ as the positive electrode. The SSC delivered an energy density of 45 Wh/kg at a power density of 785 W/kg with a retention rate of roughly 82% after 10,000 cycles at 10 A/g. The ASC delivered an energy density of 32 Wh/kg at a power density of 807 W/kg with a retention rate of roughly 84% after 10,000 cycles at 10 A g⁻¹.

OP-13

Synergistic Effect of NaTiPO₄F/MnO₂ Electrodes with Improved Super Capacitive Behavior for Enhanced Electrochemical Energy Storage Performance

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Phosphate-based electrode materials have attracted increasing attention of energy storage applications owing to their structural stability and favorable electrochemical properties. In this work, sodium titanium fluorophosphate (NaTiPO₄F), a battery-type material, was integrated with pseudocapacitive manganese dioxide (MnO₂) to enhance overall capacitive behavior. NaTiPO₄F/MnO₂ composites were synthesized via a co-precipitation method in three weight ratios (50:50, 70:30, and 80:20). Structural and morphological characterizations were carried out using XRD, FESEM, HRTEM, BET, DLS, and XPS analyses. XRD and SAED confirmed the crystalline nature of the composites, while FESEM revealed agglomerated granular clusters. BET analysis provided surface area and pore size distributions, and DLS indicated the average particle size. XPS studies before and after cycling demonstrated stable surface oxidation states, confirming good electrochemical durability. Electrochemical performances were evaluated in a three-electrode configuration using 1 M KOH electrolyte. Among the investigated compositions, the NaTiPO₄F/MnO₂ (50:50) electrode exhibited superior performance, delivering a maximum specific capacitance of 620 F g⁻¹ at 10 mV s⁻¹ (CV) and 564 F g⁻¹ at 3 A g⁻¹ (GCD), with 78% capacitance retention after 5000 cycles. Furthermore, an asymmetric NaTiPO₄F/MnO₂ // activated carbon (AC) device demonstrated a high energy density of 21 Wh kg⁻¹ at a power density of 1050 W kg⁻¹, and a maximum power density of 6989 W kg⁻¹ with an energy density of 3 Whkg⁻¹ (Figure 1). The device retained 67% capacitance and exhibited a Coulombic efficiency of 86% after 5000 charge–discharge cycles.

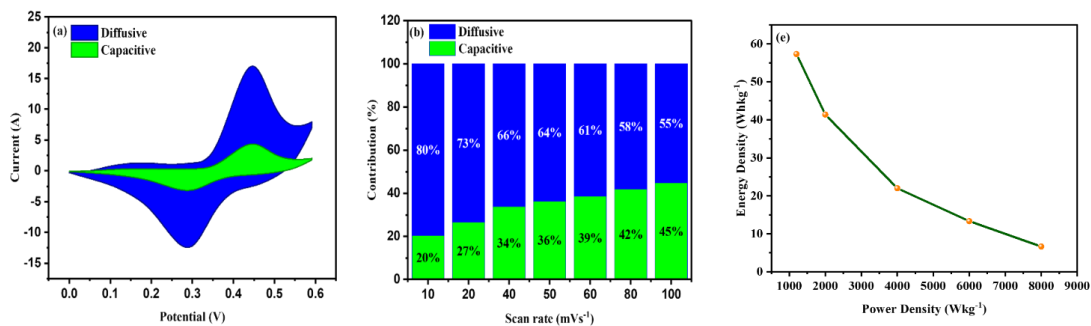


Figure 1. (a) Cyclic voltammograms highlighting the diffusive and capacitive contribution, and (b) its associated contribution in percentage as histogram. (c) Ragone plot.

Materials Electrochemistry and Electrocatalysis

OP-14

Harnessing Single Atomic FeB₂N₂ Sites toward Highly Selective Electrochemical Nitrogen Reduction

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Electrocatalytic nitrogen reduction reaction (eNRR) under ambient conditions offers a sustainable pathway for decentralised ammonia production; however, it remains fundamentally challenged by the high activation barrier of dinitrogen and the competitive hydrogen evolution reaction (HER). Atomically dispersed Fe–N–C catalysts with Fe–N₄ active sites exhibit eNRR activity, although their selectivity toward ammonia synthesis remains unsatisfactory [1,2]. Herein, we employed a boron-assisted coordination strategy to precisely tailor the electronic structure of the Fe centres and construct FeB₂N₂ sites embedded within a conductive carbon matrix. This integrated design (denoted as FeBNC) achieved an ammonia yield rate of 31 $\mu\text{g h}^{-1} \text{mg}_{\text{cat}}^{-1}$, with a Faradaic efficiency of 31% at –0.2 V vs RHE. Experimental studies suggest that FeN_x sites serve as catalytically active centres for eNRR, while the inclusion of boron atoms plays a crucial role in significantly reducing the overpotential and enhancing the selectivity of Fe-based systems. This study demonstrates the power of coupled heteroatom and atomic metal engineering within carbon frameworks, offering new insights into the rational design of advanced eNRR catalysts (Figure 1).

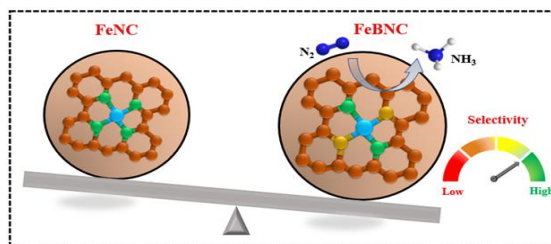


Figure 1. Schematic representation of the superior NRR activity of FeBNC over FeNC.

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Thin-film Hydrovoltaic Device based on Surface Charge-engineered Activated Carbon-PVDF Composite

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In the realm of sustainable and eco-friendly power technology, energy harvesting from hydrovoltaic devices for power generation has garnered a lot of attention. In this work, a thin-film hydrovoltaic power generator with low mass loading operating in ambient circumstances is shown. The creation of a low-cost, high-performance hydrovoltaic power generator using a composite material made of polyvinylidene fluoride (PVDF) and activated carbon (AC) obtained from bio-derived sources has led to the proposal of a revolutionary design. Despite being hydrophobic, the PVDF was added to take advantage of its capacity to increase the material's electronegativity when it interacts with solvents and functions as a binder, producing hydrovoltaic effect. A peak output of more than 1 V and an average output were effectively generated by the device that resulted from optimising the weight ratio of PVDF with AC. The device that resulted from optimising the weight ratio of PVDF with AC was able to generate a maximum power output of 14 $\mu\text{W}/\text{cm}^2$, an average current of 50 μA , and a peak output exceeding 1 V. Dropping a single drop of water on top of the device after a predetermined length of time can simultaneously sustain the generated electricity. The device demonstrated its potential for real-time and practical applications by presenting the critical capacity to resume power output after 60 days of inactivity.

OP-16

Surface-engineered Pt–Ni Catalysts for Improved Electrochemical Performance in Direct Ammonia Fuel cells

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We have reported a nanostructured platinum-nickel (Pt–Ni) alloy catalyst as an efficient electrocatalyst for ammonia oxidation, addressing key challenges in direct ammonia fuel cells (DAFCs). The global transition toward clean and sustainable energy technologies has intensified interest in carbon-free energy carriers, where ammonia has emerged as a promising alternative to hydrogen due to its high volumetric energy density, high hydrogen content, and ease of storage and transportation. Despite these advantages, the practical implementation of DAFCs is severely hindered by the sluggish kinetics of the ammonia oxidation reaction (AOR). This limitation arises mainly from the formation and accumulation of strongly adsorbed reaction intermediates on the catalyst surface, leading to catalyst poisoning and reduced activity. In our work, we have developed a flower-like Pt–Ni alloy nanostructure with an enhanced surface-to-volume ratio and a well-ordered atomic arrangement. This tailored architecture improves reactant accessibility, mitigates intermediate poisoning, and promotes efficient low-temperature ammonia oxidation. The detailed synthesis strategy, structural characterization, and electrochemical performance evaluation of the Pt–Ni catalyst will be presented at the conference.

OP-17

Metal Organic-covalent Organic Framework (MOCOF) as a Novel Porous Hybrid Material for Room Temperature NO₂ Gas Sensor

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Environmental pollution poses a significant threat to human beings through health hazards, ecosystem damage, and seasonal changes. Early detection of these hazardous and flammable gases has become crucial in ensuring public and environmental safety. Therefore, the demand for the gas

sensor is at an all-time high. But still, facing challenges with room-temperature gas sensors due to high operating temperatures, poor selectivity, and slow response/recovery times. Hence, material plays a crucial role in gas sensing properties. Herein, we report the design and synthesis of novel material MOCOF for room temperature NO_2 detection. The hybrid integration of metal nodes with covalent organic frameworks provides a synergistic combination of high surface area, tunable porosity, abundant active sites, and enhanced charge transport pathways. The chemiresistive sensor operates based on resistance variations induced by gas adsorption–desorption interactions on the material surface, enabling rapid response and recovery behaviour (Figure 1). The sensor performance was systematically evaluated in terms of sensitivity, selectivity, response/recovery time, repeatability, and long-term stability under exposure to various interfering gases. Detailed sensing metrics and comparative analysis will be presented at the conference.

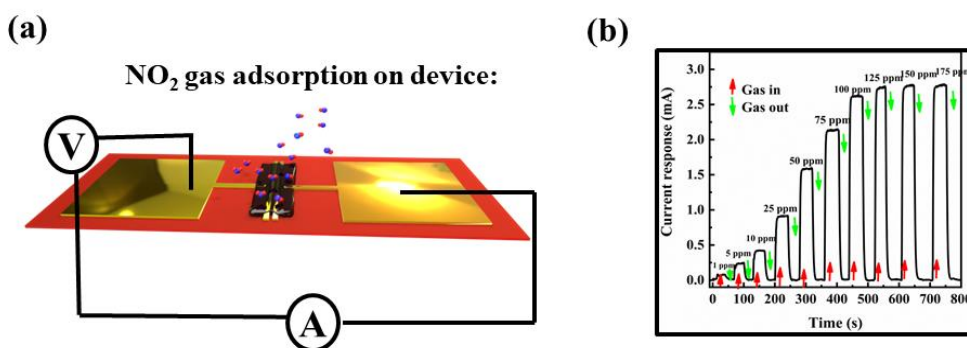


Figure 1. (a) Schematic representation of gas sensing device. (b) Current response for different NO_2 gas sensor

OP-18

Li^+ -intercalated $\text{WSe}_2\text{-CoFeOOH}$ Heterostructure for Efficient and Durable Electrochemical Saltwater Splitting

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Electrochemical water splitting is considered as one of the promising routes for sustainable hydrogen (H_2) production. However, it remains challenging due to sluggish reaction kinetics because of the competing chlorine (Cl_2) evolution and poor catalyst stability in saline environments. Herein, we report design of a Li^+ -intercalated $\text{WSe}_2\text{-CoFeOOH}$ ($\text{Li-WSe}_2\text{-CoFeOOH}$) heterostructure as a highly efficient and durable electrocatalyst for overall saltwater splitting. The heterostructure integrates layered WSe_2 nanosheets (NSs) with catalytically active CoFeOOH , while Li^+ incorporation effectively

expands the interlayer spacing (ILs) of WSe_2 , modulates its electronic structure and promotes charge transfer process. $\text{Li-WSe}_2\text{-CoFeOOH}$ has been characterized by using different spectroscopic and microscopic techniques. Furthermore, coupling between WSe_2 and CoFeOOH shows synergistic improvement in the catalytic performance towards both hydrogen evolution reaction (HER) and oxygen evolution reaction (OER). The $\text{Li-WSe}_2\text{-CoFeOOH}$ electrode exhibits low overpotentials, low Tafel slope, fast reaction kinetics and excellent long-term stability for 48 h in simulated seawater electrolytes. This work demonstrates that interfacial engineering combined with alkali ion (Li^+) intercalation is an effective strategy to overcome the fundamental limitations of saltwater electrolysis. The proposed design of the electrocatalyst provides valuable insights into developing high-performance, stable catalysts for practical seawater splitting (Figure 1).

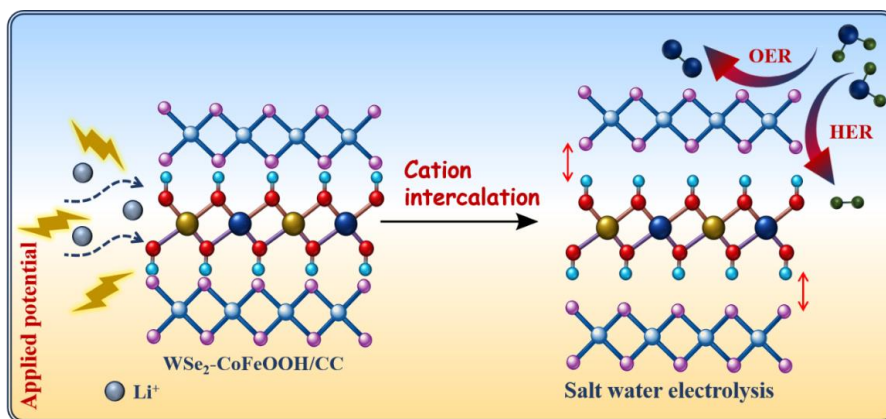


Figure 1. Schematic representation of cation-enabled sea water electrolysis.

OP-19

Tailored Cation High-entropy Metal-organic Frameworks towards Advanced Oxygen Evolution

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High-entropy metal organic frameworks (HE-MOFs) have emerged as a versatile class of materials due to their compositional flexibility and tunable physicochemical properties. In this study, we explore an Al-Zn-based high-entropy MOF for its application in the oxygen evolution reaction (OER), a crucial anodic process in water electrolysis that suffers from sluggish reaction kinetics. The designed HE-MOF features a two-dimensional array architecture that enhances electrical conductivity and facilitates

efficient charge transfer. The presence of multiple metal centres within a single framework generates synergistic interactions, increases active site availability, and promotes favourable reaction pathways. As a result, the material exhibits enhanced electrocatalytic activity and excellent stability under alkaline conditions. This work demonstrates that high-entropy engineering combined with structural optimization is an effective strategy for developing advanced OER electrocatalysts for sustainable hydrogen production.

OP-20

Magneto-Electrocatalysis of Co-Ni Alloy Electrodeposits for Hydrogen Evolution Reactions

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Co–Ni alloy with various compositions were fabricated through a one-step electrodeposition process and evaluated as electrocatalysts for the hydrogen evolution reaction (HER). The electrocatalytic behaviour of the deposited alloys were systematically investigated under both conventional electrocatalytic and magneto-electrocatalytic (0.3 T magnetic field strength) conditions. The Co–Ni alloy exhibited excellent HER activity, which was further enhanced upon the application of an external magnetic field. The magnetic field significantly improves the electron-transfer kinetics, reducing the HER overpotential from 141 mV to 114 mV and increasing the current density from 511 to 533 mA. cm⁻². Electrochemical impedance spectroscopy (EIS) further confirmed the magnetic-field-induced enhancement by showing a decrease in charge-transfer resistance (R_{ct}) from 30 Ω .cm² to 17 Ω .cm². Field-emission scanning electron microscopy (FESEM) revealed composition-dependent surface morphologies, transitioning from micro-conical and rough architectures in Co-rich alloys to smoother surfaces in Ni-rich compositions. X-ray photoelectron spectroscopy (XPS) provided insights into the surface chemistry, demonstrating composition-dependent shifts in Co and Ni binding energies. This study highlights the effectiveness of magneto-electrocatalysis in boosting the HER performance of electrodeposited Co–Ni alloys and emphasizes the potential of integrating external magnetic fields to achieve superior electrocatalytic activities.

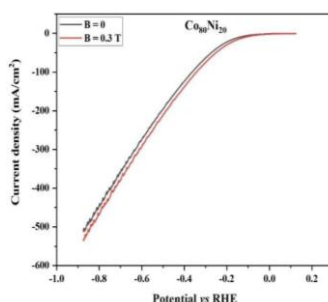


Figure 1. Linear sweep voltammetry curves of HER on electrodeposited Co₈₀Ni₂₀.

OP-21

Oxygen Evolution Reaction Kinetics Facilitated by Porous IrO₂ in PEM Water Electrolysis

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Proton exchange membrane (PEM) water electrolyzers are a matured electrolyser technology, characterized by high hydrogen evolution rates, enhanced energy density, and excellent operational flexibility. It consists of the hydrogen evolution reaction (HER) at the cathode and oxygen evolution reaction (OER) at the anode using standard benchmark catalysts such as Pt/C (cathode) and IrO₂ (anode). Due to the sluggish four electron transfer kinetics of OER the higher amount of catalyst loading is recommended to cross the energy barrier. Here, the development of an efficient, low Ir-loaded electrocatalyst is required for OER to enhance large-scale hydrogen production in a cost-effective manner. Accordingly, this work focuses on the surfactant assisted strategies in tuning P-IrO₂ for effectively utilizing the electrocatalyst for the oxygen evolution reaction. The incorporation of conventional Adam fusion method with the template assisted strategy improved the electrochemical performance. As a consequence of surfactant templating, the synthesized porous IrO₂ (P-IrO₂) has precise control of morphology and a high surface area that effectively enhances the mass transport and high accessibility of the active sites. The optimized P-IrO₂ demonstrates improved OER activity in acidic medium with the overpotential of 289 mV at 10 mA/cm² and the Tafel slope of 42 mV/dec, which is comparable with commercial IrO₂.

OP-22

Next-Generation Photoelectrochemical Flow Reactors for Integrated Bio-oil Valorisation and CO₂ Reduction

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The development of energy-efficient and sustainable routes for upgrading biomass-derived bio-oil is critical for producing renewable liquid fuels and reducing carbon emissions. Bio-oil obtained from lignocellulosic biomass is rich in oxygenated compounds, which limits its direct application as a fuel and necessitates selective deoxygenation and upgrading under mild conditions. Here, we report the design and performance of a photoelectrochemical (PEC) flow reactor for light-driven bio-oil

valorisation, integrated with electrochemical reduction reactions under continuous-flow operation. The engineered PEC flow reactor couples a semiconductor photoelectrode with a catalytic counter electrode to enable simultaneous photogenerated charge utilization and electrochemical upgrading of bio-oil components, while minimizing external hydrogen input. Continuous-flow operation enhances mass transport, improves reaction selectivity, and mitigates catalyst deactivation compared to conventional batch systems. Under simulated solar illumination, the reactor demonstrates enhanced conversion efficiency of oxygenated bio-oil model compounds toward value-added fuels and chemicals, with improved energy efficiency relative to purely thermocatalytic and electrochemical pathways. Furthermore, the reactor architecture enables integration with CO₂ reduction at the counter electrode, allowing concurrent biomass valorisation and carbon utilization within a single platform. Stability studies reveal sustained performance under extended operation, highlighting the potential of the PEC flow configuration for scalable biomass upgrading. This work establishes a proof-of-concept for next-generation PEC flow reactors as an integrated, low-energy pathway for bio-oil upgrading and carbon-neutral fuel production.

OP-23

Tuning the Electrocatalytic Activity of NiO via Fluorine Doping for the Enhanced Oxygen Evolution Reactions

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Fluorine-doped nickel oxides (NiO) were synthesised with varying fluorine concentrations to investigate their electrocatalytic activity. The crystal phase of the materials has been confirmed by XRD and TEM analysis. The surface topography was also evaluated by the FE-SEM analysis. Among all the synthesised samples, the fluorine-doped sample with 0.02 M fluorine, annealed at 500°C, exhibits superior electrocatalytic activity in the oxygen evolution reaction (OER). For instance, NF52 demonstrated excellent performance in the oxygen evolution reaction. The best-performing OER electrocatalyst of NF52 delivers the minimum overpotential of 289 mV to reach a current density of 10 mA cm⁻², with excellent electrode stability of 150 hours at the same current density. The improvement in performance is mainly due to the optimal combination of crystallinity, defect density (Ni³⁺/oxygen vacancies), and electronic conductivity; partial loss of fluorine/defects; and a reduction in active surface area and redox sites. So, the F-NiO is considered an excellent electrocatalyst for OER applications.

Tracking Carbon Health in Flow Electrode Capacitive Deionization Systems

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Flow electrode capacitive deionization (FCDI) has emerged as an alternative process for salt removal, nutrient recovery, and selective ion separation. The flow electrode, consisting of activated carbon, conductive carbon, and a supporting electrolyte, is the critical component in the FCDI cell systems, as it facilitates cyclic charge storage due to its continuous flow in the electrode chamber. The stability of 5 wt% carbon slurry employed in the FCDI system under isolated closed cycle (ICC) operation was investigated at applied voltages of 1.2, 2.0, and 3.0 V, while the conductivity of the treated water was continuously monitored over a 30-hour duration to evaluate system performance and electrode durability. The findings demonstrate that the operating voltage plays a critical role in determining flow electrode stability and long-term performance behaviour. A stable conductivity trend was observed at 2.0 V, whereas noticeable fluctuations occurred at both lower (1.2 V) and higher (3.0 V) operating voltages. At a fixed salt removal efficiency of 50%, the FCDI cell system operated at 3 V yielded an average energy consumption of 0.1 kWh mol⁻¹, which is substantially higher than the cell operation at 2 V (0.03 kWh mol⁻¹). The operation of the FCDI system beyond 2 V required higher energy without yielding consistent salt removal performance. The electrochemical assessment of the flow electrode indicates significant electrode ageing and deterioration due to surface modification and carbon oxidation reactions, with a marked decline in the carbon slurry capacitance from 80 to 27 F g⁻¹ and a reduction in surface area at the anode side from 932 to 624 m² g⁻¹ (Figure 1). These physicochemical changes affect the rheological and hydrodynamic characteristics of the flow electrode depending on its polarity during its long-term operation.

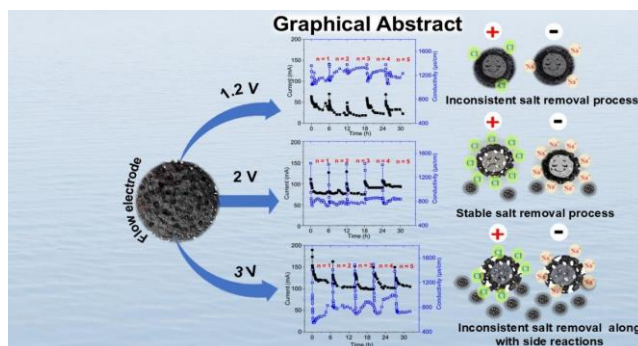


Figure 1. Schematic representation of electrochemical assessment of flow electrode for capacitive deionization.

Development of Efficient Hydrocarbon Ion-exchange Membranes for Proton Exchange Membrane Water Electrolysers

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Ion-exchange membranes function as essential materials in numerous applications, including the deionization of aqueous solutions as well as in energy conversion and energy storage systems and devices. One of the emerging and technologically important applications of ion exchange membranes is water electrolysis that produces high-purity hydrogen, a clean and sustainable energy-carrier which is envisioned as the future's fuel. Water electrolyzers utilize solid polymer electrolyte (SPE) membranes, which can be either a proton exchange membrane (PEM) or hydroxide exchange membrane (HEM). PEMs contain negatively charged functional groups, which selectively transport H⁺ ions, whereas anion exchange membranes (AEMs) possess positively charged functional groups, which selectively transport OH⁻ ions [1]. The chemical, thermal, and mechanical properties, together with ionic conductivity, are key parameters that determine membrane performance in electrolyzers. Optimizing these properties, while ensuring resistance to chemical degradation, remains a major challenge in the development of efficient and durable ion-exchange membranes. Therefore, enhancing ionic conductivity, ion-selectivity and overall stability is a major challenge in achieving a high-performance ion-exchange membrane [2]. In this work, we focus on the development of polystyrene-based hydrocarbon ion-exchange membranes (Figure 1) with enhanced ionic conductivity and long-term stability. This study involves the systematic synthesis of PEMs from styrene-containing aromatic monomers, membrane fabrication, comprehensive physicochemical characterization and evaluation of their performance in water electrolysis applications.

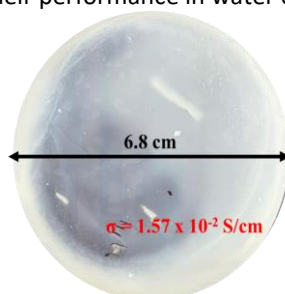


Figure 1. Photographic image of polystyrene proton exchange membrane.

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Green Solid-State Electrolytes as Nafion Alternatives for Next-Generation Proton Exchange Membrane Fuel Cell

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The increasing global energy demand and environmental concerns, such as CO₂ emissions and pollution, have accelerated the need for clean and sustainable energy technologies. Among various energy conversion systems, Proton Exchange Membrane Fuel Cells (PEMFCs) have emerged as promising candidates due to their high efficiency and eco-friendly operation. However, their performance largely depends on the efficiency of the proton exchange membrane, which facilitates proton transport within the device. In this work, a sustainable proton-conducting solid-state bio-membrane is developed using *Centella asiatica* leaf (CAL) as a host material. The membranes are doped with different ammonium salts, namely ammonium thiocyanate (NH₄SCN), ammonium nitrate (NH₄NO₃), and ammonium bromide (NH₄Br), to enhance proton conductivity. Electrolyte membranes with varying salt concentrations are prepared and optimised for proton conductivity using FTIR, XRD, and AC impedance analysis. The best-performing membranes are selected and further evaluated for their structural, thermal, mechanical, and electrochemical properties. The optimized bio-membranes showed proton conductivities of 9.31×10^{-3} S/cm (NH₄SCN), 3.37×10^{-3} S/cm (NH₄NO₃), and 3.27×10^{-5} S/cm (NH₄Br) at room temperature. These results indicate good conductivity and stability for use as proton exchange membranes in single PEM fuel cells. The optimized membranes were further evaluated in single PEM fuel cell at ambient temperature through OCV and PEMFC polarization tests, exhibiting OCV values of 448 mV (NH₄SCN), 645 mV (NH₄NO₃) and 630 mV (NH₄Br), along with maximum power densities of 0.003 mW/cm² (NH₄SCN), 0.30 mW/cm² (NH₄NO₃) and 0.60 mW/cm² (NH₄Br). Furthermore, the low-conductivity NH₄Br-based membrane was enhanced by incorporating a graphene quantum dot (GQD) nanofiller, resulting in improved ionic conductivity (2.11×10^{-3} S/cm), overall physicochemical properties, and fuel cell performance, with an OCV of 752 mV and a maximum power density of 1.57 mW/cm². The enhanced performance of the developed membrane was also compared with Nafion™ 212 under similar operating conditions. This study highlights the potential of plant-based solid bio-membrane electrolytes as a green and cost-effective alternative with promising performance for next-generation energy devices, particularly for continuous powering of low-power sensors and IoT applications.

OP-27

Hierarchical HOF-templated Ru–borophene Hybrid: Synergistic Interface Engineering toward Efficient OER in Alkaline and Marine Media

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The oxygen evolution reaction (OER) is a half-reaction with sluggish reaction kinetics, which makes water electrolysis much less efficient. To achieve a more sustainable approach to H₂ and O₂ production, it is necessary to develop highly effective and stable electrocatalysts. In this study, a ternary hydrogen-bonded organic framework (HOF)-templated Ru-modified borophene (HOF-BB-Ru) electrocatalyst is synthesized, which involves the construction of an HOF–borophene heterostructure and subsequent integration of Ru species. This novel ternary structure enables borophene, Ru, and the HOF matrix to interact effectively, making the active site more accessible, enhancing charge-transfer properties, and increasing the structure's stability. XRD, FT-IR, SEM, TEM, and XPS characterization results revealed that the ternary framework was successfully formed and chemically integrated. Electrochemical measurements, including linear sweep voltammetry (LSV), Tafel, and electrochemical impedance spectroscopy (EIS), reveal significantly improved OER kinetics of HOF-BB-Ru in various electrolyte environments. The HOF-BB-Ru catalyst exhibited low overpotentials of 349 mV in an alkaline solution, 420 mV in alkaline simulated seawater, and 473 mV in natural seawater at the current density of 50 mA cm⁻². These results indicate that the HOF-BB-Ru catalyst's ability to operate effectively in a wide range of electrolytic conditions demonstrates its strength and flexibility. This study introduces a novel heterostructure that exhibits high efficiency in HER and OER applications in real marine water environments.

OP-28

Sr₂CoRuO₆ Double Perovskite Supported on TiO₂ as a Bifunctional Electrocatalyst for Water Splitting

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Hybrid electrocatalysts that combine conductive supports with multimetallic active phases are promising for improving water-splitting efficiency. In this work, a Sr₂CoRuO₆ double perovskite supported on a porous TiO₂ scaffold was developed as a bifunctional electrocatalyst for hydrogen and

oxygen evolution reactions. The templated TiO₂ framework provides high surface area, structural stability, and efficient pathways for charge transport, while the Co-Ru double perovskite introduces multiple redox-active sites that enhance catalytic kinetics. The phase, morphology, and chemical states of the synthesized materials were investigated using X-ray diffraction (XRD), field-emission scanning electron microscopy (FESEM), transmission electron microscopy (TEM), and X-ray photoelectron spectroscopy (XPS), confirming the successful formation of the perovskite hybrid architecture. Electrochemical studies in an alkaline medium demonstrated improved catalytic activity and stability, attributed to the synergistic interaction between the porous TiO₂ support and the double perovskite layer. This study highlights the potential of templated TiO₂ supported double perovskite systems as efficient and durable electrocatalysts for overall water splitting.

OP-29

Defect-engineered Fe-Doped CeO₂/rGO with Superior Oxygen Reduction Reaction Activity for Fuel Cell Applications

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Defect engineering has emerged as a powerful strategy to enhance the electrochemical performance of metal oxides by tailoring their electronic structure, surface chemistry, and catalytic active sites. In this study, Fe-doped CeO₂ nanoparticles enriched with oxygen vacancies were successfully synthesized and uniformly anchored onto defect-rich reduced graphene oxide (rGO) through a urea-assisted calcination route under a N₂ atmosphere. The synergistic incorporation of Fe dopants and rGO support effectively promoted defect formation and electronic modulation in the CeO₂ lattice. Surface and spectroscopic analyses revealed a high oxygen vacancy concentration of 71% accompanied by an increased Ce³⁺ fraction of 65%, confirming the successful introduction of abundant defect sites. Benefiting from enhanced charge transfer, abundant active sites, and strong metal-support interactions, the optimized Fe-CeO₂/rGO-2 catalyst exhibited remarkable oxygen reduction reaction (ORR) activity, delivering a half-wave potential of 0.86 V (vs. RHE) and a high limiting current density of 7.65 mA cm⁻², which is approximately 1.3 times higher than that of commercial 20 wt% Pt/C. Furthermore, the catalyst demonstrated excellent long-term durability, retaining 94% of its initial current after 10,000 s, compared to only 66% for Pt/C, along with outstanding methanol tolerance. These results highlight the effectiveness of defect-engineered Fe-CeO₂/rGO as a promising and durable Pt-free catalyst for advanced electrochemical energy conversion applications.

Electrodeposition of Gadolinium-doped Nickel Selenide for Efficient Hydrogen Evolution Reaction in Alkaline Media

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Water electrolysis is an invasive technique for the production of hydrogen (H_2) and oxygen (O_2) with release of non-carbonaceous byproducts. Till date noble metals (Pt, Pd and Ru etc.) are considered as the bench mark catalysts to generate H_2 and O_2 with low consumption of potential energy. However, their scarcity and expensiveness reduce the large-scale utility in real life applications. Henceforth, there is an urgent need for electrocatalysts that can replace noble metal-based catalysts and are capable of showing the efficient catalytic behavior towards hydrogen evolution reaction (HER). Herein, our work emphasizes the fabrication of Gd-doped nickel selenide (Gd-NiSe) via simple electrodeposition at ambient conditions (Figure 1). The Gd-NiSe was systematically characterized using techniques such as X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), Raman, field emission scanning electron microscopy (FESEM), transmission electron microscopy (TEM) etc. The catalytic performance of Gd-NiSe towards HER was investigated through various electrochemical characterization techniques such as linear sweep voltammetry (LSV), cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS). Gd-NiSe with optimal composition exhibited low overpotential of 160 mV along with low Tafel slope of 121 mV dec^{-1} . The enhancement in the performance can be attributed to the synergistic interaction between Gd and NiSe that increases the number of active sites and enhances charge transfer process, thereby improving the catalytic performance.

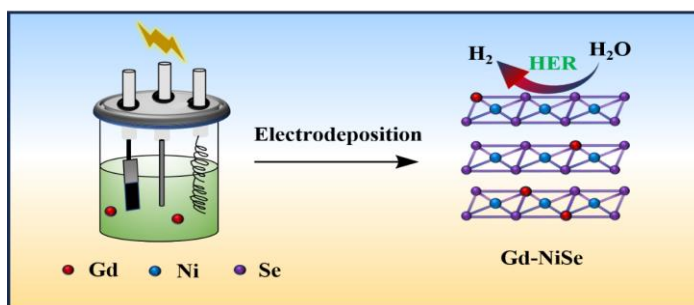


Figure 1. Schematic representation of electrodeposition of Gd-NiSe.

OP-31

Ni-based Layered Double Hydroxide Coupled with BDC for Electrochemical Ethanol Oxidation

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Hydrogen production via electrocatalytic water oxidation is considered a significant sustainable renewable source. The anodic evolution of oxygen that limits the production of H₂ due to its slow kinetics can be replaced by ethanol-assisted water oxidation, a remarkable alternative. By producing value-added chemicals by the oxidation of small organic molecules, the hampered H₂ evolution can be boosted. Such electrochemical processes require a cost-effective, sufficient, abundant, and sustainable electrocatalyst to meet the energy demand crisis. Layered Double Hydroxides are known to be competitive electrocatalysts with their excellent intrinsic performance, 2D layered structure, and exceptional stability. In recent advancements, Ni-based LDHs have garnered significant focus as a promising electrocatalyst. Herein, we have integrated BDC with Ni-based LDH, an effective strategy to enhance the electrocatalytic performance. The incorporation of Bi³⁺ into the lattice of Ni-LDH promotes the catalytic active sites and enhances the reaction kinetics. In the meantime, the BDC integration facilitates faster electron transfer due to its high surface area. The results analyzed from the experiments show that the composite electrocatalyst exhibits a lower onset potential and long-term durability.

OP-32

Boosting Hydrogen Production with Minimalist Noble Metal Footprint in Hydrogen Evolution Catalysts

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The escalating demand for sustainable energy has positioned water electrolysis as a critical technological solution for green hydrogen production. However, the commercial viability of this process is significantly hindered by the high cost and scarcity of the state-of-the-art platinum on carbon (Pt/C) catalysts. Here, in this work we explore a strategic approach to minimize the noble metal reliance by engineering heterojunction nanostructures using iron titanate (FeTiO₃) as a robust, cost-effective perovskite framework. Two distinct methodologies for surface decoration were explored to enhance the Hydrogen Evolution Reaction (HER) performance while drastically reducing

noble metal loading: (i) Ultralow Pt loading via urea-assisted reflux by edge-decorating hexagonal FeTiO₃ with Pt as quantum dots (QDs), with a Pt content of only 3.7 wt%, >5 times lower than commercial 20% Pt/C. This configuration achieved a superior HER overpotential of 191.4 mV at 100 mAcm⁻² and a remarkably low Tafel slope of 19.8 mV/dec, outperforming the commercial catalyst despite the reduced metal content. (ii) Ag-decorated heterojunctions via electrophoretic deposition (EPD) as further alternative to platinum, silver nanoparticles (Ag-NPs) were decorated on FeTiO₃ using EPD, a scalable and uniform coating technique. The resulting Ag@IT/NF electrode demonstrated an overpotential of 161 mV at 100 mA/cm⁻² and a Tafel slope of 19 mV/dec, showcasing the potential of silver as a more affordable and efficient substitute. Ultraviolet Photoelectron Spectroscopy (UPS) confirmed that the exceptional performance in both systems was achieved through an effective formation of metal-semiconductor heterojunctions. These junctions modulate the energy band structure, creating a built-in electric field that facilitates rapid, bidirectional electron transfer upon polarization. Collectively, these findings underscore a shift toward high-performance, sustainable electrocatalysts that reduce dependence on expensive noble metals without compromising catalytic efficiency.

Electrochemical Sensor

OP-33

Gold Nanoparticles Modified Enzymatic Glucose Biofuel Cell for Wearable Applications

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Monitoring fluctuations in glucose levels is essential for sustaining body wellness because of its chronic and acute impacts on human health. The self-powered nature of an enzymatic glucose biofuel cell (EBFC) can be explored for the development of stand-alone wearable patches for glucose monitoring. In this work, we report the development of a self-powered EBFC for glucose sensing with high power density and current density (Figure 1). Gold nanoparticles (AuNPs) were used to enhance enzyme loading on the bioanode, and the cathode was modified with platinum black for the reduction of oxygen. The bioanode and cathode in phosphate buffer solution were characterised by voltametric investigations. The biosensor exhibits a sensitivity of $5.3 \mu\text{A mM}^{-1} \text{cm}^{-2}$ (0.05-0.9 mM) and $28 \mu\text{A mM}^{-1} \text{cm}^{-2}$ (1-41 mM) for glucose detection. A biofuel cell was then developed that showed an open circuit voltage of 0.3 V and could produce a high current density of $199 \mu\text{A/cm}^2$ and a higher power density of $20 \mu\text{W/cm}^2$. The results obtained are promising for the development of glucose biosensors with integrated electrochromic readouts for realizing battery-free, stand-alone wearable patches.

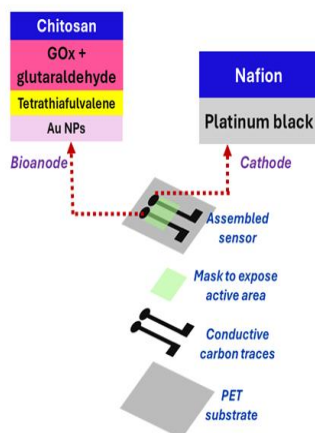


Figure 1. Illustration of self-powered enzymatic biofuel cell platform.

Integration of Self-signaling Aptamer-based Hydrogel-nanocomposite with Indigenous Screen-printed Carbon Electrodes for Progesterone Measurement

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Screen-printed electrodes provide a reproducible and scalable platform for electrochemical sensing by integrating working, reference, and counter electrodes on a single flexible substrate. Their versatility enables modification with nanomaterials and biomolecules for advanced sensing applications [1]. In this study, a flexible point-of-care electrochemical sensor was developed for progesterone detection using a screen-printing approach. Electrodes were fabricated on polyethylene terephthalate substrates using graphene and Ag/AgCl inks. A reagent-free detection strategy was employed using a methylene blue-tagged progesterone-specific aptamer immobilized on the gold nanoparticles (AuNPs). Additionally, a zwitterionic carboxybetaine methacrylate hydrogel integrated with AuNP-aptamer-tagged methylene blue was incorporated into the sensor platform. Zwitterionic hydrogels offer significant advantages due to their porous, hydrophilic, and antifouling nature, facilitating efficient bioreceptor immobilization while minimizing non-specific binding [2]. The reproducibility of the progesterone aptasensor was investigated between the five batches of printed electrodes. The developed system demonstrates potential for sensitive and reliable progesterone detection in human serum samples.

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Development of a Nanocomposite Phage Cocktail-based Impedimetric Biosensor for the Rapid Detection of *Klebsiella pneumoniae* in Environment Water Sources

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The global rise of multidrug-resistant *Klebsiella pneumoniae* in water sources poses a severe threat to public health. As a common inhabitant of surface water and sewage, *K. pneumoniae* acts as a critical reservoir for the horizontal transfer of antibiotic resistance genes. Current water quality monitoring relies on traditional culture-based methods, which are reliable but time-consuming. While molecular techniques like PCR are faster, they are expensive and require specialized personnel. Therefore, there is an urgent need for rapid, low-cost and portable sensing platforms for on-site environmental monitoring to ensure public safety. This study describes the development of a highly sensitive electrochemical biosensor using a novel ternary nanocomposite, graphitic carbon nitride (g-C₃N₄), polyaniline (PANI), and polyethyleneimine (PEI), on screen-printed carbon electrodes (SPCE). The composite provides a synergistic interface where g-C₃N₄ offers a high surface area, PANI enhances electron transfer, and the amine-rich PEI ensures the stable, oriented immobilization of a tripartite bacteriophage cocktail (AM.K3, AM.K5 and AM.K6). Bacteriophages (phages) are viruses that specifically infect and kill bacteria. They are used here as bioreceptors because they are highly specific, cost-effective and stable than synthetic antibodies under different environmental conditions like varying pH and temperature. Structural analysis via XRD, FT-IR, HR-TEM and XPS confirmed the successful formation of the composite. Electrochemical characterization using Cyclic Voltammetry (CV) and Electrochemical Impedance Spectroscopy (EIS) showed that the ternary design significantly enhanced electron transfer compared to pristine or binary materials. Upon binding to *K. pneumoniae*, the biosensor showed a linear increase in charge transfer resistance (R_{ct}) across a range of 10³ to 10⁸ CFU/mL (R² = 0.99). The platform achieved a low Limit of Detection (LOD) of 3 CFU/mL and a Limit of Quantification (LOQ) of 48 CFU/mL. The sensor remained highly selective for *K. pneumoniae* when tested against common interfering pathogens like *E. coli*, *P. aeruginosa*, *A. baumannii* and *S. aureus*. Practical applicability was further validated in spiked tap and untreated aquarium water samples, where detection was obtained for 10⁴ – 10⁶ CFU/mL *K. pneumoniae*. This phage-nanocomposite framework offers a robust, stable, low-cost and portable solution for rapid environmental water monitoring.

Stimuli-responsive β -cyclodextrin based Carrier for Loading and Unloading of Anti-tuberculosis Drugs

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Rifampicin (RIF) and isoniazid (INZ) are first-line anti-tuberculosis drugs widely used in the healthcare sector. Although vaccination with BCG reduces disease severity, tuberculosis continues to pose a serious health challenge, particularly among unvaccinated people. One of the major limitations of conventional TB treatment is the poor bioavailability and low aqueous solubility of drug molecules under physiological conditions, which reduces the therapeutic efficacy and patient compliance. These issues necessitate the development of advanced drug-delivery strategies to improve treatment outcomes. In this context, the design of a novel carrier system capable of enhancing site-specific drug delivery, bioavailability, and solubility especially for the lipophilic drug RIF is significantly important. β -Cyclodextrin (BCD), a cyclic oligosaccharide, possesses a unique structure with a hydrophobic inner cavity and a hydrophilic outer surface due to the presence of secondary and primary hydroxyl groups. Encapsulation of RIF and INZ within the BCD cavity is expected to enhance their aqueous solubility and enable sustained drug release at the target site [1]. A critical challenge in oral TB therapy is the instability of RIF in acidic environments, where it forms unwanted adducts. To overcome this limitation, the present work focuses on developing a carrier system that selectively releases drugs in the intestinal medium (pH 7.4) while suppressing release in the gastric environment (pH 1.5) (Figure 1). This pH-responsive behavior is achieved by incorporating sodium alginate (SA), which forms insoluble alginic acid under acidic conditions, thereby protecting the drug in the stomach. The co-delivery of RIF and INZ using a BCD-SA-based carrier system is expected to improve solubility, bioavailability, and site specificity, leading to enhanced therapeutic performance [2]. Additionally, the quantification of each drug from the formulation is essential for dosage optimization and quality control. Accordingly, portable, sensitive, cost-effective electrochemical and optical methods are employed to evaluate drug loading and release profile.

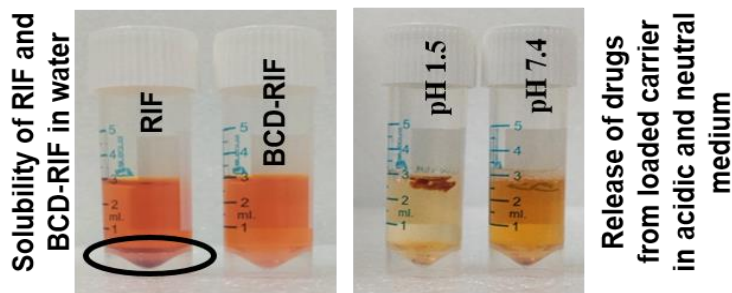


Figure 1. Stimuli responsive carrier system for drug release.

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OP-37

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

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Methotrexate (MTX) is a widely used chemotherapeutic and immunosuppressive drug with a narrow therapeutic index, requiring precise monitoring to avoid toxicity. Additionally, its persistence in the environment highlights the need for sensitive and reliable detection methods. Electrochemical sensing has emerged as a promising approach due to its simplicity, rapid response, and cost-effectiveness. In this work, a biomimetic electrochemical sensor was developed using a laser-induced graphene (LIG) electrode. LIG offers high conductivity, large surface area, and a porous structure that supports efficient electron transfer and surface modification. To enhance performance, the electrode was modified with gold nanoparticles (AuNPs), which increase the electroactive surface area and improve electron transfer kinetics. A key component of this system is Prussian Blue (PB), used as an internal redox probe. PB operates at low potentials, minimizing interference from other electroactive species and reducing electrode fouling. Beyond MTX detection, PB is widely applied in biosensors for analytes such as glucose and hydrogen peroxide due to its excellent electrocatalytic activity, stability,

and reversible redox behavior. Its use enables indirect detection, improving sensor durability and reliability. For selective recognition, a molecularly imprinted polymer (MIP) was electropolymerized using o-phenylenediamine and MTX as the template. MIPs provide high selectivity through template-shaped binding sites and are more stable and cost-effective than biological receptors. A hydrogel layer was added to protect the PB layer and maintain sensor stability without hindering analyte diffusion. The sensing mechanism is based on suppression of PB current. Binding of MTX to MIP cavities restricts electron transfer, leading to a measurable decrease in current proportional to MTX concentration. The sensor exhibited a linear range of 10 nM to 10 μ M with high selectivity and reproducibility. Overall, the integration of LIG, AuNPs, PB, and MIPs offers a robust platform for sensitive and selective detection, with potential applications extending beyond MTX to other biomedical and environmental targets (Figure 1).

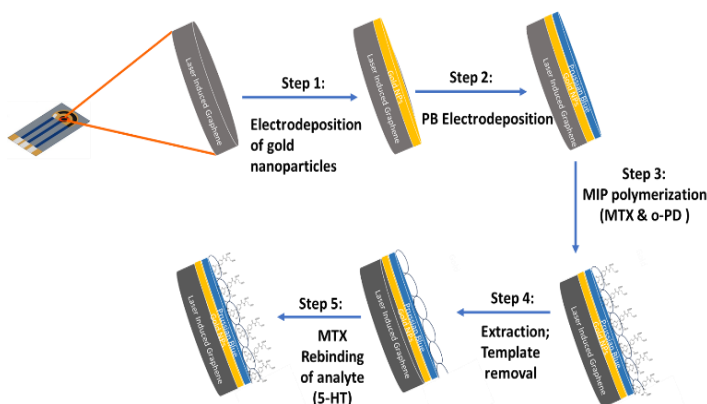


Figure 1. Schematic representation of the MTX - MIP sensor.

OP-38

Sensitive and Selective Non-Enzymatic Electrochemical Detection of Urinary Creatinine for Non-Invasive Point-of-Care Applications

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Urinary creatinine (Ctn) is a key biomarker for assessing kidney function and diagnosing renal disorders, necessitating the development of reliable, portable, and non-invasive detection platforms. Conventional creatinine detection methods (Jaffe, spectrophotometry, HPLC) are invasive, time-consuming, and require complex sample preparation and costly instrumentation; they also suffer from interference and poor portability, limiting their suitability for rapid, non-invasive point-of-care (POC) diagnostics. To overcome these limitations, electrochemical sensing platforms offer a promising

alternative due to their simplicity, high sensitivity, rapid response, and compatibility with portable devices. In this work, we report a non-enzymatic electrochemical sensing platform for the sensitive and selective detection of creatinine in human urine. The sensor is fabricated using a Ni foam-based electrode modified with NiCoFe₂O₄ nanostructures, where the enhanced electrocatalytic activity arises from the synergistic redox transitions of Ni²⁺/Ni³⁺ and Co²⁺/Co³⁺ active sites, enabling efficient electron transfer and rapid oxidation of creatinine. The developed sensor exhibits a wide linear detection range from 0.01 to 27 mM, a high sensitivity of 9.4 mA mM⁻¹ cm⁻², and a low limit of detection of 1.68 μM. The conductive and porous Ni foam substrate enhances charge transport kinetics and mass diffusion, resulting in fast response and stable performance. The sensor also demonstrates excellent selectivity against common interfering species such as uric acid, urea, and glucose, along with good repeatability and long-term stability. Its practical applicability is validated in both simulated and real human urine samples, confirming its reliability for non-invasive analysis. Overall, this work presents a cost-effective, portable, and robust non-enzymatic electrochemical sensor with strong potential for point-of-care (POC) diagnostics and real-time kidney health monitoring. Future work will focus on integrating this platform with readout electronics and self-powered systems to enable next-generation autonomous and miniaturized diagnostic devices.

OP-39

Electrochemical Sensing of Methylmalonic acid using Nanostructured TiO₂-nanorod Decorated Nitrogen Doped 3D-carbon

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Methylmalonic acid (MMA) is known to be a sensitive biomarker for the early detection of vitamin B₁₂ deficiency, which is still a common and underdiagnosed condition worldwide. In order to detect MMA in human serum and phosphate-buffered saline (PBS), we created and assessed an electrochemical sensor based on a TiO₂ nanorod/N-doped 3D carbon (TiO₂-NR/N-3DC) composite modified glassy carbon electrode (GCE). The electrochemical response of MMA was examined using cyclic voltammetry (CV) and differential pulse voltammetry (DPV). The best results were found at physiological pH 7.4. With a linear response and detection limit (LOD) of 0.09 μM, the modified electrode showed a clear reduction peak for MMA at about -0.5 V. Over several cycles, the sensor showed excellent stability and repeatability. Selectivity against common biological interfering molecules such as ascorbic acid, glucose, uric acid, Na⁺, and K⁺ was confirmed by interference studies. Serum samples were used for validation, and the findings were cross-checked using quantification

techniques to calculate the error percentage and analytical recovery. This electrochemical platform has potential for early clinical diagnosis of vitamin B₁₂ deficiency and provides a quick, sensitive, and inexpensive alternative for point-of-care MMA screening (Figure 1).

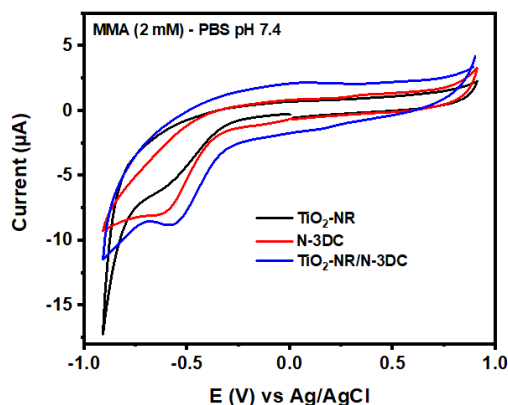


Figure 1. Comparative CVs of different electrodes measuring 2 mM MMA.

OP-40

Rational Design of a Triple-functional CuO/Amine-MCM-41/Carbon Black Heterostructure for Ultrasensitive and Selective Vitamin B₁₂ Electroanalysis

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Vitamin B₁₂ (B₁₂) is an essential micronutrient involved in key physiological processes, particularly in neurological function and red blood cell formation. Long-term deficiency of B₁₂ has been widely associated with various neurological and neuropsychiatric disorders, including Alzheimer's disease, depression, brain fog, and psychosis, highlighting the importance of maintaining adequate dietary intake to prevent deficiency. This underscores the need for reliable and sensitive detection methods for monitoring low concentration (~nanomolar) of B₁₂ in food matrices. In this work, a selective and sensitive electrochemical sensor was developed for B₁₂ detection, utilizing a CuO-decorated, amine-modified mesoporous silica (MCM-41) and carbon black based synergistic composite. The matrix enhances analyte interactions *via* amine groups, facilitating improved adsorption and electron-transfer kinetics. H₂O₂-mediated catalysis enables Co²⁺/Co⁺ redox cycling, thereby amplifying the current response. The sensor exhibits a linear range of 1–140 nM, a sensitivity of 58.8 µA nM⁻¹cm⁻², and a low limit of detection (LOD) of 119 pM using batch injection analysis (BIA). Real sample analysis showed excellent agreement with the gold-standard UPLC method, with less than 5% error, highlighting the platform's accuracy and reliability for ultrasensitive Vitamin B₁₂ detection in complex food matrices.

Laser-induced Graphene–NiO Hybrid Electrode for Electrochemical Pesticide Detection

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The widespread use of pesticides has raised serious environmental and public health concerns worldwide. Among them, paraquat (PQ) is recognized as one of the most toxic pesticides due to its high persistence and acute toxicity even at trace concentrations. Exposure to paraquat can induce severe oxidative damage to vital human organs, resulting in acute poisoning and high mortality rates. Despite regulatory restrictions in several countries, paraquat remains widely used in Indian agriculture as a fast-acting, non-selective contact herbicide for weed control in crops such as tea, cotton, rubber, sugarcane, and plantation crops. Consequently, there is an urgent need for rapid, sensitive, and reliable analytical strategies for on-site monitoring at ultra-low concentrations. Electrochemical sensing has gained significant attention for paraquat detection owing to its inherent redox activity, which enables direct and reagent-free quantification. Paraquat exhibits a well-defined two-electron, single step reversible redox process, making it particularly suitable for electrochemical analysis. However, the performance of electrochemical sensors is strongly dependent on the electrode material. In this context, we report a laser-induced porous graphene/NiO hybrid electrode (NiO-LIG), fabricated in situ using a CO₂ laser writing technique for electrochemical detection of PQ (Figure 1). The size of NiO is reduced from micrometer to nanometer range, yielding a three-dimensional, hierarchically porous graphene with high specific surface area and architecture with interconnected networks, enhancing rapid electron-transfer kinetics. Using square-wave anodic stripping voltammetry, PQ was detected over a linear range of 1–12 μM in 0.1 M phosphate buffer, with detection limits of 20 nM. The sensor demonstrates high stability, reproducibility, selectivity, and enables accurate quantification in rice wash water with recoveries nearly 100%, highlighting NiO-LIG as a scalable and versatile electrode for on-site food safety monitoring.

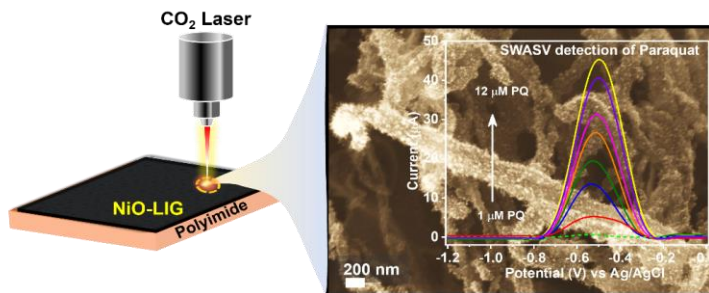


Figure 1. Illustration depicting fabrication of electrode, morphology of electrode material and SWASV for detection of paraquat.

Corrosion, Coatings & Electrochemical Process Engineering

OP-42

Synthesis, Structure and Photocatalytic Activity of Two Newly Synthesized Cadmium (II) and Manganese (II) based Metal-organic Frameworks

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Two new metal-organic frameworks containing Cd (II) and Mn (II) metal centers using ligand H₂L [H₂L= 3,3'-(1,4-phenylene-bis-(methylene-oxy) di-benzoic acid)] were synthesized by hydrothermal method (Figure 1). The coordination polymers (CPs) were characterized using FT-IR, single crystal X-ray diffraction (SCXRD), powder X-ray diffraction (PXRD) and Thermal Gravimetric analysis (TGA) characterization techniques. Complex 1 [Cd₃(L)₃(Phen)₂]_n is a trinuclear coordination polymer with 2D layered structure and is capable of formation of 3D structure through weak interactions. Complex 2 [Mn(L)(Phen)]_n is a mononuclear coordination polymer having 1D chain like structure with the capability of formation of 3D polymeric structure through intra- and intermolecular hydrogen bonding. Both CPs display distorted octahedral geometry around metal centers with +2 oxidation states. Both CPs exhibit excellent photocatalytic activity against antibiotics. Complex 1 exhibits superior photocatalytic degradation of NFZ antibiotic and Complex 2 showed good photocatalytic efficiency for SMZ antibiotic. Radical quenching experiments suggest that h⁺ (positive holes) played a pivotal role in the photodegradation of NFZ. Complex 1 showed good stability and reusability for degradation of NFZ antibiotic maintaining consistency performance over five cycles.

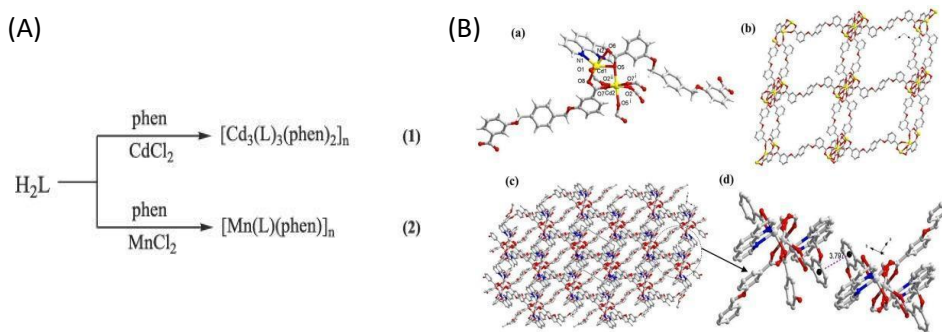


Figure 1. Schematic of synthesis and structure of Cd(II) and Mn(II)-based MOFs.

Disinfection of Hospital Wastewater by *In-situ* Aeration Induced Lab Scale Electrooxidation

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Hospital wastewater contains persistent organic pollutants mostly composed of antibiotics and pharmaceutical active compounds. Another major hazard is the pathogens. Pathogen removal from water needs specialized treatment by chlorination, UV or advanced treatment processes. An effective and alternative promising technology is electrooxidation which delivers 100% bacterial removal with no chemical dosing or exposure to hazardous UV. In addition, take care of persistent organic pollutants. In the present investigation, hospital wastewater was collected from a nearby hospital STP and 250 mL of the water was taken in a 500 mL beaker for the experiment. Removal of fecal coliform was monitored while increasing the voltage from 1.5 to 7 V keeping electrode spacing from 1 to 4.5 cm. The electrodes for electrooxidation are made of stainless steel with 2 mm thickness with an active surface area of 10x10 cm². The current consumption was in the range from 0.1 to 0.12 A. The contact time was varied from 15 to 60 mins. Another set of experiments were kept with in-situ air diffusion in electrolysis while keeping other parameters as above. Total coliform count per 100 mL of water before and after treatment has been analyzed by quantitative MPN (Most probable number). *E. coli* removal was on higher side (88%) with 7 V and 60 mins with 2 cm electrode spacing whereas with *in-situ* aeration 18% increase in the removal was achieved. The overall current consumption was low as compared with similar studies reported earlier. The process achieved up to 98% of pathogen removal from hospital wastewater via direct electron transfer on the anode surface and indirect oxidation by producing reactive oxygen and chlorinated species produced upon degradation of salts present in wastewater. The energy consumption for this lab study was calculated as 3.36 kWh/m³ for hospital wastewater with an initial COD of 450 and TDS of 1250 mg/L. The cost of electricity has been calculated as Rs. 27/m³ of water as per Rs. 8 per unit / kWh cost in Hyderabad. With an increase in water volume up to 5000 L the electricity consumption may vary from 0.18 to 3.5 kWh/m³ depending on TDS level in water, types and surface area of electrodes and contact time.

Diffusion Controlled Packed Bed Electrochemical Reactor for Heavy Metal Removal: RTD based Modelling

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A study of a packed bed electrochemical reactor was conducted using Residence Time Distribution (RTD) experiments, Computational Fluid Dynamics (CFD) simulations, DPFR (Dispersed Plug Flow Reactor) network modelling and DoE (Design of Experiments) based performance analysis. The study provided valuable insights into mixing and mass transfer characteristics in a Packed Bed Electrochemical Reactor (PBER) and a removal efficiency as high as 98%. These insights would be immensely helpful for developing an approach to optimize the reactor design and improve the performance of PBER (irrespective of the geometry of the packing). Simulations and experiments have been done in the past to improve the reactor performance and many reactor designs are available with high removal efficiencies for diffusion dominated toxic trace heavy metal removal from wastewater [1,2]. Nevertheless, no holistic design approaches or designs suited for large scale single pass continuous operations are available. Here, a 75 mm diameter, 150 mm long PBER packed with Titanium balls (cathode) enclosed with an ion-exchange membrane and a Titanium wire mesh (anode) concentrically arranged next to the membrane separator was fabricated. Residence Time Distribution studies were conducted for three different flow rates (50, 100 and 150 mL/min) using 30 ppm Pb²⁺ as a pulse tracer. The RTD results obtained were modelled using a simple network of two DPFR in parallel which indicated presence of two sets of fluid paths in the reactor each with a different mean residence time and vessel dispersion number which was further validated using a CFD simulation. A Lagrangian approach-based visualization in CFD helped visualize the flow paths. Further, a full factorial DoE based optimization of lead removal efficiency considering flow rate, feed concentration and current was conducted. Mathematical models were developed to capture the nonlinear relationships and interactive effects between the Pb²⁺ removal efficiency and the process variables. Maximum removal efficiency of 98% was obtained at continuous operating conditions of 50 mL/min flow rate, 10 ppm feed concentration and 100 mA current passed. The application of a reactor performance optimization approach developed based on this study would not be limited to trace heavy metal removal, but in the design of a reactor for any diffusion dominated electrochemical reaction.

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Metallosurfactant-based Surface Modification Strategies for Combating Microbiologically Influenced Corrosion

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Microbiologically influenced corrosion (MIC) is the outcome of a complicated biological process between a metal substrate and an electrolyte that has a lot of hostile ions and electroactive microbes in it. The metabolic activity of bacteria living under biofilm can create harsh, localized habitats with variable amounts of gases, inorganic ions, and organic acids. Surfactant-based approaches for reducing MIC primarily depend on the capacity of amphiphilic molecules to concurrently regulate electrochemical processes, microbial adhesion, and biofilm formation at interfaces (Figure 1). In addition to traditional synthetic surfactants, metallosurfactants are an interesting class with value addition [1]. Metallosurfactants are known to have lower CMC than the precursor surfactant that is known to show better performance in a variety of applications including corrosion inhibitory actions [2]. They possess impressive antibacterial activity and binding ability with the bacterial genetic material which advocates their application in bio-corrosion prevention [3].

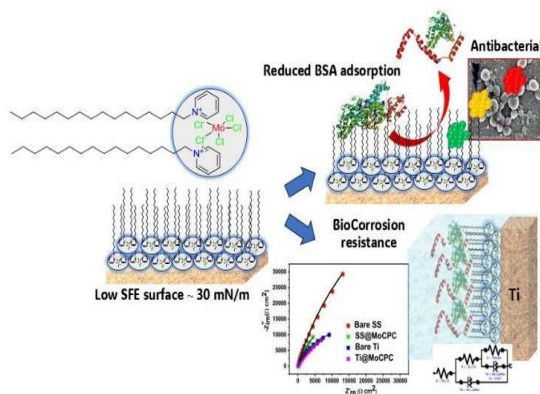


Figure 1. Representation on biocorrosion inhibition.

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Rust in Action: Metaproteomics Unmasks Hidden Players in Microbial Corrosion

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Microbiologically Influenced Corrosion (MIC) poses a chronic risk to industrial infrastructure, especially in oil, gas, and marine ecosystems. Metaproteomics was used with high-resolution tandem mass spectrometry paired with metagenomic sequencing to allow for taxonomic identification and functional annotation of expressed proteins. Metaproteomic analysis reveals previously unknown microbial contributors and functional pathways in MIC, particularly under anaerobic and oligotrophic conditions prevalent in industrial systems. The biofilm and corrosion product samples were harvested from metal coupons placed in environments with extreme MIC activity. The analysis unveiled a complex society with not only the prominent sulfate-reducing bacteria (SRB) like *Desulfovibrio* spp., but also lesser-known taxa like methanogens and fermentative bacteria that indirectly support corrosive activity. Proteins of extracellular electron transfer (EET), hydrogen cycling, and metal ion transport, indicating that these activities are at the heart of MIC mechanisms. The present study illustrates the potential of metaproteomics in uncovering the functional intricacy and covert participants in MIC. In contrast to DNA-based techniques that infer mere potential activity, metaproteomics directly observes microbial function at the protein level, which provides real-time information on the active biochemical pathways. The results favour incorporating metaproteomic monitoring into MIC surveillance programs and indicate that the selective inhibition of microbial functions will be more effective than broad-spectrum biocidal intervention. In the genome era, this strategy overwrites our concept of corrosion biology and presents new opportunities for predictive diagnosis and mitigation technology.

Sustainable Corrosion Mitigation of Automotive Metallic Materials in Fuel-grade Ethanol

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With the aim of achieving net-zero carbon emission and energy security across the globe the use of fuel-grade ethanol for blending purposes with petrol is highly recommendable as an alternative to petroleum-based fuel. Hence, there is an immense increase in utilization of fuel-grade ethanol as a renewable transportation fuel blend in India as well. But, owing to the hygroscopic nature of ethanol, it absorbs moisture or water from the environment. The accumulation of water thereby initiates corrosion in the metallic components. The corrosion issue has raised serious economic loss and concerns in fuel storage, transportation pipelines, and engine equipment in the automotive sectors. In this regard, the recent development of environment friendly organic corrosion inhibitors as additives to mitigate corrosive degradation of metallic components in such a fuel environment has emerged to ensure the durability and enhance the longevity of fuel components. This work outlines and sheds light on the corrosion phenomenon of metals in fuel-grade ethanol, thereby revealing the present trends and future perspective of the use of green organic corrosion inhibitors for protecting metallic materials susceptible to corrosion in fuel-grade ethanol (Figure 1). Thus, it makes the fuel-grade ethanol suitable for blending purposes without interfering with the engine efficiency.

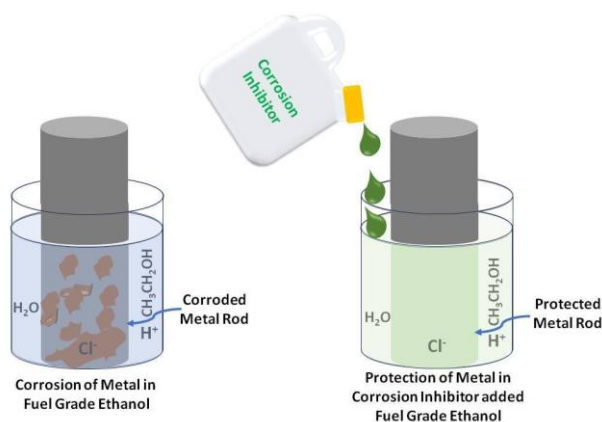


Figure 1. Fuel Grade Ethanol Corrosion Inhibition.

Electrodeposition of Fe-Co-Ni-Mo-W High-entropy Alloy for Corrosion Application

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High entropy alloys (HEAs) have created a revolutionary impact on alloy design and significantly enhance their properties. In this study, FeCoNiMoW HEA thin films were galvanostatically electrodeposited from an aqueous medium using citrate-based electrolyte with suitable additives. The deposition was carried out at a constant pH of 5, temperature of 60 °C, and current density of 10 A dm⁻², while the deposition time was varied as 15, 30, 45, and 60 minutes. The thickness of the coatings increased with higher deposition time, reaching approximately 33 μm. Scanning electron microscopy (SEM) analysis revealed a densely packed spherical structure and also the particle size increased with increasing deposition duration (Figure 1). Energy-dispersive X-ray spectroscopy (EDS) confirmed the successful co-deposition of Fe, Co, Ni, Mo, and W elements with the specified compositional ranges in the coatings. The calculated configurational entropy values exceeded 1.5R, indicating the formation of a high-entropy alloy system. X-ray diffraction (XRD) analysis showed a mixture of amorphous and nano-crystalline structure. The maximum microhardness of the coatings obtained is 895 HV for the coating deposited for 60 min. Corrosion resistance studies demonstrated that the FeCoNiMoW HEA coatings exhibit better corrosion resistance and highlight their potential for advanced protective coating applications.

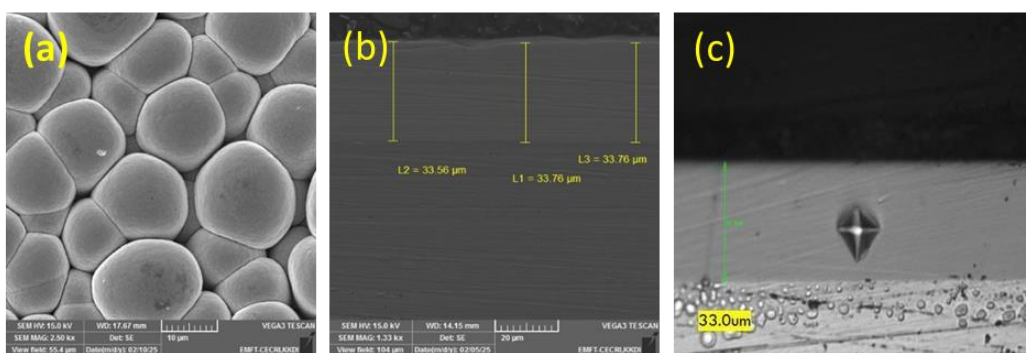


Figure 1. SEM image of (a) surface morphology, (b) cross sectional image and (c) cross sectional hardness image of FeCoNiMoW HEA alloy.

Artificial Intelligence Aided Design Engineering of Fume Hoods in Electroplating Process for Air Quality Management

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The presence of airborne particles of hazardous nature near the electroplating process plants poses serious health hazards to the workers in these industries. Two reports in the journal Scientific Reports highlights the same with experimental data [1,2]. To mitigate this risk of airborne particulate matter we propose an engineering control through modified Fume Hood Design to confine the critical area. Figure 1(a) represents a typical electroplating process shop floor (Polypropylene Electroplating Tank n.d.). The AI generated image in Figure 1(b) represents the proposed design (Microsoft CoPilot AI Prompt 1 2026). Enveloping the electroplating tanks/process-area for increased efficiency in suction. Reducing the critical area with slides/retractable sheets (of varying thickness as deemed to be appropriate) will improve the operating efficiency of the fume hood. These are for schematic representation, the better we enclose it with zero gap – the better air quality we will have.



Figure 1. (a) Typical electroplating process tanks, without extended fume hood design (b) Modified design for the Fume hood.

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A Synergistic Bio-electro-hydrometallurgical Strategy for Sustainable Metal Recovery from Waste Printed Circuit Boards

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The swift digital advancements and the ubiquitous integration of electronic devices into today's life have increased concern over critical metal supply, enhancing the economical viability of metal recovery from waste electrical and electronic equipment (WEEE). WEEE comprises diverse components, with waste printed circuit boards (WPCB) representing about 10% of total e-waste, are of significant interest owing to their high content of metals such as Cu, Zn, Al, Ni, Ag, and Au. Therefore, the effective recycling of WPCBs is vital for encouraging circular resource utilization and mitigating environmental risks. Among environmentally benign and sustainable recycling strategies, bioleaching has emerged as a promising avenue for metal extraction from WPCBs. Conventional bioleaching relies on iron and sulfur-oxidizing bacteria which are commonly employed for metal extraction from WPCBs. However, the sluggish growth kinetics lead to slow reaction rates and prolonged operation time, limiting their practical applications. Unlike conventional techniques, the bio-electro-hydrometallurgy approach integrates the bioleaching with simultaneous metal recovery from waste PCBs under applied electric fields thereby enhancing the metabolic activity of bioleaching microorganisms (Figure 1). Despite recent advances, systematic investigations on integrated bioleaching and in situ electrochemical metal recovery from mixed metal content electronic waste under controlled electrochemical conditions remain scarce. In this study, WPCBs were mechanically comminuted to a particle size.

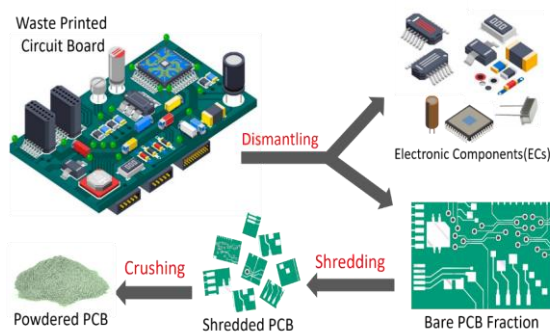


Figure 1. Schematic representation of printed circuit board (PCB) processing: dismantling, shredding and crushing to obtain powdered PCB.

POSTER PRESENTATIONS

Electrochemical Power Sources

PP-01

Sm-doped $\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$ Solid-state Electrolyte for Solid-state Li-ion Batteries: A Theoretical Approach

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Solid-State Batteries (SSBs) are emerging as a promising energy storage system, offering greater stability and reliability than traditional electrolyte-based Li-ion batteries. In this work, we investigate how Sm-doping in Lithium Lanthanum Zirconium Oxide (LLZO) at different concentrations improves ionic conductivity and stability over a fixed temperature range of 300-1200K. The phase transition from tetragonal to cubic in LLZO increases its conductivity, and Sm-doping stabilises the structure, raising its ionic conductivity from 10^{-4} S/cm to 10^{-3} S/cm, especially at high temperatures. This can be attributed to lower activation energies at optimum Sm doping concentrations and long-range diffusion path lengths that lead to better Li-ion pathways. Thus, Sm-doping in LLZO solid-state electrolytes will be a potential candidate for Li-ion SSBs.

PP-02

Enhanced Electrochemical Performance of Ni Doped BiVO_4 Hybrid Structures for Symmetric Supercapacitor Application

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Supercapacitors are increasingly attractive as promising power sources for short-duration energy pulses. Among their key components, the separator plays a crucial role in preventing internal short circuits and ensuring safe and efficient operation. All the active materials were prepared using the hydrothermal method. The Ni- BiVO_4 electrode exhibits a unique hierarchical nanostructure, characterized by enhanced electrochemical properties, a high specific capacitance, and capacitance preservation after 5,000 cycles at 10 A g^{-1} in a three-electrode system. The fabricated symmetric device achieves a specific capacitance of 78 Fg^{-1} at 1 A g^{-1} . Furthermore, it delivers an energy density of 24.6 Wh Kg^{-1} and a power density of 1034 W Kg^{-1} , while maintaining 84% capacity retention after 15,000 charge-discharge cycles.

PP-03

Lanthanum Double Perovskites as Bifunctional Oxygen Electrocatalysts for Metal-air Batteries

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Designing cost-effective and efficient electrocatalysts for oxygen reduction (ORR) and oxygen evolution (OER) remains a key challenge in advancing fuel cells and metal-air batteries. In this work, we present a noble-metal-free double perovskite oxide, LSCTMO, as a promising bifunctional catalyst. The material demonstrates excellent stability in alkaline medium (1 M KOH) and delivers significant onset potentials of 0.8 V for ORR and 1.57 V for OER versus RHE, highlighting its superior activity compared to conventional systems. The novelty of this design lies in rare-earth doping with La and Ce, which introduces redox flexibility at the A-site, enabling lattice distortion and oxygen vacancy engineering to induce electrochemical activity of OER/ORR performance. These structural modifications enhance oxygen activity and create abundant active sites, leading to improved bifunctional performance. This study highlights how rare-earth doping and oxygen vacancy engineering can unlock superior bifunctional activity in double perovskites. By combining redox flexibility with high-entropy design, LSCTMO achieves both stability and efficiency in alkaline media. Altogether, this work positions LSCTMO as a cost-effective, noble-metal-free catalyst for next-generation electrocatalyst for metal-air batteries.

PP-04

Tailoring Entropy-driven Cathode for Aqueous Sodium-ion Batteries

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Sodium-ion batteries have emerged as promising alternatives to lithium-based systems due to the natural abundance, low cost, and wide availability of sodium resources. Among various cathode materials, layered oxide cathodes have attracted significant attention because of their high theoretical capacity, favourable Na⁺ diffusion pathways, and tunable electrochemical properties. We have synthesized a high-entropy layered oxide cathode, incorporating multiple transition metals in

near-equimolar ratios. High entropy driven cathodes can enhance structural and moisture stability through entropy-driven phase stabilization and synergistic multi-element interactions. However, conventional sodium-ion batteries use non-aqueous electrolytes, which present several disadvantages, including flammability, toxicity, high cost, and complex safety management. To address these challenges, we have fabricated an aqueous sodium-ion battery, which is safer, environmentally compatible, and lower cost. In this work, a high-entropy layered oxide cathode is coupled with $\text{NaTi}_2(\text{PO}_4)_3$ (NTP) as the anode to develop a safe and stable aqueous sodium-ion battery system.

PP-05

Enhanced Electrochemical performance of Zn/Br₂ Redox flow battery Using Tungsten modified Electrodes

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Redox flow batteries have been used as viable options for the application of stationary energy storage on a large scale. Zinc-bromine redox flow battery system has attracted a lot of attention among other metal-halide redox flow batteries because of its high cell voltage, energy density and lifespan (Figure 1). However, the main problems with this flow system are related to the poor kinetics of the bromine/bromide redox reaction at the electrodes and bromine vapor production during the charge process. Surface characteristics of the positive electrode have an impact on the zinc-bromine redox flow battery's performance. Herein, we use sodium tungstate to modify a graphite felt electrode that has precise alterations made to its surface by a hydrothermal process. Very interestingly, the flow cell with tungsten modified graphite felt shows better performance over all current densities. At the high current density of 60 mA cm⁻², the flow cell with tungsten modified GF exhibits the coulombic efficiency (CE), voltage efficiency (VE) and energy efficiency (EE) of 95 %, 83% and 77%, respectively, whereas the bare exhibits only 93%, 68% and 64%, respectively. More importantly, the flow cell tungsten coated GF shows the excellent performance over 300 cycles at the current density of 40 mA cm⁻² and exhibits the CE, VE and EE of 92%, 85% and 775 %, respectively, whereas the flow cell with pristine GF delivers the CE, VE and EE of only 89%, 70% and 63%, respectively.

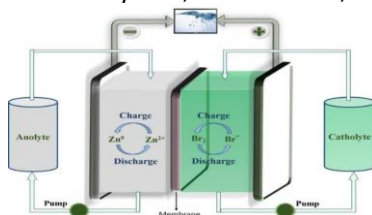


Figure 1. Schematic representation of Zn-Br redox flow battery.

Manganese Vanadate-based Positive Electrode Materials for Aqueous Zinc-ion Batteries

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As the demand for reliable and sustainable energy-storage systems continues to grow, conventional battery technologies face increasing limitations related to safety, cost, and long-term stability. Aqueous zinc-ion batteries (AZIBs) have therefore emerged as attractive candidates for grid-scale energy storage, benefiting from the abundance of zinc, aqueous electrolytes, and favourable electrochemical properties. Aqueous zinc-ion batteries (AZIBs) have attracted rapidly growing attention for grid-scale energy storage owing to their inherent safety, environmental benignity, and cost-effectiveness, as well as the high volumetric/gravimetric capacity and favourable redox potential of the Zn metal anode. The development of AZIBs is strongly governed by the selection of suitable cathode materials [1]. To date, a wide range of cathode systems have been explored, including Mn and V-based compounds, Prussian blue analogues (PBAs), organic materials, layered chalcogenides, metal oxides, poly-anionic compounds, and conversion-type materials. These diverse cathode materials highlight the broad research interest in AZIBs for large-scale energy storage applications. In this work, manganese vanadate-based materials are synthesized via a known hydrothermal method as cathodes for AZIBs [2,3]. Structural and morphological studies were carried out using X-ray diffraction (XRD) and scanning electron microscope (SEM). The synthesized material is subjected to electrochemical investigations and the obtained results are discussed in detail.

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Influence of Supporting Electrolyte and Heterostructured Electrocatalyst on Zinc Iodide Redox Flow Battery

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Redox Flow Batteries (RFBs) are among the most promising large-scale energy storage technologies. They offer the unique ability to separate energy from power, along with advantages in sustainability, scalability, and environmental friendliness. This study focuses on a hybrid zinc-iodine RFB, known for its high energy density, low cost, non-corrosivity, high solubility, and the favourable redox potentials of Zn^{2+} ($E^0 = -0.76$ V vs SHE) and I_3^-/I^- ($E^0 = 0.536$ V vs SHE) (Figure 1). Despite these advantages, the system suffers from several limitations: low iodine utilisation, the shuttle effect, Zn dendrite formation, which hinder its long-term cycling stability. To overcome these challenges, this study introduces a safe, neutral, and low-cost supporting electrolyte to both the anolyte and catholyte. The modified electrolyte system comprises KI (catholyte) and $ZnCl_2$ (anolyte), along with a chloride-based supporting electrolyte, which significantly enhances ionic conductivity and electrochemical performance. Along with the modified electrode, the role of the hetero-engineered catalyst is studied. The optimised Zn– I_2 flow cell with modified electrolyte and electrode demonstrates remarkable cycling stability over ~ 1000 cycles at a current density of 30 mA cm^{-2} , achieving a coulombic efficiency of $\sim 90\%$, an energy efficiency of $\sim 75\%$, and a power density of ~ 70 mW cm^{-2} . These results represent a substantial improvement over the conventional system, highlighting the effectiveness of the electrolyte and the electrode.

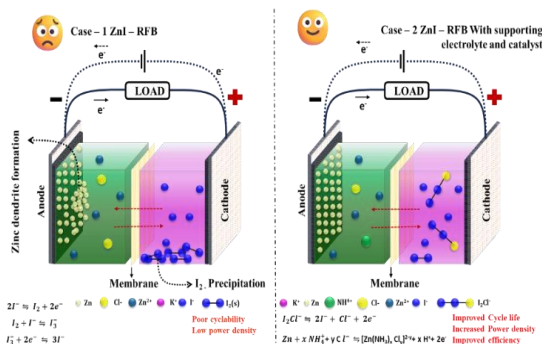


Figure 1. Schematic representation of Zn- I_2 redox flow battery.

PP-08

Engineering MoS₂/Nb₂C MXene 2D/2D Heterostructures for Enhanced Supercapacitor Performance

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The increasing depletion of non-renewable energy resources has made the development of high-efficiency and high-capacity energy storage devices critically important. Supercapacitors are promising candidates due to their rapid charge-discharge capability and high-power efficiency. However, the practical performance of supercapacitors is strongly governed by the properties of electrode materials, which play a decisive role in determining energy storage capability. Among various electrode materials, MXenes and MoS₂ have emerged as high-performance pseudocapacitive materials. However, severe restacking of MXene nanosheets significantly limits the accessibility of active sites, while the relatively poor electrical conductivity of MoS₂ restricts the full utilization of its pseudocapacitive behavior. In this work, MoS₂/Nb₂C MXene heterostructures are successfully constructed via a hydrothermal synthesis route. The resulting architecture effectively suppresses nanosheet aggregation and forms an open ion-transport network. Electrochemical investigations reveal a pronounced enhancement in capacitance, attributed to the enlarged ion-storage space and strong synergistic interactions within the heterostructure. Notably, the MoS₂/Nb₂C MXene symmetric supercapacitor delivers a high specific capacitance of 360 F/g at a current density of 0.5 A/g, along with an energy density of 21 Wh/kg. This study demonstrates an effective strategy to overcome the intrinsic limitations of individual two-dimensional materials and provides a viable design pathway for achieving superior electrochemical performance in 2D/2D heterostructured electrodes for advanced supercapacitors. Detailed material synthesis and electrochemical performance will be discussed during the presentation.

PP-09

A High-performance Zinc-ion Supercapacitor with Prolonged Cycling Stability Enabled by Tailored Redox-active Electrolyte Chemistry

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Energy storage systems that integrate multiple charge storage mechanisms offer a promising strategy for enhancing electrochemical performance. This can be achieved by incorporating polyhalide-based halogen redox couples, which provide high redox potentials and excellent solubility. However, challenges related to reversibility and phase instability remain unresolved. To address these issues, a zinc-based hybrid energy storage system was developed by introducing varying concentrations (0 – 2 M) of a redox-active electrolyte additive into ZnSO₄ electrolyte. This device, employing zinc foil as the anode and activated carbon as the cathode, delivered a high specific capacity of approximately 500 mAh g⁻¹. Furthermore, cycling studies showed stable performance with good capacity retention, indicating the effectiveness of the optimized redox electrolyte strategy. Overall, this study highlights the potential of polyhalides as promising redox-active electrolyte additives for advanced zinc-based energy storage systems.

PP-10

Multiphasic Cathodes for Sodium-ion Batteries

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With the rapid increase in global energy demand, renewable energy sources such as solar and wind power face significant challenges due to the mismatch between energy generation and consumption in both time and space. This intermittency necessitates the development of large-scale energy storage systems. Consequently, there is an urgent need for advanced energy storage materials that offer high energy efficiency, long cycle life, safety, and cost-effectiveness. Lithium-ion batteries (LIBs) have been widely adopted to meet current energy storage demands; however, the limited availability of lithium resources and high production costs have become major constraints on their long-term sustainability. Sodium-ion batteries (SIBs) have emerged as a promising alternative to LIBs owing to the natural abundance, low cost, and wide geographical distribution of sodium resources, making them particularly attractive for large-scale energy storage applications. In addition, sodium-ion batteries exhibit enhanced safety characteristics, including superior thermal stability, lower heat generation, and reduced temperature rise under abusive conditions such as overcharging, over-discharging, and short-circuiting [1]. Among various cathode materials investigated for SIBs, layered transition-metal oxides have attracted considerable attention due to their high theoretical capacity and favourable electrochemical properties. However, single-phase layered structures, such as P2- or O3-type oxides, suffer from intrinsic limitations including structural instability, phase transitions, and limited cycling durability. P2/O3 composite materials, which combine both phases in a single system, offer synergistic advantages that overcome these drawbacks and enhance electrochemical performance [2]. The biphasic structure effectively mitigates structural stress during repeated sodium insertion and extraction, thereby enhancing cycling stability, extending the operational lifespan of the battery. In

this work, a P2/O3 biphasic composite cathode material was synthesised using the sol–gel method. The structural and morphological characteristics of the material were systematically analysed using X-ray diffraction (XRD) and scanning electron microscopy (SEM). The electrochemical performance was evaluated through CV, galvanostatic charge–discharge measurements, rate capability tests, and high-rate cycling studies in sodium half-cells. The obtained results will be discussed in detail.

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PP-11

Multi-element Substitution in O3-Type Layered Oxide Cathodes for High-performance Sodium-ion Batteries

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While lithium-ion batteries have transformed the electronics and EV sector, the call for sustainable and green energy requires a quantity that Li alone cannot fulfil. With concerns over geopolitical scarcity, environmental impact, and cost, the world is transitioning to a sustainable alternative. Cobalt-free Sodium Ion batteries emerged as the most promising alternative to provide a low-cost, high-performance energy storage solution. O3-type layered oxides are emerging candidates for high-energy. However, they have complex phase transitions and structural instability at high Voltage, which hinder the commercial viability. In response to this challenge, a stable cathode material, $\text{NaNi}_{0.22}\text{Mn}_{0.33}\text{Cu}_{0.11}\text{Fe}_{0.23}\text{Al}_{0.1}\text{O}_2$, has been formulated here, and its structural, morphological, and electrochemical characteristics are investigated. The cathode material was synthesised using the Solid-State method. The structural characterisation by X-ray Diffraction (XRD) confirms the formation of a highly ordered pure phase structure. The compositional accuracy is confirmed by several further analyses, including WDXRF and flame photometry for Na stoichiometry. The inclusion of Aluminium serves to stabilise the transition metal layers, mitigating common phase transitions associated with high-voltage sodium extraction. Consequently, the Al-stabilised cathode delivers a discharge capacity of ~ 120 mAh/g in a potential window of 2.0 to 4.2 V. This research provides a cobalt-free strategy for developing chemically robust, high-performance, low-cost, high-stability O3-type cathodes for the next generation of SIBs.

PP-12

Synthesis and Electrochemical Properties of FeSe₂ Anchored g-C₃N₄ as a Potential Anode for Sodium Ion Batteries

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Sodium-ion batteries (SIB) have played a major role in recent years due to their abundant resources, low cost, and safety concerns in energy storage systems compared to lithium-ion batteries. FeSe₂, which belongs to the transition-metal chalcogenides, has garnered significant interest as an anode material for SIB due to its high theoretical specific capacity, sufficient resources, and chemical stability, with multiple redox kinetics relative to those of carbon-based materials. Yet, it suffers from severe volume expansion during sodium ion intercalation/deintercalation, leading to capacity fading. The poor intrinsic electronic conductivity of FeSe₂ hinders reversible capacity retention, and the compound is unable to withstand high current rates. As a result, the in-situ carbon conductivity of the material is improved by introducing citric acid, which encapsulates the FeSe₂ particles to form a core-shell structure, thereby hindering agglomeration via a one-step hydrothermal method. In addition, an ex-situ carbon composite of an electronegative g-C₃N₄ sheet with embedded FeSe₂/C enhances structural stability. The crystal structure and stretching vibrations of the functional groups are analyzed using XRD, FTIR, and Raman spectroscopy. The sharp crystalline peak observed along the (111) plane in the XRD spectrum confirms the pure orthorhombic structure of FeSe₂. Further, the multiple reduction peaks observed at 1.64 V, 1.05 V, and 0.67 V vs. Na/Na⁺ correspond to the insertion of Na⁺ ions into the FeSe₂ structure, initially forming Na_xFeSe₂, followed by the transformation of FeSe to Fe and Na₂Se via a conversion reaction. The composited FeSe₂/g-C₃N₄ delivers a specific capacity of 350 mA h/g at a current density of 0.1 A/g, with improved structural stability. Also, the charge-transfer resistance (R_{ct}) is observed to be 152 Ω for the FeSe₂/G-C₃N₄ composite electrode. This work demonstrates that FeSe₂/G-C₃N₄ is a suitable anode material for SIB.

PP-13

High Entropy Layered Oxides as Positive Electrode Material for Sodium-ion Batteries

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As fossil fuels and other non-renewable resources are diminishing, it is essential to prioritise the development of sustainable renewable energy sources to attain carbon neutrality. While wind, solar, and tidal energies are abundant, their intermittent nature necessitates effective large-scale energy storage solutions. Electrochemical energy storage systems, such as batteries and supercapacitors, offer promising solutions. Lithium-ion batteries (LIBs) are notable for their high energy density and moderate power density. Still, challenges arise from the uneven distribution of raw materials, safety concerns, and high costs limit the ability of LIBs to meet growing energy demands. As sodium is abundant and behaves in a similar manner to LIBs, sodium-ion batteries (SIBs) offer a promising option for large-scale energy storage and electric vehicles [1]. Among the current cathode materials, layered materials are attractive due to their high operating voltage and capacity. Nevertheless, they face challenges such as low cycling stability due to the intrinsic structural instability of the cathode material, electrolyte incompatibility with high voltages, and multiple phase transformations during cycling. These hurdles can be overcome by designing high-entropy layered cathode materials by simultaneously doping five or more selected metal ions into the transition-metal layers, thereby significantly enhancing structural entropy, reducing formation energy, and improving structural stability [2]. In this work, an O3-type high-entropy layered oxide, O3-Na(NiMnFeCoTi)₁O₂, was synthesised via the sol-gel method. Structural and morphological studies were carried out using X-ray diffraction (XRD) and scanning electron microscopy (SEM). The electrochemical performance of the material was evaluated using cyclic voltammetry, galvanostatic charge-discharge, rate capability and high-rate cycling tests in sodium half-cells, which show a decent discharge capacity and cycling performance, with suppressed phase transitions as expected. These results demonstrate that introducing configuration entropy into layered oxides effectively enhances the electrochemical properties of layered oxide cathodes for SIBs.

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PP-14

Organic Molecule-pillared NH₄V₄O₁₀ for Durable Aqueous Zinc-ion Batteries

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Due to the gradual depletion of energy resources and the environmental issues caused by the excessive use of fossil fuels, there is an increasing need for new energy storage systems. As lithium-ion batteries (LIBs), which have recently been applied as large-scale energy storage systems, reveal

safety, economic, and environmental concerns, the need for the development of rechargeable batteries is in demand. In order to overcome the disadvantages of LIBs, aqueous zinc-ion batteries (AZIBs) are the good alternative energy storage devices with unique advantages, such as cost-efficient and non-flammability for large-scale energy storage. However, their widespread applications are hindered by the development of cathode materials, sluggish intrinsic ion/electron kinetics, and unsatisfied structural stability. In order to overcome the challenges, layered Vanadium-based compounds are emerging as a promising cathode material for aqueous zinc ion batteries due to their high specific capacity, open framework structures and the multivalent redox chemistry of vanadium. But, the low intrinsic conductivity and sluggish Zn^{2+} diffusion kinetics seriously impede their further practical application. Among vanadium-based cathode materials, we report a high-performance $\text{NH}_4\text{V}_4\text{O}_{10}$ (NVO) cathode which enhances the Zn^{2+} diffusion ability. The pristine NVO delivers a high capacity of 443 mAh g^{-1} at 100 mA g^{-1} . In this work, a polar organic molecule is intercalated into NVO to achieve ultrahigh-rate and long cycling life. The pre-inserted organic molecule expands the interlayer spacing as well as stabilizes the host framework through its functional groups, constructing robust and wide ion transport channels for highly reversible Zn^{2+} de/intercalation. This work demonstrates a molecular engineering strategy for high-performance AZIBs cathodes through precisely tailored organic molecule intercalation. The material synthesis, characterization and its electrochemical performance will be discussed in detail during the presentation.

PP-15

Polydopamine-modified Cu for Dendrite-free Lithium Deposition

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Lithium metal anodes offer high theoretical capacity but suffer from challenges associated with uneven lithium deposition and dendritic growth, leading to limited cycling stability. Modifying the current collector surface provides a potential route to influence lithium nucleation behavior and improve interfacial characteristics. Herein, a polydopamine electrodeposition strategy was employed to modify copper current collectors with a thin functional interlayer aimed at improving lithium deposition uniformity. The electrochemical response of the modified collectors was investigated in relevant cell configurations to examine their influence on plating–stripping behavior. Preliminary results indicate improved deposition characteristics and enhanced interfacial stability compared to unmodified copper. These findings suggest that surface functionalization of current collectors may play a critical role in regulating lithium growth and advancing the development of more stable lithium metal-based energy storage systems.

PP-16

Designing Ester-based Electrolytes with Dual-salt Strategy for Enhanced Low-temperature Lithium-ion Battery Performance

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Lithium-ion batteries (LIBs) using conventional carbonate electrolytes exhibit limited performance at sub-zero temperatures. The increased electrolyte viscosity and sluggish Li⁺ transport at low temperature leads to reduced ionic conductivity. Electrolyte systems with low melting point and low viscosity, such as esters can be used to overcome these limitations. However, their poor compatibility with graphite electrodes remains a challenge. In this work, an ester-based electrolyte with dual-salt strategy is proposed to regulate the solvation environment. LiTFSI and LiDFOB, along with ethyl acetate-based esters and a small amount of functional additive, are used to tailor the electrolyte chemistry. The designed electrolyte system enables reduced Li⁺-solvent coordination, and promotes controlled interphase formation while retaining transport properties essential for low-temperature performance. Initial electrochemical performance was evaluated in Graphite||Li and NMC532||Li half-cell configurations. Electrochemical impedance spectroscopy shows lower interfacial resistance, indicating improved charge transfer kinetics. Cyclic voltammetry analysis indicates suppressed electrolyte reduction, suggesting enhanced electrochemical stability. The NMC532||Li half-cell, delivered an initial discharge capacity of 152 mAh g⁻¹ and shows stable cycling behaviour with 99% capacity retention over 50 cycles at room temperature. The Graphite||Li half-cell exhibited initial discharge capacity of 368.5 mAh g⁻¹. This study presents an effective strategy for designing low temperature electrolytes, enabling the application of LIBs at sub-zero temperatures.

PP-17

Electrodeposited Zinc-bismuth Alloy Anode for Rechargeable Zinc Alkaline Batteries with Improved Cycling Stability

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The development of a high-performance, flexible, and rechargeable energy storage system is critical for the next generation of wearable electronics and IoT devices. Zinc-based aqueous batteries offer a low-cost and safe alternative to lithium-ion batteries. Hydrogen Evolution Reaction (HER) and uncontrolled dendritic growth of zinc are the major challenges in the development of rechargeable Zinc metal batteries. In this work we explore electrode modification and electrolyte composition modification to address these issues (Figure 1). For this zinc bismuth alloy electrodeposited on screen printed electrodes and an optimized alkaline electrolyte with additives to suppress the HER and zinc dendrite growth. The cycling stability of the anode in the modified electrode was tested and is found to be stable for 50 cycles with a coulombic efficiency of 98% at current density of 9.55 mA/cm² compared to electrodeposited pure zinc metal. Thus, this investigation shows the potential for improving the cycling stability of rechargeable zinc metal batteries.

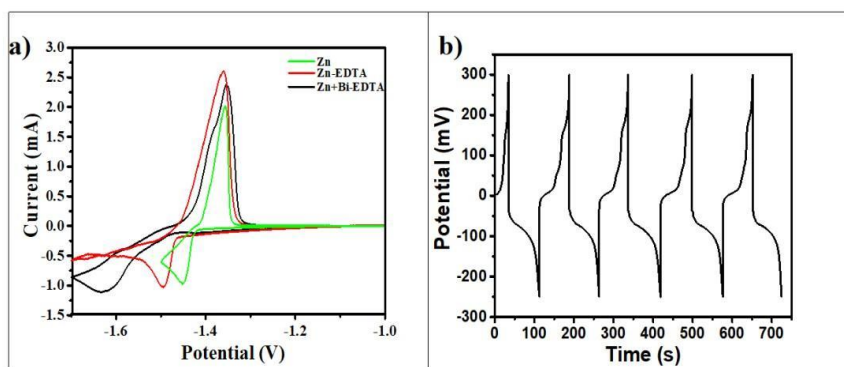


Figure 1. (a) CV for deposition of Zn from zincate solution, Zn-EDTA complex solution and co-deposition of Zn-Bi from zincate-Bi-EDTA complex solution. (b) GCD of deposited Zn-Bi half cell in modified electrolyte at current density 9.55 mA/cm².

PP-18

Built-In MXene/Metal Niobate Heterointerface with Efficient Interfacial Charge Transport for Advanced Lithium Storage and Hybrid Capacitors

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Lithium-ion hybrid capacitors (LIHCs) are rapidly gaining attention as next-generation energy storage devices, uniquely combining the high energy density of batteries with the ultrahigh power capability,

and cycling stability of supercapacitors. However, their widespread deployment is still constrained by the challenge of developing robust anode materials that can deliver high capacity, fast kinetics, and long-term stability simultaneously. Recently, MXene-based composites have emerged as promising candidates for meeting this requirement, owing to their high electrical conductivity and adaptable surface chemistry, which make them suitable for a broad range of applications. In this work, we investigate niobium-based materials such as 2D Nb₂C MXene and conversion-type CoNb₂O₆, as potential anodes for LIHCs. Their structural and surface properties were characterized using XRD, FE-SEM, XPS, and HR-TEM. While looking at electrochemical performances, Nb₂C delivers a stable specific capacity of ~190 mAh/g over 100 cycles with excellent rate capability, and CoNb₂O₆ demonstrates a higher initial capacity but suffers from rapid capacity fading due to its conversion reaction mechanism, retaining only ~200 mAh/g after 15 cycles at the same current density. To address this limitation, we propose a hybrid strategy by integrating CoNb₂O₆ with Nb₂C MXene to leverage the mechanical robustness and electronic conductivity of MXene for stabilizing the electrochemical behavior of CoNb₂O₆. Drawing inspiration from our previous work on Nb₂C/FeCo-LDH composites, various mass ratios of Nb₂C and CoNb₂O₆ were synthesized and studied to identify the optimal composition. The best-performing hybrid anode was further integrated with a high-surface-area porous carbon cathode to assemble a full-cell LIHC. Detailed structural, physical, and electrochemical analyses of the assembled system will be comprehensively discussed in the presentation.

PP-19

Experimental Investigation of Temperature and Current Rate Effects on Heat Generation in Lithium-Ion Cells

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The thermal behaviour of lithium-ion batteries is significantly influenced by operating temperature and charge-discharge rate. In this study, the reversible, irreversible, and total heat generation of cylindrical lithium cobalt oxide (LCO) cells are experimentally investigated under varying ambient temperatures (0°C, 10°C, 20°C, and 30°C) and C-rates (0.5C and 2C). The heat-generation components are evaluated using measured voltage, current, and temperature data, enabling separation of entropic (reversible) and resistive (irreversible) heat contributions. The results demonstrated that total heat generation increases notably with increasing C-rate and decreasing ambient temperature. Across the tested conditions, the minimum total heat generation of 0.113 W is obtained at 0.5C C-rate and 30°C, and the maximum is 2.705 W at 2C C-rate and 0°C. This represents a significant increase in thermal output under high-stress operating conditions, primarily due to enhanced internal resistance and polarization effects. The irreversible heat generation is identified as the dominant

contributor to total heat, particularly at 2C, where resistive losses become substantial. At lower temperatures such as 0°C, reduced ionic conductivity and slower electrochemical kinetics lead to higher internal resistance, thereby increasing irreversible heat generation. In contrast, at 20°C and 30°C, improved reaction kinetics reduce resistive losses, resulting in comparatively lower heat generation even at elevated C-rates. The reversible heat generation associated with entropy changes during electrochemical reactions exhibits comparatively smaller magnitudes and does not significantly impact the overall thermal behaviour under high C-rate conditions. However, its effect is more noticeable at lower C-rates, where it contributes modestly to the total heat generation. The temperature-time analysis further confirms that the combination of high C-rate (2C) and low ambient temperature (0°C) produces the most severe thermal conditions, characterised by increased heat generation and greater temperature rise. Conversely, operation at a lower C-rate (0.5C) and moderate temperatures (20-30°C) results in stable thermal behaviour with minimal heat accumulation. Overall, the study clearly establishes that C-rate is the primary driving factor for heat generation, while temperature modulates the magnitude of resistive losses. The observed variation in total heat generation from 0.113 W to 2.705 W highlights the importance of controlling operating conditions to ensure thermal stability (Figure 1). These findings provide valuable insights for the design of efficient battery thermal management systems and safe operation of lithium-ion batteries under varying environmental and load conditions.

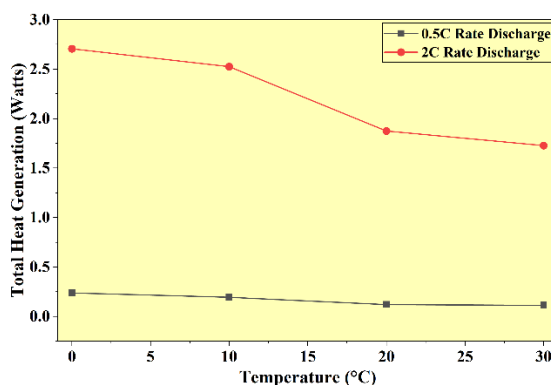


Figure 1. Effect of temperature and C-rate on total heat generation in LCO lithium-ion cells.

PP-20

Photo-assisted Capacitive Performance of Vanadium Based Supercapacitor

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Developing highly efficient solar cells merged with rechargeable energy storage systems is the key to accomplishing a sustainable future in the energy sector. Also, the global demand for energy concerning the depletion of fossil fuels has raised significant breakthroughs in developing green and clean energy resources. One of the most easily accessible energy sources on Earth is solar energy. Solar energy can be converted into electrical energy using solar cells. However, this harvested energy must be stored in a storage system like a battery or supercapacitor to supply electrical energy steadily in the desired quantity at the desired time. Solar cells are usually connected to an electrochemical capacitor or rechargeable batteries, which adds cost and complexity to the system. To address this problem, a material capable of harvesting and storing energy could reduce the cost and lessen the unpredictability of energy related to solar technologies. Semiconductors are integrated into electrochemical energy storage systems to convert solar to electrical energy, which requires no additional circuitry to convert and store energy. Ideally, combining energy harvesting and storage in a single device would remarkably improve their volumetric performance. Photoactive materials like vanadium pentoxide can be used for these applications. Herein, we have synthesised a 1D vanadium-based nanostructure by the combustion method. We have also fabricated symmetric devices using this material. There was an increase in capacitance in the presence of light. The increase in capacitance value in the presence of light is a clear indication that the photo charging-based supercapacitor will pave an innovative path in constructing futuristic energy storage devices.

PP-21

Synergistic Catalytic and Conductive Effects of CoSe@f-MWCNT - sulfur Composite Cathode in Lithium – sulfur Batteries

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Lithium–sulphur (Li–S) batteries are promising next-generation energy storage systems owing to their high theoretical energy density and low cost. However, their practical application is limited by the polysulphide shuttle effect and poor cycling stability. In this work, a ZIF-67-derived cobalt selenide

(CoSe) functionalised multi-walled carbon nanotube (f-MWCNT) composite was engineered using the sulfur host cathode to enhance the Li-S battery performance. The MOF-derived CoSe nanoparticles provide strong catalytic activity for accelerating polysulphide redox conversion, while the conductive f-MWCNT network facilitates rapid electron transport and suppresses the polysulphide migration. Structural and morphological analyses confirmed the successful formation of the CoSe@f-MWCNT hybrid architecture. The CoSe@f-MWCNT electrode in the CR2032 coin cells, demonstrated an improved redox kinetics, enhanced cycling stability, and better capacity retention. The synergistic catalytic-conductive effect of the CoSe@f-MWCNT sulfur host offers a significantly improved electrode, which is suitable for high performance lithium-sulfur batteries.

PP-22

Development of Orthorhombic Na_3TaO_4 - type Oxide Based Solid Electrolyte for All-solid-state Sodium-ion Batteries

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Solid Electrolytes (SE) are promising candidates for enabling safer rechargeable batteries with high energy- density. Developing an ideal inorganic SE that delivers high Na^+ ion conductivity, good electrochemical/chemical stability, and compatible electrode/SE interface is key for the high-performance ASSSB's. Most research on oxide-based Na^+ superionic conductors focuses on Nasicon type ($\text{Na}_3\text{Zr}_2\text{Si}_2\text{PO}_{12}$) mainly due to its high ionic conductivity and air stability. Although Nasicon has promising ionic conductivity due to mixed polyhedral framework, challenges such as formation of secondary phases during synthesis pose a major concern during electrochemical analysis. In this work we developed a new sodium solid electrolyte ($\text{Na}_x\text{M}_2^{2+}\text{TaO}_6$) free from zirconia framework and investigated its structural and electrochemical properties. The $\text{Na}_x\text{M}_2^{2+}\text{TaO}_6$ was synthesized by a multi-step solid state reaction. The $\text{Na}_x\text{M}_2^{2+}\text{TaO}_6$ was structurally analyzed using XRD and Raman spectroscopy. Impedance measurement exhibited total ionic conductivity of $1.88 \times 10^{-4} \text{ S/cm}$ at room temperature, making it a potential candidate for Na -ion conductor for all-solid- state batteries. Additionally, Galvanostatic stripping/plating studies showed that NaSSE is compatible with Na metal when cycled at different current densities from 10 to 50 $\mu\text{A/cm}^2$.

Fabrication of Screen-printed Zinc Alkaline Rechargeable Micro-battery with Silver Nanoparticles Decorated Reduced Graphene Oxide Cathode

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Silver-zinc (Ag-Zn) micro-batteries offer a safe alternative to lithium-based chemistries for wearable and implantable electronics. Here, we synthesize a silver nanoparticle decorated reduced graphene oxide (Ag-rGO) composite and electrochemically convert Ag to silver peroxide (Ag₂O₂) at 2.1 V for 1 h, yielding a rechargeable cathode. Screen printed microcells were fabricated using oxidized Ag-rGO as the cathode and a Zn plate anode in 3 M KOH. The device exhibited an open-circuit potential (OCP) of 1.89 V and a working voltage of 1.56 V. At 0.2 A g⁻¹, the battery delivered a specific capacity of 385 mAh g⁻¹ and a specific energy of 601 mWh g⁻¹. After 100 charge-discharge cycles at 1 A g⁻¹, it retained 74.15% of its capacity, indicating good cycling stability for a printed configuration. Practical demonstrations underscore relevant applications, (i) a 1.5 V calculator operated continuously for ~24 h, and (ii) a 2 V LED remained illuminated for ~2 min, evidencing the capability to support low-power, long-duration and high-power, short-duration loads. These results establish Ag₂O₂-modified graphene as an effective cathode for screen-printed, rechargeable Ag-Zn micro-batteries, combining safety, scalability, and competitive energy metrics suitable for integration into portable and wearable devices.

PP-24

Surface-Modified MgCo₂O₄ Nanostructured Electrodes for Flexible and Wearable Supercapacitor Applications

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The Yucca-plant-like bimetallic MgCo₂O₄ nanoneedle cluster arrays were directly grown on three-dimensional nickel foam using a facile and scalable one-step hydrothermal process, with reaction time governing the electrode architecture and electrochemical behavior. The MgCo₂O₄/NF electrode synthesized at 20h exhibits the highest specific capacity of 2727 C g⁻¹ at 5 mV s⁻¹, outperforming electrodes prepared at shorter reaction times. The superior performance arises from the hierarchical nanoneedle cluster morphology, which offers a large electro-active surface area and an interconnected mesoporous network, enabling rapid ion diffusion and enhanced redox kinetics. Galvanostatic charge–discharge measurements demonstrate a high specific capacity of 1416 C g⁻¹ at 1 A g⁻¹ and excellent cycling stability, with 161% capacity retention after 12,000 cycles. The fabricated symmetric coin-cell and flexible supercapacitor devices are assembled using identical MgCo₂O₄ nanoneedle cluster array electrodes and deliver excellent electrochemical performance: a maximum specific capacity of 68 C g⁻¹, an energy density of 7 Wh kg⁻¹, and a power density of 374 W kg⁻¹ for the symmetric coin-cell supercapacitor. In addition, the fabricated flexible supercapacitor device demonstrates high flexibility and mechanical robustness, highlighting its potential for extended, flexible, and wearable supercapacitor applications.

PP-25

Biomass-Derived Activated Carbon from Prosopis Juliflora Stem Using KMnO₄ activation for Symmetric Electrochemical Double-Layer Capacitors

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The need for energy storage devices with low-cost electrode materials is paramount in the race to address the energy crisis. The present work aims to turn the invasive weed Prosopis juliflora stem (PJS) into energy storage applications under the concept of turning waste into wealth. The porous carbon was prepared from PJS at different temperatures (600, 700, and 800 °C) using KMnO₄ as the

activating agent. The XRD patterns of PJS-800, PJS-700, and PJS-600 samples exhibit two broad diffraction peaks centered at around $2\theta=25^\circ$ and 43° corresponding to the (002) and (100) planes of graphitic carbon. The absence of sharp crystalline reflections confirms the predominantly amorphous nature of the activated carbon. Notably, the PJS-800 sample shows slightly enhanced peak intensity, indicating improved structural ordering at higher carbonization temperature. FESEM analysis revealed that the enhanced porosity of PJS-800 significantly improved ion diffusion and charge storage behavior. FTIR spectra revealed characteristic bands corresponding to hydroxyl (-OH), carbonyl (C=O), aromatic C=C, and C-O functional groups, confirming the presence of oxygen-containing surface functionalities. The intensity variation with increasing carbonization temperature indicates structural evolution and partial graphitization, particularly for PJS-800. The significance of synthesized carbon with distinct properties and promising electrochemical performances for supercapacitors is also explored. The symmetric EDLC cell was assembled using a LIR2032 coin cell to analyze electrochemical performance. The synthesized carbon (PJS-800) provides abundant sites, offering a significantly high energy density of 10.30 Wh kg^{-1} at a power density of 150 W kg^{-1} with an operating voltage window of 1.5 V in 1 M Na₂SO₄ electrolyte at 0.2 A g^{-1} . The rectangular CV profiles, without any redox peaks, of the PJS-800 sample indicate ideal EDLC behavior. Even at increasing scan rates, the PJS-800 sample maintains its rectangular shapes, showing enhanced reversibility.

PP-26

Cerium Oxide (CeO₂) Incorporated PAN/PANI Free-standing Electrode Derived from Electrospun Carbon Nanofibers for High-Performance Supercapacitors

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Freestanding electrodes without binders with the advantages of a continuous conductive network are improving in supercapacitor applications. In this work, PAN/PANI electrospun nanofibers with specified concentration ratios were prepared and optimised the carbonisation procedure to enhance the conductivity. Also, Cerium oxide (CeO₂) nanoparticles were prepared by a microwave-assisted technique and incorporated into PAN/PANI nanofibers at the maximum loading. The prepared materials are subjected to various physical, chemical, and electrochemical characterisations to understand their behaviour. It was noted that the asymmetric capacitor configuration PAN/PANI-Ce(20 wt%) delivers a maximum capacitance at 0.7 mA. Also, the cell exhibits better coulombic

efficiency and capacity retention with the specified concentration of cerium oxide, along with the conducting polymer and PAN polymer matrix, carbonised at an optimised temperature, resulting in higher electrochemical performance compared to the pristine PAN/PANI electrode. Our work with a flexible strategy to construct binder-free electrodes improves the efficiency of the energy storage devices.

PP-27

Synthesis and Electrochemical Characterization of $\text{Ni}_2\text{P}_2\text{O}_7$ for Zinc-Based Battery Applications

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The increasing global demand for sustainable and large-scale energy storage systems have gained the attention of rechargeable batteries. In this work, a rechargeable aqueous Zn – $\text{Ni}_2\text{P}_2\text{O}_7$ battery was fabricated using a solid-state reaction method by varying the concentration of zinc doped nickel pyrophosphate. 0.05 wt.% zinc doped nickel pyrophosphate electrode material shows best electrochemical performance due to the diffusion controlled reversible redox behavior. The structural properties of the synthesized materials were characterized using powder X-Ray diffraction, to confirm the phase formation and crystallinity. The electrochemical performance was evaluated using cyclic voltammetry, galvanostatic charge – discharge and Electrochemical Impedance spectroscopy to investigate redox behavior, specific capacity and charge transfer resistance. The enhanced long – term stability and higher energy density shows its practical application.

PP-28

Electrochemical Performance of Zifl - Graphitic Carbon Nitride Nanocomposite Electrode for Supercapacitor Application

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Metal–organic frameworks (MOFs), particularly zeolitic imidazolate frameworks with linker modulation (ZIFL), have garnered significant attention as electrode materials for supercapacitors owing to their high surface area, tunable porosity, and structural diversity. ZIFL was initially

synthesized via a room-temperature method, yielding a distinctive two-dimensional leaf-like morphology. The electrochemical performance was further enhanced by integrating ZIFL with graphitic carbon nitride ($g\text{-C}_3\text{N}_4$), forming a ZIFL@GCN nano composite. The composite was synthesized through a wet chemical route. The materials were further characterised by XRD, FT-IR, BET and FESEM. From FT-IR and FESEM the integration of $g\text{-C}_3\text{N}_4$ with ZIFL were confirmed with corresponding peaks and morphology. From BET analysis the surface area of $g\text{-C}_3\text{N}_4$, ZIFL, ZIFL@GCN were found to be 11, 69 and 40.6 m^2/g . This synergistic integration leverages the conductive and chemically stable nature of $g\text{-C}_3\text{N}_4$ with the high surface area and porosity of ZIFL, resulting in improved electron transport and enhanced electrochemical activity. Electrochemical characterization using a three-electrode configuration revealed a specific capacitance of 580 F/g at a current density of 1 A/g, establishing the potential of the ZIFL@GCN nano composite as a high-performance electrode material for energy storage applications. The charge storage behaviour was explored using a two-electrode system with supporting activated carbon and subjected to CV and GCD techniques. The specific capacitance of 34.74 F/g at 1 A/g reveals the good charge storage capability of the ZIFL@GCN nano composite. To study the stability test device subjected to a 5000 cycles and retention capacity of 59% obtained, with maximum power and energy density of 5995 W/kg and 25 Wh/kg.

PP-29

In-situ hydrothermal Synthesis of Mxene/NiCo-BTC MOF Hybrid Nanosheets for High-performance Supercapacitor Electrodes

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Using Trimesic acid (BTC) as the organic ligand, a novel hybrid nanocomposite of Ni-Co metal-organic-framework (MOF) and MXene ($\text{Ti}_3\text{C}_2\text{Tx}$) was synthesized via a facile one-step hydrothermal method for high performance supercapacitor electrodes. The 2D/2D hierarchical architecture with its in-situ growth of ultrathin NiCo-BTC MOF nanosheets on MXene leverages the surface terminations of Mxene for strong interfacial bonding, preventing restacking and composite degradation. While Mxene enhances conductivity and ion diffusion pathways, the rigid BTC ligand coordinates $\text{Ni}^{2+}/\text{Co}^{3+}$ bimetallic nodes to provide synergistic redox activity. The electrochemical evaluation in 3 M KOH electrolyte exhibited a specific capacitance of 400 Fg^{-1} at 4 Ag^{-1} , along with excellent cycling stability retaining 90% capacitance after 5000 cycles at the same current density. This Mxene/NiCo-BTC hybrid demonstrates superior pseudocapacitive performance, positioning it as a promising electrode material for advanced energy storage systems.

PP-30

Engineered Urchin-like Hierarchical $\text{Co}_3\text{O}_4/\text{MnS}_2/\text{g-C}_3\text{N}_4$ Heterostructure for Superior Supercapacitors

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The CMGN heterostructure, comprising Co_3O_4 , MoS_2 , and $\text{g-C}_3\text{N}_4$, was synthesized via hydrothermal processing combined with ultrasonication. X-ray diffraction verified distinct crystalline structures, while FTIR analysis clarified functional groups and interfacial linkages. High-resolution electron microscopy revealed distinctive urchin-like architectures formed by interlinked, crumpled nanosheets, indicating uniform assembly and strong interfacial integrity. XPS spectra confirmed elemental ratios and valence states. Electrochemical assessments via cyclic voltammetry, galvanostatic charge-discharge, and impedance analysis showcased exceptional performance. In a three-electrode configuration, the CMGN electrode delivered a specific capacitance of 1188 F g^{-1} at 1 A g^{-1} . Furthermore, the asymmetric full-cell device achieved impressive energy density paired with high power output, while demonstrating excellent capacitance retention over extensive cycling. These attributes position transition metal chalcogenide heterostructures as highly viable candidates for next-generation supercapacitor electrodes.

PP-31

Hybrid PVDF- MoS_2 Architectures for Flexible Solid-State Supercapacitor with Superior Charge Storage Properties

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Flexible solid-state supercapacitor (SSs) as promising next-generation energy storage devices with the combination of high-power performance, mechanical flexibility, fast charge-discharge and long cyclic stability. In this work we fabricated the free standing of PVDF- MoS_2 composite films via a scalable-assisted solution casting method. By embedding the exfoliated MoS_2 nanosheets within the PVDF matrix facilitates β -phase crystallization and strengthens interfacial polarisation, thereby enhancing electrochemical performance. The optimized PVDF- MoS_2 (80:20, PM82) based Symmetric supercapacitor (SS) delivers an areal capacitance of 218 F/cm^2 at 10 mV/s sweep rate, an energy density 16 mWh/cm^2 , and a power density of 218.55 mW/cm^2 at 0.22 mA/cm^2 in gel electrolyte. The device retains 54 % capacitance after 1000 cycles after initial value. Additionally, density functional

theory (DFT) analysis reveals a reduction in the HOMO–LUMO gap from 6.96 eV (PVDF) to 3.48 eV (PVDF–MoS₂), confirming enhanced charge transfer. PVDF–MoS₂ composite based SSs shows strong potential application uses in the portable, wearable, and flexible energy storage systems.

PP-32

Double Cross-linked PVA-PAA Gel Polymer Electrolyte Enabling High Power Density, Dendrite Suppression, and Long-life Flexible Zinc-air Batteries

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Rechargeable zinc–air batteries are a greener and safer alternative to lithium batteries; however, they suffer from poor reversibility due to zinc dendrite growth and water-splitting reactions in aqueous electrolytes. One strategy to overcome these drawbacks is replacing aqueous electrolyte with solid polymer electrolyte (SPE). In this work, we developed solid polymer membranes based on poly (vinyl alcohol) PVA and poly (acrylic acid) PVA-PAA blends synthesized via a solution casting method. The optimized PVA-PAA membrane achieve a high specific capacity (e.g., ~736 mAh g⁻¹) and excellent capacity retention (e.g., ~57% after initial cycles in early testing). Our findings suggest that PVA-PAA solid polymer membranes are highly effective candidates for high-performance, flexible, and safe zinc-ion energy storage systems.

PP-33

Hydrothermal Synthesis and Electrochemical Properties of NASICON - type Na₃V₂(PO₄)₂F₃ Cathodes for Na-ion Batteries

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Sodium-ion batteries (SIBs) have emerged as a promising alternative to lithium-ion batteries due to their abundant resources and low cost. However, suitable cathodes for SIBs needed to be developed, as they play a vital role in enhancing electrochemical performance. The NASICON-type Na₃V₂(PO₄)₂F₃ (NVPF) polyanionic cathode is an excellent candidate for SIBs, offering a high operating potential and durable structural stability. However, it also suffers from poor electronic conductivity, which limits its

practical applications. In this regard, the present NVPF nanostructures were synthesized using a simple one-step hydrothermal method. The X-ray diffraction pattern is well indexed to the tetragonal system with space group $P4_2/mnm$, with lattice parameters $a = b = 9.0464 \text{ \AA}$, $c = 10.6875 \text{ \AA}$, and $V = 874.64 \text{ \AA}^3$. The electrochemical performance of the NVPF cathode assembled in 2032-coin cells was studied using Galvanostatic charge/discharge (GCD), cyclic voltammetry (CV), and electrochemical impedance spectroscopy (EIS). The CV curve shows two distinct pairs of redox peaks corresponding to the $V3^+/V4^+$ redox couples. The first redox pair in the low voltage region ($\sim 3.6 \text{ V}/3.5 \text{ V vs. Na/Na}^+$) was attributed to the Na^+ ion insertion/extraction from the Na2 sites, and the high voltage redox pair ($\sim 4 \text{ V}/3.9 \text{ V vs. Na/Na}^+$) corresponded to the subsequent Na^+ ion insertion/extraction from Na1 sites. Furthermore, the prepared NVPF cathode delivers a specific discharge capacity of 138 mAh/g at 0.1 C. The EIS reveals that the solution resistance (R_s) and the charge transfer resistance (R_{ct}) of the cells were 12.58 Ω and 104.46 Ω , respectively.

PP-34

High Areal Capacitance Flexible Supercapacitors Based on Electro-grafted Polypyrrole-coated Carbon Cloth

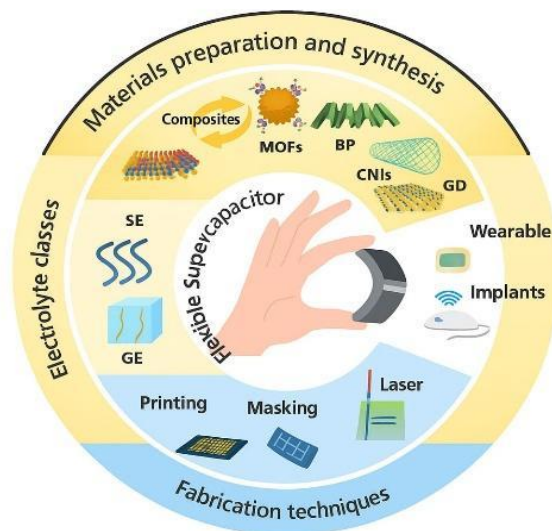
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The development of flexible energy storage devices demands electrode materials that combine high electrochemical performance with excellent mechanical robustness. In this study, Polypyrrole (PPy) is uniformly deposited onto pretreated carbon cloth (PCC) via an electro-grafting-assisted electropolymerization of pyrrole. This facile, additive-free strategy yields a well-adhered, homogeneous PPy layer, providing enhanced ion diffusion and efficient electron-transport pathways. The resulting PPy@CC electrode exhibits a high areal capacitance of 1200 mF cm^{-2} in a three-electrode configuration, with 66% capacitance retention after 10,000 charge–discharge cycles at a current density of 10 mA cm^{-2} . In a symmetric two-electrode system, the device delivers an areal capacitance of 333 mF cm^{-2} , retaining 74% of its initial performance over 5000 cycles. Furthermore, the assembled flexible supercapacitor demonstrates excellent mechanical stability, maintaining consistent electrochemical performance under repeated bending at angles of 0°, 90°, and 180°. Practical applicability is validated by successfully powering a light-emitting diode (LED) using three devices connected in series, while additional energy modulation is achieved through series and parallel configurations. Overall, this work presents a simple, scalable, and environmentally friendly approach for the fabrication of high-performance flexible supercapacitors, highlighting their potential for next-generation wearable and portable electronic applications (Scheme 1).



Scheme 1. Illustrate the fabrication of flexible super capacitor for next generation wearable and portable electronic applications.

PP-35

Air stable Nickel/Cobalt free Layered Oxide Cathodes for High Capacity Sodium-ion Batteries

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The environmental and economic problems associated with Nickel and Cobalt implied to design the cathode materials using earth abundant elements such as manganese and iron-based compositions. The doping of copper delivers the structural stability and rechargeable capacity of P2 type cathode. Improving structural stability and air stability by co-doping of copper with magnesium. Here, we report, $\text{Na}_{0.67}\text{Cu}_{0.2}\text{Mn}_{0.75}\text{Mg}_{0.05}\text{O}_2$ sodium-ion cathode materials synthesized by solid state method. The compound crystallizes in P2 type structure with crystal structure of $\text{P6}_3/\text{mmc}$ symmetry. XRD analysis, Raman analysis and FESEM analysis are used to study the structural and morphological properties. It exhibited in the initial discharge capacity of 140 mAh g^{-1} at 0.2 C rate between 1.5 V and 4.0 V. To study the individual process happening inside the cathode material during charging and discharging, the distribution relaxation time analysis is used. This work established an effective approach for acquiring the nickel/cobalt free, high capacity and air stability sodium cathodes.

Investigation of 1 kW all Vanadium Redox Flow Battery with Flow Field Embedded in Gasket

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To meet the growing global energy demand, it is essential to integrate intermittent renewable energy sources with efficient energy storage systems. Redox Flow Batteries (RFBs) are widely recognized as a promising option for storing renewable energy from solar and wind sources. Among the various RFB systems investigated, All Vanadium Redox Flow Batteries (AVRFBs) possess unique advantages such as easy scalability, long service life, stable performance, enhanced safety, recyclability, and greater design flexibility [1]. One of the key components influencing battery performance is the flow field, which ensures uniform distribution of the electrolyte across the electrodes [2]. In this work, a 1 kW All Vanadium Redox Flow Battery (AVRFB) stack was assembled, consisting of 24 cells with an active area of 450 cm² per cell. The stack incorporated a flow field design embedded within the gasket. It delivered an average output power of 1 kW at a current density of 30 mA cm⁻². The performance of the AVRFB stack was evaluated at various current densities, and the corresponding efficiencies were recorded. The 1 kW stack demonstrated with an excellent cycling stability over more than 50 cycles and achieved efficiencies of 79% voltage efficiency (VE), 64% coulombic efficiency (CE), and 51% energy efficiency (EE) at a current density of 30 mA cm⁻² (Figure 1). These results indicate that the AVRFB system is a promising and efficient technology for large-scale energy storage applications.

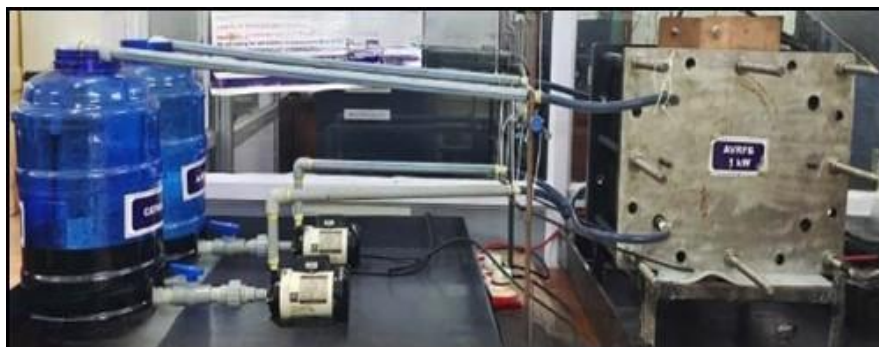


Figure 1. Lab setup of 1 kW VRFB stack.

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Fabrication and Testing of High-performance Flexible Symmetric Supercapacitor Using Copper Cobaltite Spinel Nanostructures

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Flexible supercapacitors using materials with high surface area, superior charge transport, and strong mechanical integrity are the best choice for powering flexible and wearable devices. In this work, a Copper Cobaltite (CuCo_2O_4), spinel metal oxide was prepared by annealing of copper cobalt hydroxide prepared by urea hydrolysis method. Urea hydrolysis method provides controlled and gradual nucleation, resulting in smaller and more uniform nanoparticles. Subsequent annealing of the hydroxides results in the formation of CuCo_2O_4 with a spinel structure. The morphology and crystal structure of copper cobaltite was examined using TEM and XRD techniques, confirming the presence of the cobalt copper spinel phase. The symmetric supercapacitor fabricated exhibited a high areal capacitance of 28.51 mF cm^{-2} at a current density of 0.5 mA cm^{-2} , energy density of $5.702 \text{ } \mu\text{Wh cm}^{-2}$, power density of $299.97 \text{ } \mu\text{W cm}^{-2}$ and a capacitance retention of 78% after 8000 charge discharge cycles (Figure 1). The flexibility of the fabricated supercapacitor was tested at six different bending angles and the corresponding cyclic voltammograms did not exhibit significant change. These results indicate the potential application of the fabricated supercapacitor for powering wearable energy storage devices.

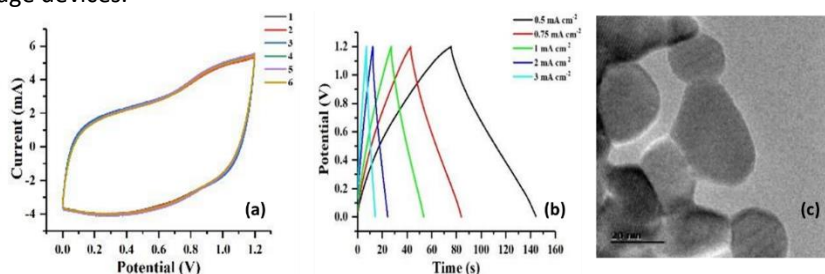


Figure 1. (a) Flexibility test of the fabricated supercapacitor, (b) galvanostatic charge discharge curves at different current densities, (c) TEM image of copper cobaltite.

PP-38

Tuning the Electrochemical Performance of ZnO/NiS via MWCNT for Enhanced Energy Storage Application

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Supercapacitors, also known as ultracapacitors have emerged as a promising energy storage device due to their high-power density, rapid charging-discharging and excellent cycle life. They effectively bridge the gap between conventional capacitor power density and battery energy density. However, carbon-based materials provide high power density, excellent cyclic stability and fast charging-discharging rate but the disadvantages are low specific capacitance and energy density compared to batteries. Metal oxides and sulfides-based materials provide high specific capacitance and energy density due to faradaic reaction and the disadvantages are lower cyclic stability and power density. By combining carbon-based materials with metal oxides and sulfides have significantly increased their energy density and cyclic stability. The ZnO/NiS/MWCNT-x (x = 1, 5, 10%) nanocomposite synthesized via a hydrothermal method exhibits a high specific capacitance, outstanding cyclic stability and excellent rate capability. A key differentiator of our system is the optimization of MWCNT incorporation, which has been carefully tuned to achieve an equilibrium between material conductivity, stability, and electrochemical activity. This work demonstrates the potential of integrating metal oxides, sulfides, and carbon-based nanocomposites to achieve high-efficiency supercapacitors. These advancements make the supercapacitors a highly promising technology for the future energy storage system. The prepared samples will be characterized using XRD, SEM, FTIR, Raman spectroscopy, and electrochemical studies. The findings from these experimental analyses will be discussed in detail.

PP-39

Investigation of a Low-Cost Additive for Enhancing Uniform Zinc Deposition in Alkaline Zinc-Based Flow Batteries

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Among various RFB chemistries, the zinc–iron flow battery system offers several key advantages, including low material cost, inherent operational safety, and reduced environmental impact compared to vanadium- and lithium-based systems. Furthermore, the use of aqueous electrolytes enhances intrinsic safety due to their non-flammable nature [1]. Alkaline zinc–iron redox flow batteries (AZIRFBs) exhibit a relatively high open-circuit voltage of approximately 1.75 V [2]. However, in alkaline media, challenges such as zinc dendrite formation due to non-uniform electrodeposition, parasitic hydrogen evolution reactions, and membrane degradation limit long-term cycling stability. The introduction of suitable electrolyte additives can regulate the Zn^{2+} solvation structure and interfacial chemistry, homogenize electric field distribution, and reduce nucleation overpotential. These effects promote uniform Zn^{2+} flux and controlled crystal growth, enabling compact zinc electrodeposition while suppressing dendrite formation and undesired side reactions. Consequently, the electrochemical stability and cycling life of the system are significantly improved [3]. Galvanostatic charge–discharge (GCD) measurements were performed at various current densities ranging from 20 to 120 mA cm^{-2} . Long-term cycling of the bare alkaline zinc–iron flow battery was conducted at 50 mA cm^{-2} for up to 108 cycles (Figure 1). The half-cell studies, flow cell performance, and post-cycle analyses will be discussed in detail.

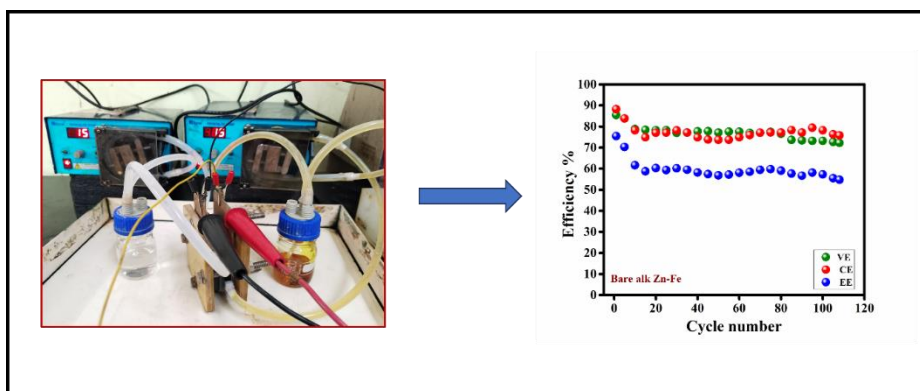


Figure 1. Lab setup of alkaline zinc-based flow batteries along with various energies performance.

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PP-40

Development of spinel-type cathode (AB₂O₄) for Aqueous Zn-ion Storage Applications

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Zinc-ion batteries (ZIBs) have become an exciting area of research and development in energy storage, offering several distinct advantages over traditional battery technologies, including high theoretical capacity, cost-effectiveness, high safety, environmental friendliness, and the abundance of Zinc. The suitability of ZIBs for large-scale energy storage applications is further enhanced by their compatibility with aqueous electrolytes. To achieve efficient zinc-ion storage, a high-performance cathode material was developed. In this study, Hausmannite (Mn₃O₄), a stable manganese oxide with a spinel crystal structure, was synthesized at different temperatures. To understand their structural characteristics and charge-storage methods, the synthesized materials underwent various physical and electrochemical characterizations. Among the prepared samples, the cathode synthesized at an optimized temperature exhibited a high specific capacity above 460 mAh g⁻¹, along with good capacity retention, demonstrating its potential for advanced aqueous zinc-ion battery applications.

PP-41

Hydrazide-hydrazone Cobalt Complex-derived Porous Co₃O₄ as a High-performance Electrode for Supercapacitors and Hydrogen Production

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The development of efficient and multifunctional electrode materials for sustainable energy storage and conversion remains a significant challenge in modern electrochemistry. In this work, a cobalt-based coordination complex derived from a hydrazide-hydrazone ligand was synthesized and systematically evaluated, alongside the ligand and Co_3O_4 , for electrochemical energy storage and electrocatalytic applications. Structural integration between the cobalt center and the redox-active ligand framework enabled enhanced electrochemical activity and charge-transport behaviour. Cyclic voltammetry measurements revealed prominent, reversible redox peaks corresponding to the $\text{Co}^{2+}/\text{Co}^{3+}$ transition, confirming the dominant behaviour of the Co-complex electrode. The material delivered a high specific capacitance of 402 F g^{-1} at mV s^{-1} , significantly outperforming the ligand (183.6 F g^{-1}) and Co_3O_4 (236.8 F g^{-1}). galvanostatic charge-discharge analysis exhibited symmetric triangular profiles with excellent rate capability, retaining appreciable capacitance even at higher current densities. Electrochemical impedance spectroscopy showed reduced solution and charge-transfer resistance for the Co-complex electrode, indicating accelerated electron transport and improved ion-diffusion kinetics. Long-term cycling studies confirmed excellent electrochemical durability, with superior capacity retention over 1000 cycles compared to reference materials. Furthermore, electrocatalytic investigations Co_3O_4 showed an enhanced hydrogen evolution reaction (HER) activity with an overpotential ($\sim 37 \text{ mV}$) and a cobalt complex ($\sim 150 \text{ mV}$) highlighting the multifunctional nature of the synthesised material. The synergistic interaction between cobalt oxides and the conjugated ligand framework enhances conductivity, rapid redox kinetics, and structural stability. These findings demonstrate that the cobalt coordination complex is a promising next-generation supercapacitor electrode and bifunctional water-splitting catalyst.

PP-42

ZnZrO₃ Coupled with Nb₂C MXene: A Novel Hybrid Electrode for Efficient Charge Storage in Supercapacitors

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Now-a-days energy storage materials have become more and more important in our day-to-day life due to the intermittent nature of renewable energy resources, and the depletion of non-renewable resources. These results in the need and development of electrochemical energy storage devices like batteries, supercapacitors, and fuel cells. Among them, supercapacitors show very good power density but moderate energy density, fast charge-discharge capability and long cycling stability superior to batteries. In this current work, ZnZrO₃ (ZZO) is being composited with the Nb₂C MXene to increase the overall performance of the device through the synergistic effect of both. ZZO provides redox active site due to oxygen vacancy, broad working potential window and excellent cycling

stability due to its good structural stability comes from perovskite structure. Whereas Nb₂C MXene provides abundant active sites and high conductivity but suffers with restacking issues due to the van der Waals force between the sheets. This issue can be overcome by introducing ZZO flakes into the sheets of Nb₂C in various ratios which provides more active sites by preventing sheets to restack. The bare ZZO and the best performing Z/N 1:2 provides the specific capacitance of 511 F/g and 591 at 2 A/g current density. The full cell device consisting of symmetric ZZN 1:2 || ZZN 1:2 in 1 M H₂SO₄ electrolyte provides the specific capacitance of 420 F/g with the high energy density of 29 Wh/kg with 354 W/kg power density. Even at a current density of 5 A/g, the device exhibits capacitance of 128 F/g with higher power density of 3600 W/kg with 9 Wh/kg energy density. The detailed material characterization and electrochemical performance evaluation will be discussed.

PP-43

Pressure-Driven Hierarchical NiP/NiCoP-rGO Heterostructures with Mixed Morphology for High-Performance Supercapacitors

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The development of advanced electrode materials with high energy and power density is essential for next-generation supercapacitor applications. In this work, hierarchical NiP/NiCoP heterostructures with mixed nanoflower and anisotropic morphologies anchored on reduced graphene oxide (rGO) are synthesized via a pressure-driven hydrothermal approach followed by phosphorization. The influence of carbon support is systematically investigated by varying rGO loadings (30, 50, and 60 mg), with bare NiP/NiCoP serving as a benchmark. X-ray diffraction (XRD) analysis confirms the formation of crystalline NiP/NiCoP phases, while morphological studies reveal nanoflower-like aggregates along with rod/needle-like features uniformly distributed over conductive rGO sheets, forming a hierarchical architecture with enhanced interfacial contact. Electrochemical evaluation in a three-electrode configuration demonstrates a significant improvement in capacitive performance, where NiP/NiCoP/rGO-50 delivers a high specific capacitance of 1536 F g⁻¹, compared to 917 F g⁻¹ for bare NiP/NiCoP. The enhanced performance is attributed to the synergistic effects of mixed morphology, which provides abundant electroactive sites and facilitates efficient ion diffusion, along with the conductive rGO network that improves charge transport. Preliminary device-level evaluation further indicates improved energy storage characteristics for the optimized composite compared to the bare material. These findings highlight the importance of morphology engineering and optimized carbon integration in designing high-performance electrode materials for advanced supercapacitor applications.

PP-44

Sonochemical Synthesis and Electrochemical Properties of $g\text{-C}_3\text{N}_4\text{@MoO}_3$ Heterostructure Modified Glass Fiber Separator for Li-S batteries

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Lithium-sulfur batteries are among the most promising sustainable energy storage devices for rapid technological advancement (electrification) due to their high energy density ($\sim 2600 \text{ Wh kg}^{-1}$), theoretical capacity ($\sim 1675 \text{ mAh g}^{-1}$), long cycle life, lightweight design, fast charging capability, and stable voltage. Even though it has notable advantages, its practical applications are hindered by intrinsic challenges, such as the shuttle effect of Lithium Polysulfides, volume expansion, and uneven deposition of Li ions, which lead to the formation of dendrites on the anode. Herein, $g\text{-C}_3\text{N}_4\text{@MoO}_3$ heterostructures were prepared via sonochemical synthesis for the modification of glass fiber (GF) separators, thereby increasing Li^+ ion transport efficiency between electrodes by hindering the polysulfide shuttle effect. Further, the physicochemical characterization and electrochemical performance of pristine $g\text{-C}_3\text{N}_4$ and MoO_3 were evaluated, both used as GF-modified separators. The X-ray diffraction pattern confirms the orthorhombic crystal structure of the MoO_3 phase. The FESEM images reveal the formation of a sub-micron-sized, well-defined, rectangular plate-like morphology. The Raman and FTIR spectral analyses corroborated the presence of stretching vibrations of Mo-O functional groups. The cyclic voltammogram of the assembled CR 2032-type Li-S coin cells using the $g\text{-C}_3\text{N}_4\text{@MoO}_3$ -modified glass fiber separator exhibited two distinct reduction peaks at 1.9 V and 2.3 V vs. Li/Li^+ and a single oxidation peak at 2.5 V vs. Li/Li^+ , indicating reversible electrochemical reactions. The GCD of $g\text{-C}_3\text{N}_4\text{@MoO}_3$ displayed an initial discharge capacity of around 900 mAh g^{-1} at 0.2 C rate with cycling stability, which is higher than that of $g\text{-C}_3\text{N}_4$ and -MoO_3 -modified separators. Further, the $g\text{-C}_3\text{N}_4\text{@MoO}_3$ cells exhibited the lowest electrode/electrolyte interface resistance, resulting in the lowest R_{ct} values and enhanced Li-ion diffusion compared to the others.

PP-45

Phosphate Based High Voltage Cathode Material for Sodium Ion Batteries

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Sodium-ion batteries are considered as a promising alternative to lithium-ion batteries and are being extensively studied worldwide. NASICON (Sodium (Na) super ionic CONductor) materials are highly attractive due to their specific 3D framework structure, stable long-term cycling ability, and high Na^+

mobility. Meanwhile it faces some issues of low ionic conductivity and low operating voltage and low capacities. In order to address this issue, we are investigating the crystal chemistry of M^{3+}/M^{2+} formula $Na_xM'M(PO_4)_3$ ($M, M' = Sc, Ti, V, Cr, Fe, Mn, Co, Ni$) mixed NASICON as a potential high voltage cathode material and a solid-state electrolyte for sodium ion battery. The cathode material is synthesised by solid-state method. Structural characterization (XRD) reveals the phase and space group of Rhombohedral R3C. FE-SEM AND EDX mapping shows uniform distribution of elements. The molar concentration is obtained from WDXRF and flame photometer. The oxidation state of elements is evaluated by XPS. The electrochemical studies demonstrate that a capacity of 67 mAh/g, in the voltage range of 1.5 V to 4.4 V with capacity retention of 71%. In order to address the issue of low ionic conductivity carbon coating with acetylene black is employed which increase the capacity to 90 mAh/g and conductivity. The obtained ionic conductivity value shows about 10^{-6} S/cm reveals that material can act as a solid-state electrolyte. These results suggest that the studied compound is an excellent candidate for sodium-ion battery applications. Overall, this work identifies phosphate-based NASICON materials as highly promising high-voltage cathode materials for next-generation sodium-ion batteries.

PP-46

Alizarin Based Metal Organic Redox Flow Battery as an Efficient Storage Device for Renewable Energy Sources

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Redox flow batteries are emerging as promising systems for large scale renewable energy storage due to their flexibility, safety, and scalability. However, conventional RFB technologies suffer from high cost, low energy density, and reliance on scarce or expensive active materials. To address these limitations, we report a novel Metal-Organic Redox flow battery system utilizing manganese ions as the catholyte and alizarin red, an anthraquinone-based organic molecule, as the anolyte. The Mn/ARS redox flow cell was designed and evaluated under ambient conditions in an acidic medium. The system exhibits a high open circuit voltage of 1.43 V vs Ag/AgCl and delivers a power density of 3 W L⁻¹ at low electrolyte concentration. Electrochemical performance was assessed through galvanostatic charge-discharge cycling, demonstrating excellent reversibility and stability. Remarkably, the cell maintains 99.9% capacity retention after 100 cycles, indicating minimal degradation of the active species. The coulombic efficiency (CE) improves with increasing current density and stabilizes at 82% during extended cycling at 40 mA cm⁻². The voltage efficiency (VE) and energy efficiency (EE) were recorded as 60% and 49% respectively, confirming consistent electrochemical behaviour. The integration of a metal ion with an organic redox-active molecule provides a cost-effective to conventional inorganic systems. The Mn/ARS redox couple demonstrates promising electrochemical characteristics, making it a viable candidate for next-generation flow battery technologies.

Engineered Integration of NiNb₂O₆ and Nb₂C MXene for Advanced Lithium-ion Capacitors

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The increasing demand for portable electronics and electric vehicles has created an urgent need for energy storage devices that can deliver both high energy density and high-power density. Lithium-ion capacitors (LICs), which combine the advantages of lithium-ion batteries and supercapacitors, are promising candidates. However, the development of efficient anode materials with fast charge transfer and long cycling stability remains a major challenge. In this work, we report a novel hybrid anode material, NiNb₂O₆@C/Nb₂C, designed to improve the electrochemical performance of LICs. The composite consists of nanostructured NiNb₂O₆ particles coated with a conductive carbon layer and integrated with two-dimensional Nb₂C MXene nanosheets. NiNb₂O₆ provides high theoretical capacity through multivalent redox reactions, while the carbon coating enhances electrical conductivity and structural stability. Nb₂C MXene contributes metallic conductivity, large surface area, and fast lithium-ion transport, enabling rapid charge storage. The NiNb₂O₆@C electrode delivers a high reversible capacity of 328 mAh/g at 0.1 A/g, mainly due to its pseudo capacitive behavior. After combining with Nb₂C, the hybrid structure shows improved electron and ion transport, resulting in excellent rate capability and cycling stability. Structural and surface analyses using XRD, SEM/TEM, and XPS confirm the successful formation and uniform distribution of the composite. Electrochemical measurements, including cyclic voltammetry and galvanostatic charge-discharge tests, demonstrate enhanced performance. When assembled into a full LIC device with a porous carbon cathode, the system is expected to deliver a balanced energy-power performance suitable for fast-charging applications. This study highlights the synergistic effect between NiNb₂O₆ and Nb₂C MXene and provides useful guidelines for designing high-performance anode materials for next-generation lithium-ion capacitors.

PP-48

NASICON Based Electrolyte Optimization for All-solid State Sodium-ion Batteries

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Solid-state sodium ion batteries have emerged as promising candidates for next-generation energy storage systems owing to their enhanced safety and potential for high energy density. In this study, $\text{Na}_3\text{Zr}_2\text{Si}_2\text{PO}_{12}$ (NZSP), a NASICON-type solid electrolyte, was employed to investigate sodium-metal compatibility and interfacial stability. The synthesis procedure has been optimised by changing the reaction temperature, time and other reaction conditions to obtain a dense pellet with less ZrO_2 impurity using a solid-state synthesis procedure. Impedance measurements reveal that the conductivity values were obtained in the range of 10^{-3} S/cm. Symmetric cells were assembled by sandwiching NZSP pellets between Sodium metal electrodes. Stripping and plating measurements were performed at various current densities like 10, 20, 40 and 50 $\mu\text{A}/\text{cm}^2$. Electrochemical measurements reveal stable cycling for more than 50 hours with low overpotential, indicating efficient Na^+ transport across the electrolyte and a favourable electrode-electrolyte interface. Stable stripping and plating for long hours highlight the electrochemical stability of NZSP against sodium metal. These results indicate that NZSP is a viable solid electrolyte for sodium metal, offering good ionic conductivity and interfacial compatibility. This study provides insights into interface behaviour and lays the groundwork for further optimisation of solid-state battery systems.

PP-49

Lithium Doped $\text{Na}_{0.67}\text{Ni}_{0.33}\text{Mn}_{0.67}\text{O}_2$ (NNMO) Cathode for Superior Sodium-ion Battery Performance

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P2-type layered transition-metal oxides are capable cathode materials for sodium-ion batteries (SIBs) due to their encouraging Na^+ diffusion pathways and high theoretical capacity. On the other hand, its practical use is restricted by structural instability and quick capacity decay caused by Jahn-Teller distortion, Na^+ /vacancy ordering and irreversible phase transitions which occur during cycling. In this study, the structural role and electrochemical impact of lithium incorporation in P2-type $\text{Na}_{0.67}\text{Ni}_{0.33}\text{Mn}_{0.67}\text{O}_2$ -based cathodes are investigated. Lithium doping is introduced via solid-state synthesis

reaction route to obtain Li-modified $\text{Na}_{0.67}\text{Ni}_{0.33}\text{Mn}_{0.67}\text{O}_2$. Structural analysis exposes that Li can occupy either prismatic Na sites or octahedral transition-metal sites reliant on Na deficiency and composition. Li substitution at Na sites stabilizes the layered structure, suppresses Jahn-Teller distortion, and mitigates the P2–O2 phase transition, leading to enriched cycling stability and improved Na^+ diffusion kinetics. In contrast, Li occupation at transition-metal sites increases specific capacity but compromises structural durability. Benefiting from optimized Li incorporation and precursor engineering, the synthesized cathode provides a reversible capacity of 120 mAh g^{-1} at 0.1 C with 90% capacity retention after 50 cycles at $\text{C}/10$. This paper will highlight the importance of Li site occupancy in regulating structural stability and electrochemical performance towards designing high-performance P2-type cathodes for sodium-ion batteries.

PP-50

Electrochemical Enhancement & Improving Kinetics and Stability in Zinc-Iron Redox Flow Batteries

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Neutral Zinc–Iron Redox Flow Batteries (ZIRFBs) represent a highly promising, cost-effective, material abundance, and inherently safe operating conditions. Both zinc and iron serve as redox-active species in ZIRFBs, offering advantages such as affordability, environmental compatibility, and suitable redox potentials for long-duration energy storage. However, the practical implementation of $\text{FeCl}_2/\text{FeCl}_3^-$ based catholytes is challenged by issues such as iron hydroxide precipitation, sluggish redox kinetics, hydrogen evolution, and active species crossover [1]. These challenges are further aggravated by the opposite charge characteristics of the redox species, complicating membrane design and stability. To address these limitations, electrochemical and electrolyte modifications were introduced to enhance redox kinetics, suppress hydrogen evolution, reduce species crossover, and improve reversibility. These improvements significantly enhance the overall cell performance. The optimized ZIRFB achieves an average coulombic efficiency of 98% over 50 cycles and an average energy efficiency of 80% at a current density of 20 mA cm^{-2} (Figure 1). Even at higher current densities (100 mA cm^{-2}), the energy efficiency remains above 80% , and demonstrating robust electrochemical performance of the zinc-iron redox flow cell [2]. The electrolyte formulation and electrode design strategy incorporated in ZIRFBs will be discussed in detail. This approach supports the development of cost-effective, durable, and scalable grid-level energy storage systems, facilitating the large-scale integration of renewable energy sources.

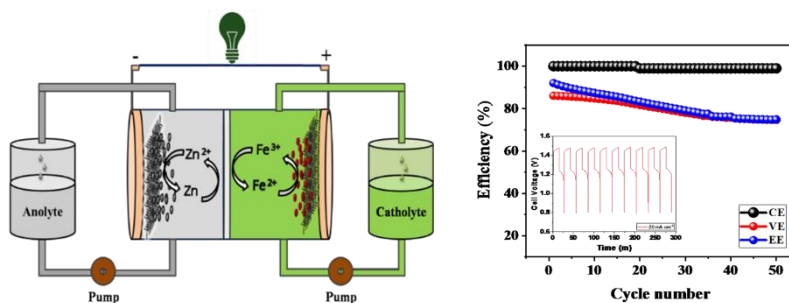


Figure 1. Schematic of Zn-Fe redox flow batteries along with various energies performance.

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PP-51

Aluminium-Sulfur System: A Sustainable Battery Chemistry

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Central to the emerging electric mode of transportation are batteries. Lithium-ion battery technology. The current workhorse, is beset with concerns about large-scale production of key constituents such as lithium and cobalt as well as their supply chains. India, in particular, depends entirely on imports for these metals. It was under this scenario that a seminal paper appeared in 2006 [1], which reported highly reversible plating–stripping of aluminium in an ionic liquid electrolyte, triggering worldwide interest in an alternative to lithium-ion, one based on cheaper, safer and environmentally benign elements: aluminium and sulphur. Aluminium is the most abundant metal in the earth’s crust. India is a top-ten bauxite producer (600 million tons of ore in proven reserves) and the second-biggest smelter of aluminium in the world. Aluminium has a gravimetric charge density of 2980 mAh/g (Li: 3862 mAh/g) and a volumetric charge density of 8040 mAh/cc (Li: 2060 mAh/cc). However, its standard electrode potential is -1.67 V (Li: -3.045 V), which means that aluminium-based cells will have lower voltages. Sulfur, at 1675 mAh/g, has the highest capacity among solid cathodes. The non-aqueous electrochemistry of Al–S batteries [2,3] is based on the reaction: $2Al + 3S \rightarrow Al_2S_3$, which translates to a theoretical energy density of 1314 Wh/kg at an E0 of 1.227 V. The Al–S system presents no risk of thermal runaway, which means that there is no battery explosion by overheating. Even a conservative estimate should lead to a practical battery of 400–500 Wh/kg (lithium-ion: 150–200

Wh/kg), making Al-S batteries hugely attractive for high-end applications such as electric traction—all at one-third the cost of lithium-ion.

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PP-52

Electrodeposited Metal-chalcogenides for Symmetrical Micro Supercapacitor Application

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Electrochemical energy storage (EES) devices play an important role in meeting the demand for electrical energy. Predominantly, electrochemical pseudo capacitors (PCs) are considered as one of the potential candidates for fulfilling the energy requirement. In this work, metal chalcogenides (MCs) were fabricated on stainless steel substrate by simple, cost-effective electrode position method for micro supercapacitor application. The device utilizes electrochemically prepared MCs thin film on stainless steel substrate as both the positive and negative electrodes, respectively. The phase structure and crystalline size of the electrodeposited film were confirmed via XRD and AFM. The fabricated thin film PCs showed excellent performance at a tested potential window of -1 to 0 V. The maximum values for specific energy density 6.7 μwh and specific power density 5.6 mW cm^{-2} were specific capacitance 58.34 mF cm^{-2} obtained from PCs. This indicates the excellent performance of the PCs under various conditions. Consequently, the fabricated MCs, electrodeposited active electrode materials of the present work will play a significant role in the various electronic applications by supplying the energy demand.

The Electrochemical Properties of $\text{Li}_{1.3}\text{Al}_{0.3}\text{Ti}_{1.7}(\text{PO}_4)_3$ Modified Glass Fiber Separator for Lithium-sulfur Batteries

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Lithium Sulfur Batteries (LSB) have garnered significant attention for high-energy storage applications owing to their high theoretical capacity of 1675 mAh g^{-1} and high energy density of 2600 Wh kg^{-1} . However, their commercialization is hindered by practical limitations, such as the “Polysulfide Shuttling Effect,” which causes active material loss, poor coulombic efficiency, and reduced cycle life. In this work, $\text{Li}_{1.3}\text{Al}_{0.3}\text{Ti}_{1.7}(\text{PO}_4)_3$ LAMP was synthesized using the molten flux method, with urea as the flux agent. The structure and morphology of the prepared samples are characterized using X-ray diffraction, Fourier transform infrared spectroscopy, Raman spectroscopy, and field emission scanning electron microscopy. Herein, we report the NASICON-type solid electrolyte (LAMP) as a separator modifier in conventional Glass Fiber Separator employed in LSB. The fast Li^+ ion conductor in LAMP allows Li^+ ions to pass through, while it is impermeable to polysulfide anions (S_x^-). Thus, this battery architecture effectively suppresses polysulfide shuttling, thereby improving cycle performance. The electrochemical performance of the assembled 2032-type Li-S cells delivers an initial discharge capacity (calculated from the 2nd cycle) of $1177.02 \text{ mAh g}^{-1}$ at 0.2C-rate, which is only 414 mAh g^{-1} for uncoated GF separators. After 10 cycles, the LAMP@GF separator retained the capacity of 982 mAh g^{-1} , which was only 322 mAh g^{-1} for uncoated GF separators at the same rate (Figure 1). The lower charge-transfer resistance (Value) measured from the EIS indicated faster redox kinetics and improved battery performance. Thus, LAMP can be considered as a promising candidate for the separator modification in LSB.

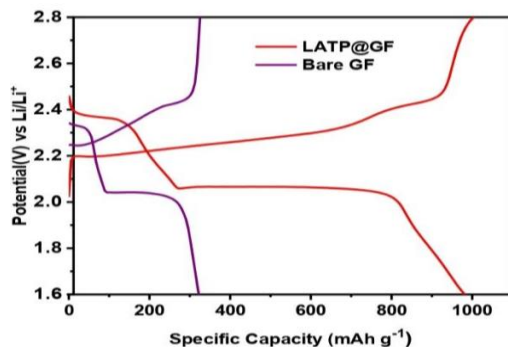


Figure 1. 10th discharge capacity at 0.2C rate for bare and LAMP-coated separator.

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Effect of Acid-based Additive on the Negolyte of Zinc-Vanadium (Zn-V) Hybrid Redox Flow Battery

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Energy consumption has been increasing globally, which leads to the demand for safe, efficient, less cost and large-scale energy storage technologies. Redox flow batteries (RFBs), one of the leading energy storage systems, are particularly attractive because of their flexible system design, high energy density, excellent rate capability, and the use of non-flammable aqueous electrolytes. Unlike conventional batteries, including lithium-ion systems where energy is stored within solid electrodes, RFBs store energy in liquid electrolytes containing redox-active species. However, concentration and potential gradients during battery operation, may cause migration of redox species across the membrane, which results in capacity fade, electrolyte imbalance, reduced coulombic efficiency, and undesired side reactions. In this regard, we achieved better performance of the zinc–vanadium (Zn–V) redox flow system by pH modification. In the anolyte side, one of the strongest mineral acids is employed as a supporting acid electrolyte in the anolyte side, which regulates pH and boosts the redox reversibility of zinc. The addition of mineral acid to the negative electrolyte effectively suppressed side reactions, enhanced ionic conductivity, improved cycling stability, and marginally reduced electrolyte crossover. The assembled Zn-V system delivered a total cell voltage of 1.89 V. Under optimized additive conditions, the cell demonstrated a stable operation for more than 100 cycles with a coulombic efficiency exceeding 75%.

PP-55

P-doped Graphitic Carbon Nitride for Screen-printed Supercapacitors

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Microsupercapacitors (MSCs) are energy storage devices bearing dimensions in the micrometre range employed for powering electronic devices. Developments in wearable electronics necessitate the use of flexible charge storage devices. The hybrid of heteroatom-based precursors with g-C₃N₄ plays a significant role in energy storage applications due to the active sites created by the heteroatom. In this work, phosphorus-incorporated g-C₃N₄ in three different compositions was developed via pyrolysis of melamine with sodium phosphate at 500 °C for 3 h. The XRD pattern confirmed the doping of phosphorus over the g-C₃N₄ network by the appearance of peaks at 2θ=19.98 and 33.02°. Luminescent behaviour of optimum sample (PMCN-12) revealed that it exhibits the emission wavelength of 423 nm. Importantly, redox mediators are employed for amplifying the charge storage behaviour via the incorporation of pseudocapacitance. Here, the energy storage behaviour of P-based g-C₃N₄ composites was investigated in an acidic electrolyte containing the optimum concentration of KI as a redox additive. Among the three various hybrids, the P-incorporated g-C₃N₄ in which the mass proportion of dopant and melamine are in 1:2 has delivered an enhanced areal capacitance of 1122 mF cm⁻² at 10 mA cm⁻² in 1 M H₂SO₄ solution containing 0.15 M KI.

PP-56

Co-Ni/ Carbon Nanofiber Composite Bifunctional Electrocatalyst for Zinc-air Batteries

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The advancement of zinc-air batteries (ZABs) depends on the development of cost-effective bifunctional electrocatalysts for oxygen reduction (ORR) and oxygen evolution (OER) reactions. The commercial viability of conventional electrocatalysts, such as Pt/C for ORR and RuO₂/IrO₂ for OER, is further limited by their high cost [1]. Although transition metal-based systems are more affordable, their practical use is frequently constrained by issues such as inadequate exposure of catalytically active sites, poor electrical conductivity, and nanoparticle aggregation. Here, we report a Co-Ni oxide/Carbon Nanofiber (CN/CNF) composite, in which a conductive one-dimensional carbon nanofiber framework provides mechanical stability and continuous electron transport pathways. The cobalt-nickel oxide species are incorporated onto the carbon scaffold, enabling uniform dispersion of catalytically active sites and improved electronic modulation [2,3]. This integrated structure offers a rational platform for developing cost-effective bifunctional electrocatalysts. The composite exhibits a bifunctionality index (ΔE) of 0.91 V_{RHE} between the half-wave potential (E_{1/2}) 0.60 V_{RHE} and the OER overpotential 280 mV at 10 mA cm⁻² (E_{j10}). This study also underscores the potential of CN/CNF composite as suitable bifunctional electrocatalysts for next-generation zinc-air batteries.

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PP-57

Halogen-Free LiBOB-based Electrolytes for Safer and Sustainable Lithium-ion Batteries

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Modern lithium-ion battery electrolytes commonly incorporate fluorinated compounds to improve electrochemical performance and stability. However, their use introduces concerns related to safety, environmental impact, and cost particularly due to hydrogen fluoride generation and hazardous production. Among all fluorine-free salt alternatives, lithium bis (oxalate) borate (LiBOB) is a promising salt due to its good thermal stability, moderate ionic conductivity, and safer decomposition products compared to LiPF₆. It also forms a stable oxygen-rich SEI on graphite anodes, effectively suppressing solvent co-intercalation and enhancing interfacial stability. In this work, a halogen-free electrolyte based on LiBOB in ethylene carbonate (EC) and dimethyl carbonate (DMC) is investigated as a sustainable and high-performance electrolyte system. The EC: DMC solvent combination ensures an optimal balance between high dielectric constant and low viscosity, facilitating efficient lithium-ion transport, while LiBOB contributes to enhanced interfacial stability and suppressed electrolyte decomposition. The initial electrochemical performance of the developed electrolyte was evaluated using graphite||Li and NMC532||Li half cells. Additionally, Li||Li symmetric cells were assembled in an argon-filled glove box to examine lithium stripping and plating behavior, demonstrating stable and uniform lithium deposition. Electrochemical characterization using a Biologic battery cycler revealed an initial discharge capacity of 362.5 mAh g⁻¹ for graphite||Li and 151.4 mAh g⁻¹ for NMC532||Li at 0.1C rate. Electrochemical impedance spectroscopy (EIS) indicated low interfacial resistance, suggesting improved charge transfer kinetics. The enhanced electrochemical performance is attributed to the formation of a stable, LiBOB-derived SEI/CEI, which effectively mitigates interfacial degradation and enhances cycling stability.

SLI vs EFB vs VRLA: Understanding the Differences for Micro-hybrid Applications

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The increasing integration of micro-hybrid technology in modern vehicles has significantly altered the performance requirements of automotive batteries. Unlike full hybrid systems, micro-hybrid vehicles do not rely on electric propulsion for vehicle motion; however, they demand substantially higher battery utilization compared to conventional internal combustion engine (ICE) vehicles. A critical component enabling this functionality is the Start–Stop system, in which an Integrated Starter Generator (ISG) automatically shuts down the engine during vehicle standstill and restarts it instantly upon driver demand. During these idle periods, the battery is required to sustain multiple auxiliary loads including air conditioning, lighting, infotainment systems, and navigation units. The reduction in engine idling enabled by this system results in fuel savings of approximately 8–10% relative to conventional vehicles. Consequently, the market demand for Start–Stop compatible lead-acid batteries is expanding rapidly, with projections indicating that nearly 70% of vehicles in the Indian market may adopt this technology by 2030. This study presents a comparative evaluation of three lead-acid battery technologies—conventional Starting, Lighting, and Ignition (SLI), Enhanced Flooded Battery (EFB), and Valve Regulated Lead Acid (VRLA/AGM)—for suitability in micro-hybrid automotive applications. Performance assessment was conducted under standardized test protocols in accordance with EN 50342-6, focusing on micro-cycle endurance at 17.5% depth of discharge (DoD) and deep-cycle endurance at 50% DoD. Key performance parameters analyzed include cycle life, charge acceptance, and degradation mechanisms under partial state-of-charge (PSoC) operating conditions typical of Start–Stop duty cycles. The results demonstrate that conventional SLI batteries exhibit limited cycling durability in micro-hybrid conditions primarily due to electrolyte stratification and reduced charge acceptance. Enhanced Flooded Battery (EFB) systems exhibit improved cycling performance by delaying stratification through optimized plate formulations, carbon additives, advanced separators, and structural reinforcement. In contrast, VRLA/AGM batteries effectively mitigate electrolyte stratification through immobilized electrolyte design, thereby providing superior cycle stability and endurance under repeated Start–Stop operation.

Filter Paper Reinforced Polymer Composite Membrane for Zinc-bromine Redox Flow Battery Applications

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In Redox Flow Batteries (RFBs), membranes serve two vital purposes: they keep redox-active species from crossing over between the two half-cells and enable selective ion transport to preserve charge neutrality. In a Zinc–Bromine Redox Flow Battery (ZBRFB), filter paper (FP)-reinforced polymer composite membranes, FP@PVA+BCA (filter paper with polyvinyl alcohol and a bromine complexing agent) and FP@PAN (filter paper with polyacrylonitrile), were systematically fabricated and assessed (Figure 1). With a coulombic efficiency (CE) of 87.51%, voltage efficiency (VE) of 81.10%, and energy efficiency (EE) of 70.98% at a current density of 20 mA cm⁻², the FP@PVA+BCA membrane exhibits exceptional electrochemical performance. The membrane demonstrated great stability under high-power operation, maintaining an EE of 60.12% even at a higher current density of 50 mA cm⁻². Additionally, after 100 cycles at 20 mA cm⁻², the ZBRFB constructed with the FP@PAN membrane exhibits exceptional cycling stability, with CE of 89%, VE of 82%, and EE of 72%. These results show that filter paper-derived composite membranes are viable substitutes for RFB applications because of their competitive electrochemical performance, low cost, mechanical flexibility, and environmental friendliness.

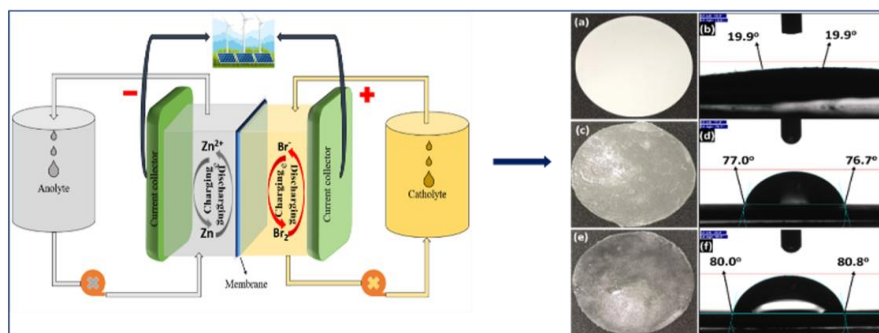


Figure 1. Schematic diagram of ZBRFB system and photographic images of (a) FP, (c) FP@PVA+BCA membrane, (e) FP@PAN Membrane, (b,d,f) contact angle profile.

Heterostructured Ag₂O₂/MoO₃ Cathode with Dual Redox Activity for Stable and High-capacity Zinc-based Rechargeable Batteries

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Rechargeable zinc–silver alkaline batteries have attracted considerable attention as safe, high-energy-density, and cost-effective energy storage systems; however, their practical applications are limited by poor cathode conductivity, silver dissolution, and structural degradation during repeated conversion reactions. In this work, an Ag₂O₂–MoO₃ composite cathode was rationally designed to exploit the synergistic advantages of electrochemically active silver oxide and the structural stability of molybdenum oxide in alkaline media. The composite was synthesized via a facile route to form a heterostructured architecture that enhances electronic conductivity and provides abundant active surface sites for OH[−]-mediated redox reactions. Electrochemical evaluation demonstrates that the Ag₂O₂–MoO₃ cathode delivers improved specific capacity, reduced polarization, and enhanced cycling stability compared with pristine silver oxide. The improved performance is attributed to the dual redox activity of Ag species, pseudocapacitive contribution from Mo centers, and the structural buffering effect of MoO₃, which mitigates silver dissolution and electrode degradation during repeated Ag oxide–Ag conversion reactions. Furthermore, the heterointerface facilitates faster reaction kinetics and stabilizes the electrode–electrolyte interaction in alkaline electrolyte. The electrochemical behavior of the fabricated cathode was systematically investigated using a Swagelok-type cell assembled in a coin-cell configuration. This study highlights that integrating silver oxide with molybdenum oxide is an effective strategy for engineering durable and high-performance cathodes for rechargeable Zn–Ag alkaline batteries, offering insights into composite oxide design for next-generation alkaline energy storage systems.

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Catalytic Metal Sulfide-embedded Sulfur Cathodes Coupled with Functional Separator Coating for high-capacity Li-S Batteries

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The global demand for new battery technologies that meet future requirements emphasises the sustainable energy solutions. Among them, lithium-sulphur (Li-S) batteries are upfront in the list owing to their high theoretical energy density and low material cost. However, their practical application is limited due to the poor cycling stability. In this work, the cathode activity was enhanced by using metal sulphide catalysts (WS_2 and MoS_2) incorporated with a conductive carbon matrix, which supports the sulphur utilisation and redox kinetics. These sulphur host cathode composites were prepared via mechanical ball milling method at different weight ratios and the active material was loaded $1.5\sim 2$ mg/cm². Among samples of different weight ratio S@ WS_2 -GNS (70:20:10) demonstrated superior electrochemical performance when compared to other samples along with MoS_2 as a catalyst system, delivering an average discharge capacity of 755.09 mAh g⁻¹ at 1C and 715.04 mAh g⁻¹ at 0.5C with stable capacity retention over 100 cycles. Furthermore, separator modification using a WS_2 -Ketjen Black coating on polypropylene (PP) facing the 20% WS_2 cathode significantly enhanced the cyclic stability, achieving higher capacity with improved capacity retention (71.01% over 100 cycles). The improved electrochemical behaviour is attributed to the synergistic effect of the cathode and separator, which may be due to the effective suppression of polysulphide migration and accelerated redox conversion. This strategy demonstrates a practical scaling up using a simple method for cathode and separator co-engineering for the high-performance Li-S batteries.

PP-62

Influence on Reduced Graphene Oxide Infused Nickel Phosphate-trimesic Acid Metal-organic Framework for High Energy Density Hybrid Supercapacitors Application

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The study investigates the effect of reduced graphene oxide mass dispersion @ 25, 50, 75, and 100 mg through in-situ process into Trimesic Acid-Nickel Phosphate Metal Organic Framework (MOFNP) as synthesized by facile microwave technique. The XRD study confirms monoclinic crystalline geometry (JCPDS No. 33-0951) and NP coordination with MOF by co-folding the new appearance of (711) with NP (130) and (101), and (045) with (031). The MOFNPG-2 composite has shown enhanced intensity increases the crystallinity. SEM shows nucleated rectangular morphology for MOFNPG-2 revealing crystallinity. Raman studies show that MOFNPG2 presents ID/IG ratio 1.01 suggesting its well coordination with MOFNP. BET studies reveal higher specific surface area ($59.75 \text{ m}^2 \text{ g}^{-1}$) for MOFNPG2 and exhibits mesoporosity (3.14 nm) type-II/ IV Langmuir isotherm. The deconvoluted XPS confirms oxidation states and chemical compositions of MOFNPG2. The CV profile identifies maximum oxidation for MOFNPG2 @ 5 mV s^{-1} and reveals EDLC / pseudocapacitance contribution and reflecting higher specific capacitance 854 F g^{-1} @ 1 A g^{-1} . The FCD MOFNPG2//rGO registers 175 F g^{-1} @ 1 A g^{-1} and energy density 79 Wh kg^{-1} . The Resr is lower ($0.19 \Omega \text{ cm}^{-2}$) for FCD improvises electrode-electrolyte kinetics which results in enhanced conductivity for high energy density supercapacitor applications.

PP-63

A Sustainable Biowaste-derived Hard Carbon with Tunable Structure for Sodium-ion Batteries

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Sodium-ion batteries (SIBs) are emerging as a promising alternative to lithium-ion systems due to the natural abundance and low cost of sodium resources. Among various anode candidates, hard carbon (HC) has demonstrated significant potential for practical applications. In this work, a sustainable hard carbon material was synthesized from a low-cost biowaste precursor and systematically evaluated against a commercial hard carbon (Kuranode- Type 2). The structural properties of the prepared HC were investigated using X-ray diffraction, surface area analysis, and Raman spectroscopy, revealing a predominantly disordered framework with tunable microstructure. Processing conditions and carbonization temperature were systematically tuned to remove impurities and regulate interlayer spacing, defect density, and surface characteristics, respectively. The optimized material exhibited a high initial coulombic efficiency of 87% and delivered a reversible capacity of $\sim 300 \text{ mAh g}^{-1}$ at a current density of 0.02 A g^{-1} , demonstrating performance comparable to commercial hard carbon. Electrochemical analysis indicates that the improved performance arises from a balanced microstructure that facilitates sodium-ion storage while minimizing irreversible reactions. The results highlight the potential of biomass-derived HC as a competitive and sustainable alternative for large-scale sodium-ion battery applications. Ongoing studies are focused on detailed kinetic analysis and full-cell configuration to further validate practical applicability.

Highly Efficient $\text{Pt}_{3-x}\text{Co}_{0.5+y}\text{Ni}_{0.5+y}/\text{C}$ Electrocatalysts Prepared via a Single-step Solid-state Route for PEM Fuel Cell Cathodes

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The development of cathode catalysts with enhanced oxygen reduction reaction (ORR) activity and long-term durability is pivotal for advancing polymer electrolyte membrane fuel cells (PEMFCs). Although Pt-based alloys have been widely investigated, their practical implementation remains constrained by issues related to stability and complex synthesis routes. Recently, chemically ordered Pt-alloys have attracted significant attention due to their optimized electronic and geometric structures, which markedly improve ORR kinetics. In this study, we report, for the first time, a one-step solid-state synthesis of $\text{Pt}_{3-x}\text{Co}_{0.5+y}\text{Ni}_{0.5+y}/\text{C}$ ($x = 0, 1, 2$; $y = 0, 0.5, 1$) nanoparticles supported on carbon. Among the compositions explored, $\text{Pt}_2\text{Co}_1\text{Ni}_1/\text{C}$ emerged as the most promising, exhibiting outstanding performance in both half-cell and full-cell evaluations. Notably, the catalyst achieved a mass activity nearly seven times higher than that of commercial Pt/C in acidic media, meeting the U.S. DOE 2025 targets. In addition, it demonstrated excellent electrochemical stability, retaining significant activity even after 50,000 potential cycles. Under practical PEMFC operating conditions, $\text{Pt}_2\text{Co}_1\text{Ni}_1/\text{C}$ delivered a peak power density exceeding that of commercial Pt/C, highlighting its strong potential for real-world applications. Overall, this work presents a scalable, single-step strategy for the synthesis of high-performance and durable ORR catalysts, offering promising directions for next-generation fuel cells and clean energy technologies.

Copper Oxide Integrated Nitrogen-doped Hollow Carbon Spheres for Supercapacitor Application

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In this work, we report the preparation of a heteroatom composite comprising the unique structure of CuO embedded N-doped carbon hollow sphere. This composite, designated CuO-NHCS, features a precisely engineered three-dimensional architecture of CuO-NHCS that facilitates extensive interfacial contact between the electrolyte solution and the electrode. Such a design is pivotal in enhancing both ion and electron transport, which significantly improves the material's ability to store charge. Simultaneously, the nitrogen-doped hollow carbon sphere materials significantly improve electrochemical characteristics. In these modified materials nitrogen doping makes high specific surface area, which boosts conductivity and electron transfer in carbon materials. The CuO-NHCS composite exhibits a high specific capacitance of 882 F g^{-1} at 2 A g^{-1} in $1 \text{ M H}_2\text{SO}_4$ and excellent cycling stability of more than 95 % after 10000 cycles. Moreover, the three-electrode supercapacitor assembled by CuO-NHCS coated on graphite sheet (as a working electrode) and reference electrode is Hg/HgO. The counter electrode employed is platinum.

Materials Electrochemistry and Electrocatalysis

PP-66

Bandgap Modulation via Quantum Confinement in g-C₃N₄-sensitized GFETs: Visible-blind Deep-UV Detector

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UV detectors are crucial for applications in environmental monitoring, telecommunications, and biomedical diagnostics. Graphene, with its high carrier mobility and ambipolar transport, is a promising candidate for high-speed photodetection; however, its low optical absorption limits responsivity. We report, for the first time, a graphitic carbon nitride thin film-sensitized graphene field-effect transistor (GFET) fabricated via electron beam evaporation, enabling uniform, adherent, and bandgap-tuneable films through quantum confinement. The carbon-rich ECNTF enhances UV absorption and carrier generation, which overcomes the key limitations of pristine graphene. The resulting GFET/ECNTF device exhibits excellent performance with high electron mobility (1210 cm²·V⁻¹·s⁻¹), ultrafast photo response time (12.95 ms rise, 28.45 ms recovery), and a signal-to-noise ratio (SNR ≈ 122). Furthermore, it demonstrates high operational stability for more than 200 cycles under ambient conditions. This novel integration of e-beam-coated g-C₃N₄ thin film with graphene gives a scalable, efficient, and visible-blind UV photodetection platform for next-generation optoelectronic applications.

PP-67

Prussian Blue Analogues as Earth-abundant Electrocatalysts for chloride Oxidation Reactions

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The development of non-precious electrocatalysts capable of selectively oxidizing halide ions is crucial for seawater electrolysis, water treatment, halogen-based systems, and energy storage systems. Here, we demonstrate that Prussian Blue (PB) and its analogues (PBAs) act as efficient electrocatalysts for chloride oxidation (Cl⁻), and that their catalytic behavior is strongly administered by the amount

of crystalline water present in the framework. The different Prussian Blue analogues (PBAs) samples were synthesized by a one-pot co-precipitation method, utilizing different precursors in different concentrations of the solution. As-prepared samples were characterized by Fourier Transform Infrared (ATR-FTIR) spectroscopy, thermogravimetric analysis (TGA), and X-ray diffraction (XRD), which verified the structural integrity and assessed the quantity of water content, which significantly impacts electrochemical performance. The Thermogravimetric analysis and Rietveld refinement were used to get information on coverage by crystal water and Cl^- which is correlated to the selectivity of OER and ClOR. In summary, we investigated and confirmed that PBAs are viable and cost-effective electrocatalysts capable of replacing precious metals in halide-dominant electrochemical processes.

PP-68

Energy-Saving Multifunctional Electrocatalyst Based on NiAl LDH–MXene Heterostructure for HER, OER, and Hydrazine Oxidation Reaction

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Designing efficient and multifunctional electrocatalysts is essential for advancing low-energy hydrogen production. A hybrid catalyst composed of NiAl layered double hydroxide (LDH) anchored on $\text{Ti}_3\text{C}_2\text{T}_x$ MXene nanosheets demonstrates outstanding electrocatalytic performance for the hydrogen evolution reaction (HER), oxygen evolution reaction (OER), and hydrazine oxidation reaction (HyOR) in alkaline media. Structural and surface characterizations (XRD, SEM, TEM, and XPS) confirm a flake-like layered morphology with strong interfacial integration, promoting enhanced charge transfer, abundant active site exposure, and electronic modulation. The NiAl LDH–MXene composite exhibits low overpotentials and Tafel slopes for HER and OER, while significantly outperforming OER when HyOR is employed as the anodic process. Owing to the lower thermodynamic potential and faster kinetics of HyOR ($E^0 = -0.33$ V vs. RHE), the overall water splitting cell voltage is reduced to below 0.21 V at 10 mA cm^{-2} which over 1.55 V lower than traditional HER–OER system using the same catalyst. This dramatic energy savings highlights the catalytic synergy and multifunctionality of the composite electrode. The catalyst also shows excellent stability across all reactions, establishing it as a promising platform for sustainable and energy-efficient hydrogen generation.

Underpotential Deposition-Validated 2D Au–Bi Heteroepitaxy for Precision-Controlled Electrocatalytic Interfaces

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Interfacial electrochemistry, achieving atomic-level precision on electrode surfaces is fundamentally more important to optimize the electrocatalytic efficiency. This study investigates the electrocodeposition of gold (Au) and bismuth (Bi) metals on a glassy carbon electrode (GCE), focusing on the formation of a highly ordered Au-Bi bimetallic interface. By precisely modulating the overpotential, the deposition is steered toward instantaneous nucleation, facilitating a heterogeneous epitaxial growth process. This growth follows the Frank-van der Merwe (FM) mechanism, where the strong substrate-adsorbate interaction ($E_{\text{Au-Bi}} > E_{\text{Bi-Bi}}$ or $E_{\text{Au-Au}}$) ensures a strictly layer-by-layer (2D) growth mode. The structural evolution is experimentally validated by the presence of Underpotential Deposition (UPD) kind of peaks, confirming the formation of a Bi monolayer on Au sites at potentials more positive than the bulk equilibrium value. This heterogeneous epitaxial 2D growth creates a uniform and stable bimetallic lattice that significantly enhances electrocatalysis for the oxidation of small organic molecules. The mechanism is governed by a bifunctional effect, where the Bi-UPD sites promote the adsorption of oxygenated species at low potentials, effectively scavenging poisons from the neighbouring Au active sites. The resulting Au-Bi bimetallic surface plays a pivotal role in enhancing electrocatalysis, particularly for the oxidation of small organic molecules. The mechanism is governed by a bifunctional effect, where the Bi-UPD species promote the adsorption of oxygenated groups at low potentials, effectively scavenging carbonaceous poisons from the neighbouring Au active sites. This synergistic interaction, supported by the high-surface-area 2D lattice, results in a significant reduction in overpotential and superior catalytic stability. These findings provide a robust framework for the development of advanced electrocatalytic interfaces in electroanalytical and energy efficient electrochemical reactions like CO₂ to value added chemicals applications.

PP-70

Design and Optimization of Open Bipolar single Electrode System for Low-potential ECL

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A transparent open bipolar electrode (BPE) electrochemiluminescence (ECL) platform was developed using a soft-lithography-fabricated PDMS microchamber integrated on a fluorine-doped tin oxide (FTO) substrate. The dual-chamber dumb-bell architecture enables spatial separation of anodic and cathodic reactions while maintaining electrical coupling through the electrolyte. The conventional FTO-based configuration exhibited non-uniform polarization and required high operating voltages, limiting ECL efficiency and compatibility with potentiostatic control. To address these limitations, selective modification of the FTO substrate was employed to electrically isolate the anodic and cathodic regions, resulting in uniform anodic polarization and significantly enhanced ECL emission at substantially reduced operating potentials. In addition, incorporation of a gel electrolyte in the cathodic chamber improved platform stability and operational durability. The optimized platform delivers stable, low-voltage, and uniform ECL performance, offering a versatile and transparent architecture suitable for analytical and biosensing applications in complex biological matrices.

PP-71

Fe Single-Atom Engineered Metallic 1T-MoS₂ for High-efficiency Overall Water Splitting

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The rational design of highly active and cost-effective electrocatalysts for water splitting is crucial for sustainable hydrogen production. In this work, we report the synthesis of Fe single-atom doped metallic 1T-phase MoS₂ (Fe-1T MoS₂) as an efficient bifunctional electrocatalyst for water splitting applications. The incorporation of isolated Fe atoms into the 1T MoS₂ lattice was achieved via a

controlled synthesis strategy, enabling modulation of the electronic structure and exposure of abundant active sites. Morphological and structural analyses reveal the formation of few-layered, sheet-like nanostructures with enlarged interlayer spacing, facilitating enhanced electrolyte accessibility and charge transport. Advanced characterization confirms the successful stabilization of atomically dispersed Fe sites within the MoS₂ framework without the formation of Fe clusters. The metallic 1T phase further improves electrical conductivity compared to the semiconducting 2H counterpart. Electrochemical evaluations demonstrate that the Fe–1T MoS₂ catalyst exhibits significantly enhanced activity toward both hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) in alkaline media. The catalyst delivers a low overpotential to achieve a current density of 10 mA cm⁻², along with a small Tafel slope, indicating favorable reaction kinetics. Additionally, the material shows excellent durability and long-term stability under continuous operation. The superior performance is attributed to the synergistic effect between the conductive 1T MoS₂ phase and the atomically dispersed Fe active centers, which optimize hydrogen adsorption energy and facilitate reaction intermediates. This study provides an effective strategy for engineering single-atom catalysts based on transition metal dichalcogenides for high-performance water splitting systems.

PP-72

Waste to Wealth: Upcycling Molten Salt Derived Nd Slag into Ni/Nd Composite Coatings as Efficient Electrocatalysts for Alkaline Water Splitting

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Upcycling and repurposing of metal-containing bulk industrial wastes into electrocatalysts is a sustainable strategy by reducing dependency on harmful traditional mining practices, promotes urban mining, lowers energy consumption and offers economic benefits. In this work, Nd slag generated during rare earth molten salt electrowinning process was repurposed into an effective electrocatalyst for water splitting application (scheme). The collected Nd slag was washed several times to remove water soluble salts and insoluble residue was characterized using various physico-chemical characterization techniques. The electrode fabrication involves dispersing Nd slag into the nickel bath to prepare a Ni/Nd metal matrix composite (MMC) coating on a mild steel substrate through an electroplating technique at 50°C. The electrocatalytic activity of the electroplated Ni/Nd MMC coatings was evaluated for oxygen evolution reaction (OER) in alkaline medium. The electrochemical results indicate that the Ni/Nd MMC catalyst exhibits better catalytic activity with low overpotential of 280 mV at 10 mA/cm². Detailed evaluation of Ni/Nd MMC under various fabrication conditions are under progress. This work provides a simple and efficient approach to convert electrolytic slag into an efficient electrocatalyst for enhanced water splitting reactions (Figure 1).

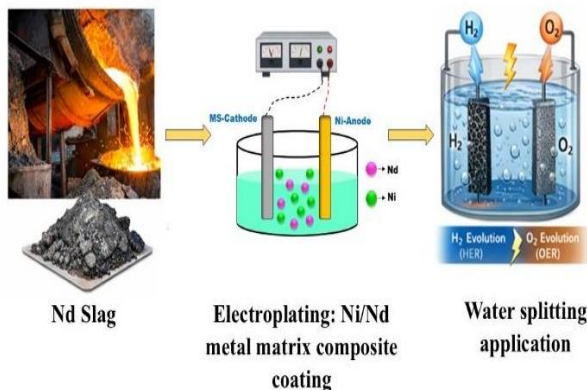


Figure 1. Schematic representation of the synthesis of a Ni/Nd metal matrix composite coating from Nd slag via electroplating and its application as an efficient electrocatalyst for water splitting.

PP-73

Flexible and Portable Hydrovoltaic Power Generator Device Using MgAl LDH/GO Composite

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The rapid growth of Hydrovoltaic technologies by scavenging renewable energy sources for power generation provides a promising approach for self-powered devices. Out of recent literature, carbon-based materials with tunable properties were considered preferred choices to harvest electrical energy through Hydrovoltaics due to their higher surface charge and porous nature. Here in this work, we are going to explore carbon-based derivatives in energy harvesting sectors. Commercially available carbon paste is used as the electrodes, allowing electrons, generated by water interaction to travel efficiently to the external circuit, enhancing output voltage and current. The MgAl-GO composite is coated evenly over the interdigitated carbon electrodes. This LDH-GO composite has a naturally high affinity for water and increased ion mobility pathways, which enhances the Hydrovoltaic performance. The hydrogel is the main essence of the device which improves moisture-induced electricity generation. The gel is pasted on one end of the device evenly, and this holds water in a semi-solid form, allowing ions to move through it like in a liquid electrolyte. When water contacts the device, the hydrogel absorbs and retains moisture on one side, creating a strong wet-dry gradient. The water then diffuses into the MgAl-GO layer, where high surface charge density and hydrophilicity promote ion dissociation. These ions then migrate across the interdigitated carbon electrodes, generating a streaming current and potential. The layered structure greatly enhances moisture adsorption, ion mobility, and charge separation, resulting in efficient hydrovoltaic power generation.

Unveiling the Influence of Zeolite-Imidazole Framework Synthesis via the Precipitation Method on the Electrocatalytic Activity of Derived Carbon

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Carbon materials derived from zeolite imidazole frameworks (ZIFs) show great potential as electrocatalysts for a range of electrochemical reactions, such as the oxygen reduction reaction (ORR). However, the ability to rapidly and efficiently produce ZIFs on a large scale is essential for creating electrocatalytically active carbon materials for broad applications. Adjusting the solvent composition is necessary for the mass production of ZIFs, yet the effects of these adjustments on the electrochemical properties of the resulting electrocatalysts are often neglected. This research examined how different solvents used in the precipitation synthesis of bimetallic (Co and Zn) ZIFs affect the electrocatalytic properties of the resulting carbon materials. Specifically, ZIFs were synthesized using methanol, a water-triethylamine (TEA) mixture, and a water-dimethylformamide (DMF) mixture. The findings reveal that ZIFs synthesized in a water-TEA mixture produce carbon materials (Co-TEA) with superior electrochemical performance, characterized by a higher density of active reaction sites and improved electrochemical performance and stability for the ORR, compared to those produced from methanol (Co-MOH) and water-DMF mixtures (Co-DMF). The study highlights the crucial role of solvent selection in shaping the morphology, porosity, and catalytic properties of ZIF-derived carbon. The surface-doped nitrogen content and balanced Co^{3+} and Co^{2+} ions in Co-TEA, along with the high density of mesopores, increased the reaction site density of Co-TEA compared with those of Co-MOH and Co-DMF. Notably, the electrochemical stability of Co-TEA surpasses those of Co-MOH, Co-DMF, and commercial Pt/C. Co-TEA exhibited a negative shift of only 17 mV in $E_{1/2}$ after 10,000 cycles between 0.6–1 V. These findings reveal that the electrochemical performance of the derived carbon is closely linked to the synthesis conditions, highlighting the potential of water-TEA-mediated ZIF synthesis as a promising strategy for developing nonprecious electrocatalysts for practical applications (Figure 1).

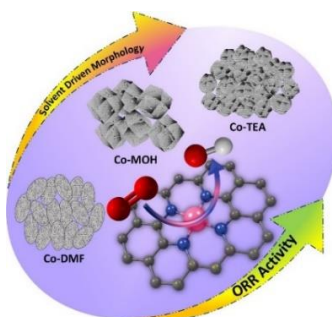


Figure 1. Correlation between solvent driven morphology and ORR activity.

PP-75

Design of a Trimetallic MnCuFe Metal-organic Framework as a Bifunctional Electrocatalyst for Overall Water Splitting

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In this work, a trimetallic MnCuFe metal–organic framework (MOF) based on an H₃PDC (1H-Pyrazole-3,5-dicarboxylic acid) linker was synthesized using a solvothermal approach and evaluated as an electrocatalyst for the hydrogen evolution reaction (HER), oxygen evolution reaction (OER), and overall water splitting. The incorporation of manganese, copper, and iron within a porous MOF architecture is intended to provide multiple redox-active centers, improved electrical conductivity, and a higher density of catalytically active sites. Structural and morphological characteristics of the synthesized material were examined using X-ray diffraction (XRD), field-emission scanning electron microscopy (FESEM), transmission electron microscopy (TEM), and energy-dispersive spectroscopy (EDS) mapping, while surface chemical states were analysed using X-ray photoelectron spectroscopy (XPS). Electrochemical measurements performed in alkaline electrolyte demonstrated enhanced catalytic performance of the MnCuFe MOF, showing reduced overpotential and favourable kinetics for both HER and OER compared with corresponding monometallic systems. The synergistic interaction among the three transition metals and the robust framework provided by the H₃PDC linker contribute to improved charge-transfer behaviour and catalytic stability. These findings suggest that MnCuFe-based trimetallic MOFs are promising candidates for efficient and sustainable electrocatalytic water splitting and offer a potential pathway for designing multimetallic MOF platforms for energy conversion applications.

PP-76

Synergistic Effect of VS₂ and Ag₃PO₄ Composite Catalysts for Efficient and Stable Hydrogen Evolution Reaction in Acidic Media

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Currently the growing need for clean and renewable energy sources has gained immense interest for addressing the environmental damage caused by fossil fuels. Electrocatalytic water-splitting that generates hydrogen with almost no pollution has emerged as a practically viable method. Hydrogen

gas (H_2) production through the electrochemical hydrogen evolution reaction (HER) is a critical process in promoting clean and sustainable energy sources. This study presents the analysis of VS_2 and Ag_3PO_4 composites by varying the weight percentage of VS_2 with Ag_3PO_4 as an electrocatalyst for HER by coating samples on the carbon cloth and serving as a working electrode. VS_2 a transition metal dichalcogenide, has demonstrated remarkable electrochemical activity owing to its layered structure with abundant active sites, and promotes rapid hydrogen evolution reaction. Unlike many TMDCs, the VS_2 exhibits intrinsic metallic conductivity which drastically reduces the charge transfer resistance that enables more efficient electron transport during the HER activity. Ag_3PO_4 shows distinctive catalytic properties that could be attributed to the unique electronic structure. The weight percentage of VS_2 varied as 1, 3, and 5 wt% in Ag_3PO_4 with least potential obtained for A5V is 219 at 10 mA/cm^2 among the other prepared samples. Through the systematic electrochemical testing the performance of these materials is evaluated for their overpotential, Tafel slope and Electrochemical active surface measurements. The results reveal that VS_2 and Ag_3PO_4 combination is a potential composite for improving the HER with 12 hr stability in acidic condition.

PP-77

Sn-doped Bi_2O_3 as an efficient and robust catalyst for Oxygen Evolution Reaction

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This work reports a structurally engineered Sn-doped Bi_2O_3 electrocatalyst for the alkaline oxygen evolution reaction (OER). A series of nanocatalysts were synthesised by varying the ratio of Sn (0.25, 0.50, 0.75, 1 wt %). An overpotential close to 335 mV was observed at 10 mA cm^{-2} current density with a Tafel slope of 74 mV/dec for the optimized catalyst (Figure 1). Also, the optimized catalyst was found to be stable under different current densities. Considering this, an H-type cell was also constructed for understanding the practical viability of the synthesised catalyst using two different current collectors.

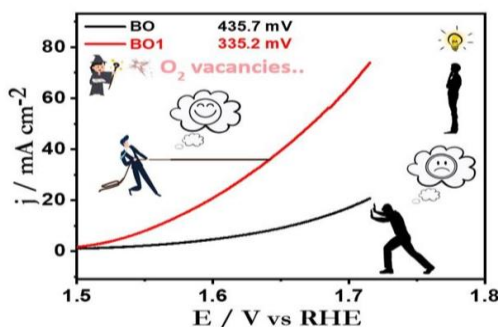


Figure 1. Current vs potential graph of Bi_2O_3 electrocatalysts.

Rational Design of a Ce-Cu Based Bifunctional Catalyst for Efficient and Durable Alkaline Water Electrolysis

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Rising energy demand and pollution from fossil fuels highlight the need for sustainable energy solutions. Electrocatalytic water splitting offers a clean route for hydrogen production, but its efficiency is limited by the slow kinetics of the Hydrogen and Oxygen Evolution Reactions (HER and OER). Although noble metals such as Pt, Ir, and Ru provide excellent catalytic performance, their high cost and scarcity hinder large-scale use. To overcome these challenges, this study focuses on developing a low-cost and efficient electrocatalyst using cerium (Ce) and copper (Cu). The catalyst was synthesized with a 1:1 molar ratio to take advantage of the complementary properties of both metals. Cerium contributes through its variable oxidation states, which enhance redox reactions, particularly for OER, while copper improves electrical conductivity and supports hydrogen adsorption, benefiting HER. Together, they create a synergistic effect that enhances overall catalytic performance. The material was thoroughly characterized using XRD, XPS, Raman, and FT-IR techniques to confirm its structure and chemical composition, while FE-SEM was used to examine its surface morphology. Electrochemical performance was evaluated using LSV, CV, and EIS in alkaline conditions. The results show that the Ce-Cu catalyst performs efficiently as a bifunctional electrocatalyst, achieving an overall water splitting potential of 1.72 V at 10 mA cm⁻². Stability tests further confirm its durability during continuous operation. Overall, this work demonstrates that Ce-Cu based materials can serve as promising, affordable alternatives to noble metal catalysts for sustainable hydrogen production.

PP-79

Copper-based Metal Organic Framework Electrocatalyst for Anion Exchange Membrane Water Splitting

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Global escalating energy demand, rapid growth of greenhouse emissions, and the gradual exhaustion of fossil fuels constitute one of the humanity's most strenuous challenges. Hydrogen energy is a promising alternative to fossil fuels and is considered as a significant energy carrier. Among various methods for producing hydrogen, electrochemical synthesis is an efficient, eco-friendly, and viable option that produces hydrogen and oxygen with zero carbon emissions. Anion exchange membrane water electrolysis (AEMWEs), which combines the benefits of proton exchange membrane water electrolysis and conventional alkaline water electrolysis systems, is a potentially affordable and sustainable method for producing high-purity hydrogen. This study examines the transition metal-based metal organic framework, Cu MOF electrocatalyst with highly active, durable porous crystalline material, and acts as a bifunctional electrocatalyst for the AEMWEs. Cu MOF exhibited better OER activity with 1.64 V and HER with -0.41 V at a current density of 10 mA cm^{-2} in 0.1 M KOH vs Hg/HgO. It demonstrates a better current density of 12 mA/cm^2 in 1 M KOH with a crystallite size value of 107.49 nm . This work may furnish a chance to design a bifunctional electrocatalyst for the development of AEMWEs.

PP-80

Tailoring Copper Cobalt Oxide Decorated Nitrogen-doped Hollow Carbon Spheres as a Bifunctional Oxygen Electrocatalyst

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The increasing demand for sustainable energy has led to renewed interest in zinc-air batteries (ZA). While ZA offers high energy density and performance, their practical application is limited by the sluggish kinetics of oxygen reduction and evolution reactions (ORR and OER) at the air cathode. Noble metal catalysts, such as Pt and $\text{RuO}_2/\text{IrO}_2$, are highly efficient but expensive and unstable. To address

these limitations, researchers have explored cost-effective alternatives, including metal oxide-based catalysts like cobalt oxide spinel (Co_3O_4) and copper oxide (CuO). However, these materials suffer from limited active sites and low conductivity. Heteroatom-doped carbon materials offer high conductivity but lack the necessary active sites for OER. To overcome these challenges, a synergistic approach involving the integration of metal oxides and carbon materials has been pursued. This study presents a novel single-step method to synthesize cobalt-phase-enriched CuCo_2O_4 within nitrogen-doped hollow carbon spheres. This innovative approach leverages the combined advantages of both components, resulting in a highly efficient and durable bifunctional oxygen electrocatalyst. This development holds significant potential for advancing ZA technology and other sustainable energy storage solutions.

PP-81

Medium-entropy Transition Metal Chalcogenides for Synergistic Enhancement of Electrochemical Performance Towards HER

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Electrochemical water splitting is considered as one of the promising methods for the generation of sustainable hydrogen (H_2) with zero carbon emission. Pt, Pd and Ru noble metals are widely acknowledged as benchmark catalysts for electrochemical water splitting. However, their high cost and limited availability pose a major challenge towards their industrialization. Hence, it is highly desirable to construct low-cost catalysts with earth abundant elements, which can replace noble metal-based catalysts. In this regard, medium entropy transition metal chalcogenides (TMCs) have drawn substantial interest to generate H_2 and O_2 via electrochemical hydrogen and oxygen evolution reactions (HER/OER) respectively. In this work, we have designed non-noble metal based medium entropy TMCs through a facile solvothermal approach. The material shows robust HER performance in 1.0 M KOH. The as-synthesized medium entropy TMCs has been characterized using powder X-ray diffraction (pXRD) and other microscopic techniques such as field emission scanning electron microscope (FESEM), high-resolution transmission electron microscope (HR-TEM). The HER performance of the fabricated catalyst (FeMoCuSe) was investigated via various electrochemical characterization techniques such as cyclic voltammetry (CV), linear sweep voltammetry (LSV), chronoamperometry and chronopotentiometry. The synthesized FeMoCuSe achieves least overpotential along with lowest Tafel slope compared to individual metal chalcogenides. The catalyst also exhibits high conductivity and long-term cyclic durability for 48 h. The excellent HER performance of FeMoCuSe reveals the effectiveness of medium-entropy materials, which can lead to the low-cost industrial H_2 production.

Aromatic Hydrocarbon-based Heterogeneous Anion Exchange Membranes with Tailored Heterostructures

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Anion exchange membranes (AEMs) are critical components in advanced electrochemical technologies, including water electrolyzers, fuel cells, and desalination systems. Heterogeneous AEMs provide distinct advantages due to their synergistic structural design, which improves ionic conductivity, minimizes swelling, and enhances long-term stability under alkaline conditions. This study reports the development of high-performance heterogeneous AEMs based on polyvinyl pyrrolidone (PVP) and polyvinyl benzyl chloride (PVBC) polymer blends, an emerging and underexplored material system. The formation of well-defined polymer–polymer interfaces within the membrane matrix enhances interfacial compatibility, facilitates efficient ion-transport pathways, and improves structural integrity (Figure 1). Such interfacial engineering effectively addresses the limitations of conventional AEMs, leading to improved conductivity, durability, and mechanical robustness. The synthesized membrane exhibits a promising ionic conductivity of 5.2×10^{-3} S/cm, demonstrating the effectiveness of the heterogeneous design and interfacial interactions. Fourier-transform infrared spectroscopy (FTIR) and nuclear magnetic resonance spectroscopy (NMR) confirm strong functional group interactions and chemical compatibility between PVP and PVBC within the composite matrix. Overall, the enhanced mechanical strength, alkaline stability, and ion-transport properties highlight the potential of this heterogeneous membrane as a promising candidate for next-generation electrochemical devices, supporting the advancement of sustainable clean-energy technologies.



Figure 1. Photographic image of membrane.

Electrochemical Ammonia Synthesis from Nitrate and Nitric Oxide Using Copper Foam Prepared *via* Electrochemical Method

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The rise in global energy demand and excessive usage of fossil fuels significantly impacted the nitrogen cycle, causing severe air and water pollution. A significant contribution comes from Haber's process, consuming 27.4-31.8 GJ of energy per ton of ammonia produced, accounting for 3% of global CO₂ emissions. Therefore, developing a sustainable, eco-friendly approach, such as electrochemical NH₃ synthesis, is required to balance the nitrogen cycle and indirectly minimize CO₂ emissions. In this study, a highly porous, surface-reconstructed copper foam with nano-threads was prepared, and its performance was evaluated in both batch (H-cell) and flow-cell setups for NO₃⁻ reduction. The catalyst exhibited a remarkable ammonia yield of 162 mg/h cm² in the H-cell and 183 mg/h cm² in the flow cell, with a maximum Faradaic efficiency of 95.6% in 0.1 M NO₃⁻ electrolyte. The enhanced activity of the as-prepared catalyst is due to the presence of abundant active sites formed via electrochemical reconstruction of copper oxide to copper. Additionally, a proof-of-concept was shown for synthesizing nitrate from gaseous nitric oxide via chlorine- and oxygen-mediated electrochemical oxidation, which was subsequently utilized for electrochemical NH₃ production. The synthesized NH₃ was effectively recovered by argon stripping and crystallized as ammonium chloride (NH₄Cl), a stable compound that has direct applications in pharmaceuticals, fertilizers, and battery systems. This work presents a sustainable, scalable strategy for NH₃ production from nitrogen oxides, offering a potential pathway to decentralized, green ammonia synthesis (Figure 1).

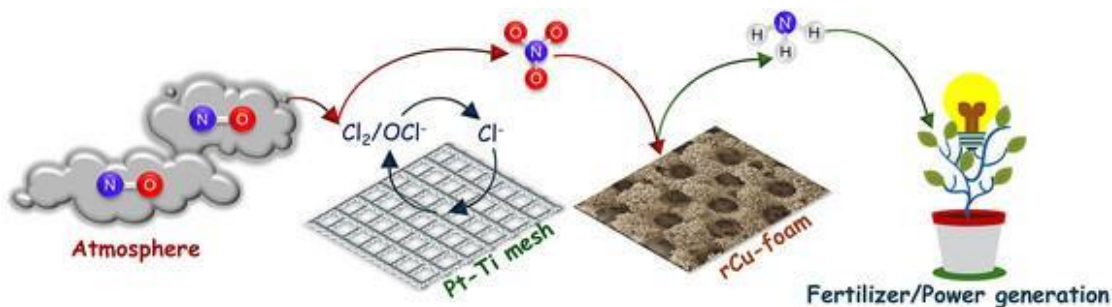


Figure 1. Graphical abstract.

Potentiostatic Electrodeposition of Ni–Co–P on Graphite: A Simple Route to High-performance HER Catalysts

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The pursuit of sustainable hydrogen production has accelerated the development of non-precious metal-based electrocatalysts for efficient water splitting. Among various candidates, transition metal phosphates (TMPs) have attracted significant attention due to their abundance of redox-active metal centres and proton-accepting phosphate groups that enhance electrical conductivity and expose abundant active sites. Nickel cobalt phosphate (NiCoP) stands out because of the synergistic interactions among Ni, Co, and P, which promote charge transfer and catalytic efficiency. In this study, Ni-Co-P thin films were fabricated on conductive graphite sheets *via* a facile, binder-free potentiostatic electrodeposition method, enabling precise control over phosphorus concentration. Structural and surface characterisations using XRD, XPS, SEM, FESEM, and HRTEM confirmed the formation of phase-pure Ni-Co-P with uniform morphology and defect-rich nanostructures, which facilitated improved electrochemical performance. The optimised NiCoP(1.6)/GS electrode demonstrated outstanding hydrogen evolution reaction (HER) activity in 1.0 M KOH, requiring an overpotential of only 140 mV to achieve a current density of 50 mA cm⁻² and exhibiting a low Tafel slope of 81 mV dec⁻¹. The superior catalytic activity and durability, maintaining stability over 50 hours of continuous operation, are attributed to efficient electron transport, the stabilising effect of strong P–O bonds, and enhanced proton adsorption on the negatively charged phosphate surface. Overall, this work highlights the potential of electrodeposited Ni-Co-P as a cost-effective, durable, and high-performance electrocatalyst for alkaline hydrogen evolution, offering an attractive alternative to noble metal-based systems.

Strategically Modified Ni-based Layered Double Hydroxide Electrocatalysts: Enhanced Electrochemical Oxygen Evolution Reaction Performance in Alkaline Water Electrolysis

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The advancement of alkaline water electrolysis is critically dependent on the development of low-cost, high-performance electrocatalysts for oxygen evolution reaction (OER). While Ni-based layered double hydroxides (LDHs) show immense potential, their efficiency is often restricted by sluggish charge transfer kinetics. In this study, we present a comprehensive investigation into Ni-based LDH heterostructures—specifically focusing on NiFe, NiCo, and NiCr systems—to overcome these intrinsic limitations. Our approach explores three distinct modification pathways: (i) NiFe LDH/CQD/MWCNT: The integration of Carbon Quantum Dots (CQDs) and Multi-Walled Carbon Nanotubes (MWCNTs) creates a hierarchical conductive network that promotes rapid electron transport and increases active site exposure, (ii) In-intercalated NiCo LDH/MWCNT: The intercalation of Indium ions expands the LDH interlayer spacing, facilitating faster ion diffusion and modulating the electronic environment of the Ni-Co centers. (iii) Fe-doped NiCr LDH: Precise tuning of Fe-doping concentrations in the NiCr LDH lattice optimizes the adsorption-free energies of OER intermediates (-OH*, -O*, and -OOH*). All three systems have been extensively characterized structurally. Electrochemical evaluations demonstrate that these strategic modifications significantly enhance OER activity. The CQD/NiFe LDH/MWCNT achieves a current density of 100 mA/cm² at a low overpotential of 172 mV with a Tafel slope of 37 mV/dec and stability tests further reveal that the carbon-supported heterostructures maintain exceptional durability over 100 hours, attributed to the strong interfacial coupling between the LDH and the MWCNT support. The In-intercalated NiCo LDH system exhibits excellent electrocatalytic properties for OER, with a low overpotential of 196 mV at a current density of 100 mA/cm², a low Tafel slope of 35 mV/dec, with excellent stability. This is achieved through the introduction of new energy levels in the bandgap region in the LDH by the intercalation of indium cations. NiCr LDH exhibits an interesting behavior, with the Cr in the 3+ valency state, thereby regulating Ni to be in the 2+ valency state. The 1:1 NiCr LDH exhibits a high overpotential of 276 mV for a current density of 100 mA/cm². Increasing the molar ratio of nickel enables the variable valency Ni²⁺/Ni³⁺ of nickel, resulting in good electrocatalytic activity as evidenced by the lower overpotential of 236 mV at 100 mA/cm² current density. Doping with 5 mol% iron significantly enhances the electrocatalytic activity of the LDH, resulting in a 203 mV overpotential at 100 mA/cm², with a Tafel slope of 63 mV/dec. This work underscores the synergy between strategies such as interlayer cation intercalation, ternary metal doping, and carbon-based heterostructuring, providing a robust framework for designing the next generation of non-noble metal electrocatalysts for sustainable hydrogen production.

In-Situ Sulfurization of NiCo Binary Oxysulfides on Seaweed-derived Carbon Supports: Engineering Robust Bifunctional Interfaces for Superior HER and OER

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Exploration of the potential of waste carbon-based catalysts from seaweed as a sustainable and efficient material for water-splitting reactions. Seaweed biomass, especially *Gracilaria edulis*, is converted into carbon-rich material along with metal nanoparticles through the solvothermal method and exhibits excellent electrocatalytic properties. The resulting seaweed-derived transition metal-decorated materials, especially NiCo-oxysulfide (NiCo-SWDC), demonstrate enhanced oxygen evolution reaction (OER) and hydrogen evolution reaction (HER) activity, making them promising candidates for water splitting. The unique structure and composition of NiCo-SWDC contribute to their improved performance, offering a sustainable and cost-effective alternative to traditional electrocatalysts. The optimum catalyst loading is a ratio of 1:05 for OER in 1M KOH medium, showing a low overpotential of OER of 340 mV at 10 mA cm⁻² with a Tafel slope of 80 mV dec⁻¹. In addition, the same NiCo-SWDC also shows HER at the overpotential of 280 mV at 10 mA cm⁻² with a Tafel slope of 170 mV dec⁻¹ (Figure 1). The long-term stability test was carried out for up to 50 h. By using an economical and ecologically friendly synthetic approach, the current study offers fresh insights into the creation of scalable and highly effective bifunctional catalysts.

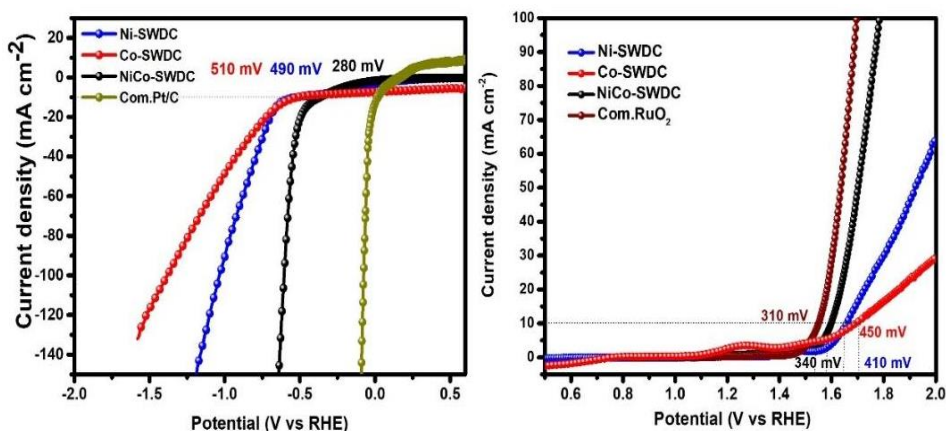


Figure 1. OER and HER overpotential plots for NiCo-SWDC.

PP-87

Polymerized Photosensitive EDOT-coated Cotton Fabric as Efficient Solar Thermal Interfacial Evaporation and Hydro-Voltaic Power Generation

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In this study, we report a polymerized photosensitive poly(3,4-ethylenedioxythiophene) (PEDOT)-coated cotton fabric as a two-dimensional (2D) interfacial device for simultaneous solar-driven evaporation, hydrovoltaic power generation, and water purification using dye. The porous and hydrophilic structure of cotton facilitates efficient water transport through capillary action, while the PEDOT coating provides photothermal conversion and electrical conductivity. The interaction between water flow and the charged PEDOT surface induces a hydrovoltaic effect, generating a measurable electrical output. In addition, the PEDOT layer contributes to dye adsorption and degradation, enabling effective purification of contaminated water. The integrated system demonstrates stable performance and multifunctionality without the need for external power sources. This work highlights a simple, low-cost, and scalable approach for developing advanced textile-based platforms for clean water production and renewable energy harvesting.

PP-88

Synergistic Electrocatalytic Performance of SrTiO₃–Graphene Oxide Composites for the Hydrogen Evolution Reaction in Acidic Medium

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The hydrogen evolution reaction (HER) is a pivotal process in sustainable energy technologies, particularly in water splitting for hydrogen production. This study investigates the electrocatalytic performance of SrTiO₃ (strontium titanate) and graphene oxide (GO) composites for HER. SrTiO₃ a perovskite oxide is known for its excellent photocatalytic properties, while GO offers a high surface area and superior electronic conductivity. By combining SrTiO₃ with GO, we aim to enhance the HER activity through synergistic effects. SrTiO₃ holds immense potential for its application, offering unique properties and versatility. GO because of its superior electrical conductivity, chemical stability, and large surface area, graphene oxide (GO) has demonstrated considerable promise in energy storage applications. These properties can improve the efficiency of energy storage devices. This research

aims to harness the unique properties of SrTiO₃-GO composites for hydrogen evolution reaction, The SrTiO₃-GO composites have electrical, mechanical, and electrochemical properties, making them ideal candidates for HER application. The characterizations (like XRD, SEM, TEM, XPS, UV, and Raman) confirm the presence of composite material, this study investigates the synthesis and optimization of SrTiO₃-GO composites to achieve enhanced electrochemical performance for hydrogen evolution reaction (HER) application.

PP-89

Engineering 2D Ni(Co, Mn) Layered Double Hydroxides for Urea-enabled Energy-saving Hydrogen Generation

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The transition towards sustainable energy systems demands cost-effective and high-performance electrocatalysts capable of driving multiple electrochemical reactions efficiently. Hybrid water electrolysis, in which the sluggish oxygen evolution reaction (OER) is replaced by the thermodynamically favourable urea oxidation reaction (UOR), has emerged as an energy-saving strategy for hydrogen production. In this study, we develop two-dimensional Ni-based layered double hydroxide (LDH) nanostructures as multifunctional electrocatalysts for hydrogen evolution (HER), OER, and UOR in alkaline media. NiCo-LDH and NiMn-LDH nanosheets were synthesized via a simple one-pot co-precipitation approach, yielding ultrathin 2D architectures with abundant exposed active sites and enhanced electrolyte accessibility. The intrinsic structural advantages of the 2D LDH framework, including a high surface-to-volume ratio, tunable metal cation composition, and interlayer ion transport pathways, enable efficient catalytic activity. The optimized catalyst delivers low overpotentials of 360 mV for HER and 90 mV for UOR at 50 mA cm⁻². When integrated onto a conductive nickel foam substrate, the NiCo-LDH/NF electrode operates as both anode and cathode in a hybrid electrolyzer, achieving a reduced cell voltage of 1.66 V at 10 mA cm⁻². The synergistic combination of the 2D LDH nanosheet architecture and the highly conductive three-dimensional nickel foam support facilitates rapid charge transfer, abundant catalytic interfaces, and robust operational stability. This work highlights the structural and compositional versatility of 2D Ni-based LDHs as promising multifunctional platforms for energy-efficient, urea-assisted hydrogen production, offering a viable pathway toward next-generation sustainable hydrogen technologies.

High Performance Transition Metal Based Nanohybrid Electrocatalyst for Boosting the Kinetics of OER

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The advancement of kinetically efficient and economically viable electrocatalysts for the oxygen evolution reaction, the anodic half-reaction in water electrolysis, is essential to overcome the sluggish four-electron transfer process that limits sustainable hydrogen production via alkaline water electrolysis. The nanohybrid $\text{NiBi}_2\text{O}_4/\text{g-C}_3\text{N}_4$ is synthesised via a facile wet chemical method followed by thermal treatment. Exemplary formation of the synthesised nanohybrid is analysed by using X-ray diffraction studies, Scanning Electron Microscopy, and FT-IR spectrometer respectively. Further, the electrochemical studies demonstrate superior OER activity, achieving a low overpotential of 280 mV at 10 mA cm^{-2} , along with an enlarged electrochemically active surface area. Subsequently, Tafel studies show the nanohybrid exhibits a lower Tafel slope value of 85 mV dec^{-1} , which evidences higher kinetics in the reaction mechanism of the oxygen evolution reaction, and the very low charge transfer resistance enhances the electronic conductivity of the synthesised material. The improved activity is attributed to synergistic interaction between the NiBi_2O_4 and $\text{g-C}_3\text{N}_4$, which enhances electron mobility and structural stability during prolonged operation. Overall, this study substantiates a promising strategy for designing next-generation, earth-abundant electrocatalysts for efficient water oxidation and renewable energy applications (Figure 1).

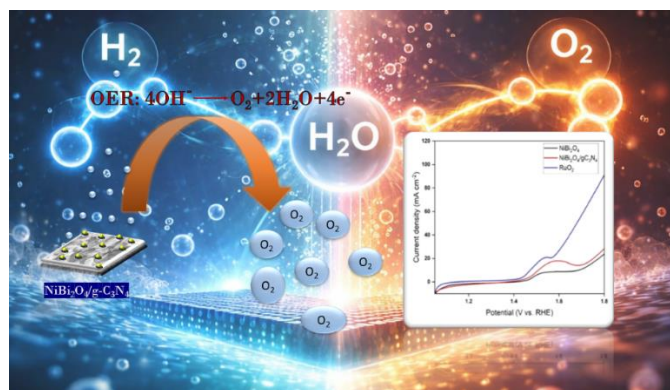


Figure 1 Graphical abstract on OER with representative LSVs.

PP-91

Optoelectronic Property Modulation in Lead-free Layered $A_3Bi_2Cl_9$ Perovskites via Cation Engineering for UV Photodetector Applications

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The influence of A-site cation methylammonium (MA^+), formamidinium (FA^+), and guanidinium (GA^+) on the structural, electronic and optical properties of layered $A_3Bi_2Cl_9$ perovskite is systematically investigated. An increase in the cation size induces the lattice expansion, accompanied by a reduction in bismuth-chlorine orbital overlap, which leads to a progressive widening of the electronic bandgap. UV-visible absorption measurements show a systematic increase in optical bandgap from 3.27 eV for $MA_3Bi_2Cl_9$ (MBC) to 3.46 for $FA_3Bi_2Cl_9$ (FBC) and further to 3.61 eV for $GA_3Bi_2Cl_9$ (GBC), establishing a direct structure-property relationship. Ultraviolet photoelectron spectroscopy probes the corresponding deepening of the valence band maximum from -5.82 eV (MBC) to -6.41 eV (FBC) and further to -6.80 eV (GBC). The X-ray photoelectron spectroscopy confirms that the tuning occurs without altering the Bi^{3+} -Cl framework. Field-emission scanning electron microscopy reveals corresponding variations in film morphology. The vertical ITO/ $A_3Bi_2Cl_9$ /Ag photodetectors evaluated at 365 nm illumination show that the FA-based device achieves the most favourable performance, with a responsivity of 10.96 A W^{-1} , specific detectivity of 1.9×10^{11} Jones, and EQE of 3725%. The enhanced response is attributed to the closer alignment between the excitation photon energy and the FBC bandgap, demonstrating that modest A-site-tuned band-edge shifts can be leveraged to optimize the photo response for specific UV bands in such lead-free perovskite detectors.

PP-92

Defect-Tuned Spinel Oxides via Sol-gel Synthesis for Selective and Efficient Electrochemical Ammonia Production from Nitrate

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Electrocatalytic nitrate reduction (eNO_3RR) is gaining attention as a dual-benefit strategy for sustainable ammonia production and environmental remediation. By providing a low-energy and decentralized alternative to the traditional Haber-Bosch process, eNO_3RR not only reduces carbon

footprint but also helps mitigate nitrate pollution in water systems. However, the multi-electron transfer steps involved in this reaction, along with competing hydrogen evolution reactions (HER), make it a challenging process. Achieving high selectivity and activity demands precise tuning of catalyst surface and electronic properties. In this work, we report the design of a highly efficient spinel oxide electrocatalyst synthesized via a simple and scalable sol-gel method. This synthesis approach allows precise control over composition and morphology, producing phase-pure nanostructured spinels with abundant active sites. To further boost catalytic performance, we implement a synergistic strategy that combines compositional doping, engineered structural defects, and oxygen vacancy modulation. These modifications create an optimized surface electronic environment that enhances the adsorption and activation of key intermediates (*NO_3 , *NO_2 , *NOH), accelerates the rate-determining steps, and effectively suppresses undesired HER pathways.² Even without advanced structural modifications, the catalyst exhibits outstanding activity under ambient conditions, delivering an ammonia yield rate of $2.1 \text{ mmol h}^{-1} \text{ cm}^{-2}$ at -0.7 V vs RHE and Faradaic efficiency of 85.5% at -0.4 V vs RHE. These results underscore the intrinsic catalytic potential of the spinel oxide framework and highlight the effectiveness of the sol-gel synthesis in exposing reactive facets and preserving surface integrity (Figure 1). This work reveals that even unmodified spinel oxides can achieve high-performance eNO_3RR , serving as a strong baseline for future studies involving defect engineering or doping. Moreover, it emphasizes how scalable, low-cost synthesis routes can yield practical catalysts for green ammonia production and environmental cleanup.



Figure 1. Oxygen vacancies modulate active sites to promote efficient NO_3^- reduction reaction pathways.

In Situ Anodization of Ni-Sn Alloys Obtained Through Galvanic Exchange Deposition for Oxygen Evolution Reaction

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Ni-based metallic alloys overcome the demand of noble metal for the generation of hydrogen while sluggish reaction kinetics of oxygen evolution reaction (OER) mandates large overpotentials during water spitting [1]. To achieve desired OER performance, rarely available Ru and Ir oxides are used. Oxides/hydroxides of transition metals/alloys are explored as replacement to these noble metals. However, the attachment of these transition metal (TM) oxides/hydroxides to current collectors using binders results in several issues such as poor conductivity, blocking electrocatalytic active sites, etc. [2]. Another adaptable method to generate oxides/hydroxides is anodization of TMs which can provide a highly conductive metallic base with strongly bonded oxide/hydroxide layers on the surface. Ni-Fe metallic alloys subjected to direct anodization and *in situ* anodization after fluorination in alkaline medium, exhibited low overpotentials for OER [3, 4]. However, no reports are available regarding the impact of surface anodization on the improved electrocatalytic activity of Ni-Sn alloys towards OER. The preparation of Ni-Sn deposits through electrodeposition or electroless deposition with phosphorus (NaH₂PO₂) or boron-based reducing agents are widely reported. For the first time, Ni-Sn deposit was obtained through galvanic exchange deposition using copper metal as reductant in ethaline deep eutectic solvent at ambient conditions. The resultant Ni-Sn is *in situ* anodized by cycling anodically between 1.0 and 1.8 V Vs. RHE in 1 M KOH solution. The electrocatalytic activity of Ni-Sn coatings increased during voltammetric cycles indicating that the formation of oxides/hydroxides layers of Ni and Sn on the surface. The Ni-Sn deposits obtained from solutions containing various mole ratios of Ni and Sn (Figure 1) were subjected to anodization; Increase in OER activity was observed with increase in Sn content in terms of lower overpotentials and higher current density. Improvement in OER activity due to surface oxidation via *in situ* anodization was concurred by various characterization techniques such as AFM, FE-SEM, XPS and XRD. The effortless preparation, direct anodization of Ni-Sn deposits with strong adhesion on metallic substrate can overcome the problems in electrode fabrication, mechanical stability, conductivity as well as catalytic efficiency during electrocatalysis.

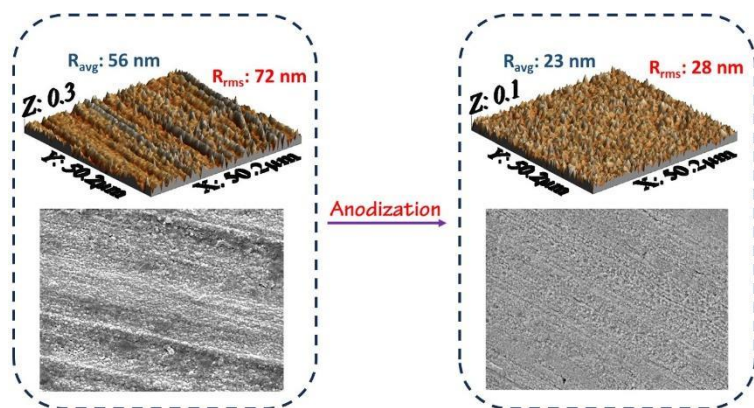


Figure 1. AFM and FE-SEM analysis of Ni-Sn deposit before and after anodization.

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PP-94

Improving the Power Conversion Efficiency of Perovskite Photovoltaics Using a Bilayer Structure

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A combined material and device-related analysis is much needed to understand the working principle to explore the efficiency potential of triple cation-based Perovskite Solar Cells (PSCs). Therefore, here, density functional theory (DFT) and SCAPS-1D-based studies were reported to evaluate the photovoltaic (PV) performance PSCs. DFT is first applied to assess and extract structural and optoelectronic properties (band structure, density of states, Fermi surface, and absorption

coefficient) of the considered absorber layer. Furthermore, to look for a suitable combination of the charge transport layer, a total of nine HTLs (Cu_2O , CuSCN , P3HT, PEDOT: PSS, Spiro-MeOTAD, CuI , V_2O_5 , CBTS, and CFTS) and six ETLs (TiO_2 , PCBM, ZnO , C_{60} , IGZO, and WS_2). Meanwhile, the crucial hurdle to commercialization is the 3D perovskite's instability. The development of bilayered (3D/2D) junction perovskites as light absorption materials has proven to be one of the most dependable approaches for stabilizing PSCs without compromising their power conversion efficiency (PCE) owing to the passivation capability of the massive organic cations. In this, the 3D/2D perovskites with optimized interfaces are developed by using a Ruddlesden–Popper (2D) phenylethylammonium lead iodide (PEA_2PbI_4) film on the top of a 3D triple-cation CsFAMAPbIBr perovskite and the device architecture is $\text{FTO/TiO}_2/\text{CsFAMAPbIBr/PEA}_2\text{PbI}_4/\text{Spiro-MeOTAD/Au}$. The effects of operating temperature, series and shunt resistances, Mott–Schottky, capacitance, generation and recombination rates, quantum efficiency, and current–voltage density were also examined. The resulting PV properties were also compared with previously published data. Results reported in this study will pave the way for the development of high-efficiency solar cells in the future.

PP-95

Nanostructured First Row-Transition Metal Electrocatalysts for Conversion of Glycerol to Value Added Chemicals

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The electrochemical oxidation of glycerol is the versatile approach for the conversion of biodiesel byproducts into value added chemicals such as formic acid, glycolic acid, glyceraldehyde and glyceric acid. This approach enables a more efficient utilization of glycerol and has the potential to fulfil the projected future requirements for formic acid, which serves as a promising fuel for both direct and indirect formic acid fuel cells. However, the existing challenges associated with the catalysts include low oxidation activity and conversion rates. Consequently, development of an efficient catalyst to overcome these difficulties is more challenging. Noble metal and their alloys (e.g., Pt, Pd, Au, PtBi, PdBi, PdAg) are widely used as an efficient electrocatalyst for glycerol oxidation which offer advantages of catalytic GOR at very low potential however they possess several limitations including high cost. Earth abundant transition metal-based catalysts represent a promising alternative to noble metal for glycerol oxidation. Among these catalysts, Cu-based catalyst exhibits promising large-scale application owing to their low cost, environmental friendliness and high formate selectivity. However, achieving high activity, selectivity, and stability simultaneously in copper – based catalysts for GOR remains a challenge [1,2]. In this study, Cu nanoparticle decorated TiO_2 nano rod (Cu/TiO_2 NR) has been developed as an electrocatalyst for glycerol oxidation. The catalyst demonstrates enhanced

activity and selectivity towards formate with an efficiency of 92% at 1.4 V (RHE). This research provides compelling insights for the development of cost-effective transition metal based electrocatalyst for GOR.

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PP-96

Engineering Mn-doped $\text{LaCoO}_3/\text{g-C}_3\text{N}_4$ Heterostructures as Bifunctional Electrocatalysts for Enhanced ORR and OER Performance

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The search for efficient and low-cost electrocatalysts for oxygen reduction reaction (ORR) and oxygen evolution reaction (OER) is important for improving metal–air batteries and water-splitting devices. In this work, LaCoO_3 (LCO), Mn-doped LaCoO_3 (LCMO), $\text{g-C}_3\text{N}_4$, and their heterostructured composites were successfully synthesized. LCO and LCMO were prepared by a citrate-assisted sol–gel method followed by calcination at 700 °C, while the composites with $\text{g-C}_3\text{N}_4$ were obtained through a hydrothermal process at 150 °C for 12 h. The synthesized materials were analysed using XRD, FTIR, FESEM, and EDX. XRD confirmed the formation of the perovskite phase, whereas FTIR verified the presence of metal–oxygen bonds and $\text{g-C}_3\text{N}_4$. FESEM images showed that the perovskite particles were distributed over the layered $\text{g-C}_3\text{N}_4$ surface, creating a porous structure with more exposed active sites. The ORR and OER performances of the materials were studied in alkaline medium using electrochemical techniques. The heterostructured Mn-doped LCMO/ $\text{g-C}_3\text{N}_4$ composite showed the best activity, with improved ORR onset potential, and a lower Tafel slope of 68 mV/dec, whereas LCMO exhibited a lower OER overpotential of 235 mV at 100 mA/cm², smaller charge-transfer resistance and better stability than pristine LCO. The enhanced performance can be attributed to the combined effect of Mn doping, which modifies the electronic structure of LaCoO_3 for OER and the $\text{g-C}_3\text{N}_4$ support for ORR which promotes faster electron transfer and provides more active sites. The results suggest that the LCMO/ $\text{g-C}_3\text{N}_4$ heterostructure is a promising bifunctional electrocatalyst for future sustainable energy applications.

Iodine Redox Gel-driven Hydrovoltaic Energy Generation Using LDH–PVP Composite

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Hydrovoltaic energy harvesting has attracted increasing attention as an alternative and sustainable approach for converting ambient water evaporation into electrical energy. This phenomenon relies on evaporation-induced ion migration, interfacial charge separation, and electrochemical potential gradients within hydrated materials. Layered double hydroxides are promising candidates for hydrovoltaic applications due to their high surface area, tunable composition, ion-exchange capability, and layered structure, which facilitate ionic transport. Incorporation of redox-active systems such as iodine/iodide ($I_2/I^-/I_3^-$) further enhances charge transfer processes. The synthesized LDH–PVP iodine/iodide gel was uniformly coated onto carbon cloth, which served as one electrode. Another carbon cloth was placed on top to form a sandwich-type device architecture. Evaporation from the gel surface induces directional ion transport within the electrolyte, generating a continuous current. The effects of evaporation, electrode material, device orientation, and hygroscopic hydrogel assistance on electrical output are systematically investigated. The hydrovoltaic power generation mechanism in the LDH–PVP iodine/iodide gel system is attributed to the synergistic effects of evaporation-induced ion migration and redox-assisted charge transfer. Water evaporation creates a concentration gradient within the gel, driving the migration of iodide and triiodide ions. Simultaneously, the I_2/I^- redox couple facilitates electron transfer at the electrode interfaces, resulting in continuous electrical output. The LDH layers provide confined ionic pathways, while PVP enhances water retention and structural stability. This work demonstrates the successful synthesis and application of an LDH–PVP iodine/iodide gel for hydrovoltaic energy harvesting. While the voltage output is primarily governed by inherent electrochemical potentials, the current density is strongly influenced by water evaporation, device orientation, and moisture availability. These findings provide valuable insights for the rational design of efficient hydrovoltaic energy harvesting systems. When water comes into contact with LDH–PVP iodine/iodide gel, protons and hydronium ions will ionize the surface functional groups and create a concentration gradient on the material-water interface which results in the streaming potential. A 50 μ l of water poured on the top electrode, an open circuit voltage of 350 mV and a short circuit current of 100 μ A were measured. As time proceeds, potential difference starts increasing and short circuit current decreases and gradually reaches a steady state under ambient conditions.

Pt Single Atoms on CeO₂ Nanoparticles for Electrocatalytic Oxygen and Hydrogen Evolution Reaction

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Single atom catalysts (SACs) have emerged as a promising class of catalytic materials due to their maximum atom utilization efficiency and unique electronic structures. Platinum-SACs consist of isolated metal atoms individually dispersed and stabilized on metal oxides. This atomic scale dispersion fundamentally alters the catalytic behaviour of Pt, leading to enhanced activity. In this work, we discuss the facile hydrothermal preparation of CeO₂ nanoparticles. Then, Pt-SACs on CeO₂ NPs are achieved by DC sputtering. In electrochemical applications, CeO₂ has emerged as a highly promising support material for SACs in electrocatalytic oxygen evolution reaction (OER) and hydrogen evolution reaction (HER) due to its unique redox property, high oxygen storage capacity, and abundant oxygen vacancies. When Pt metal atoms are anchored onto the CeO₂ surface, strong metal support interactions stabilize the single atoms and modulate their electronic structure. Pt-CeO₂ reduced the overpotentials for both HER and OER demonstrate that interfacial engineering of Pt compared to bare CeO₂ is attributed to electronic modulation of Pt by Ce³⁺/Ce⁴⁺ redox couples and oxygen vacancies (Figure 1).

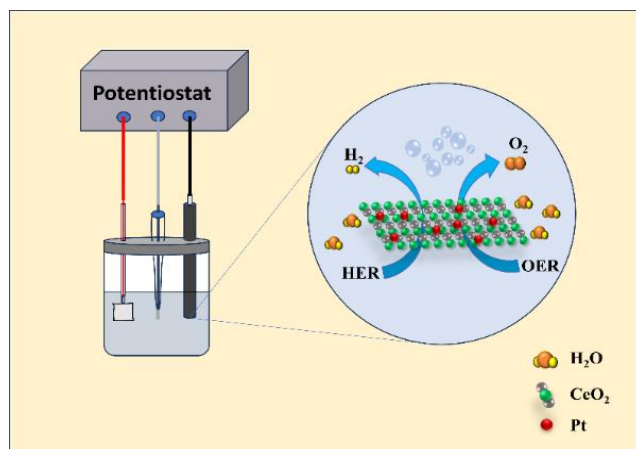


Figure 1. Graphical abstract.

Development of MOF-derived $\text{Mn}_2\text{O}_3/\text{t-ZrO}_2$ Decorated on $\text{g-C}_3\text{N}_4$ Nanosheets Modified Flexible Electrode for Electrochemical Quantification of Butylated Hydroxyanisole in Food Products

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The widespread incorporation of synthetic preservatives in processed foodstuffs necessitates vigilant monitoring to safeguard consumer health. Butylated hydroxyanisole (BHA), while effective as an antioxidant, poses toxicological concerns when present beyond permissible limits. This investigation presents the fabrication of a flexible electrochemical sensing platform based on a screen-printed carbon electrode (SPCE) modified with a ternary nanocomposite comprising manganese oxide (Mn_2O_3) and tetragonal zirconia (t-ZrO_2) derived from bimetallic metal-organic framework (MOF), integrated with graphitic carbon nitride ($\text{g-C}_3\text{N}_4$) nanosheets (Figure 1). The $\text{g-C}_3\text{N}_4$ component was synthesized through thermal polycondensation of melamine, while the MnZr-based MOF precursor was prepared via hydrothermal route followed by controlled calcination at 400 °C to yield the $\text{Mn}_2\text{O}_3/\text{t-ZrO}_2$ heterostructure. The subsequent ultrasonication process facilitated homogeneous dispersion of the oxide phases onto the carbon nitride matrix. Comprehensive physicochemical characterization employing X-ray diffraction, attenuated total reflectance-Fourier transform infrared spectroscopy, and X-ray photoelectron spectroscopy confirmed the successful formation of the composite with preserved crystal phases and favorable interfacial interactions. Microscopic investigations revealed rhombus-like oxide nanoparticles intimately anchored on wrinkled, porous $\text{g-C}_3\text{N}_4$ layers, providing abundant electroactive sites and enhanced surface area. Voltammetric assessment demonstrated that the $\text{Mn}_2\text{O}_3/\text{t-ZrO}_2@ \text{g-C}_3\text{N}_4$ modified electrode exhibits remarkable electrocatalytic activity toward BHA oxidation under physiological pH conditions through a diffusion-governed process. Under optimized parameters, the developed sensor displayed an extensive linear range from 0.1 to 1400 μM , with a detection limit of 150 nM. The platform exhibited exceptional operational stability, satisfactory reproducibility with relative standard deviation below 5%, and remarkable selectivity against common interfering species. Practical applicability was validated through successful recovery experiments in diverse food matrices, establishing the proposed sensor as a reliable, economical tool for routine quality assessment in food safety monitoring applications.

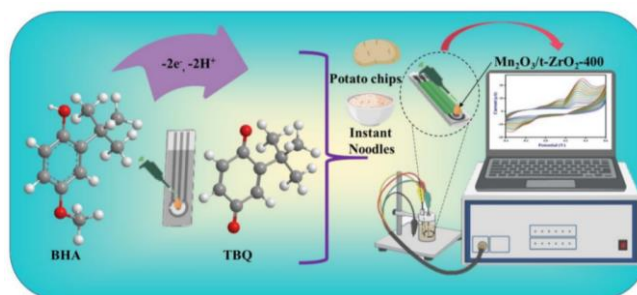


Figure 1. Graphical abstract.

PP-100

A Novel Azide-linked Defective Dicubane Tetranuclear Ni(II) Cluster with High Catalytic Activity and Stability Toward the Hydrogen Evolution Reaction

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The design of efficient, environmentally benign, long-lasting, and sustainable electrocatalysts for water splitting is essential for the progress of renewable energy systems, especially considering the continued reliance on fossil fuels that leads to energy shortages and serious environmental harm. In this work, a centrosymmetric tetranuclear nickel(II) cluster with a rare end-on azide-bridged motif was synthesized via a simple slow-evaporation method. The complex, formulated as [C₄₂H₅₀Ni₄N₁₆O₁₀], features a defective dicubane Ni₄N₄O₂ core in which each nickel ion is hexacoordinated. Single-crystal X-ray diffraction analysis shows that the compound crystallizes in the orthorhombic Pbc_a space group. Each Ni(II) center exhibits a distorted octahedral coordination environment, resulting in a well-defined tetranuclear architecture. Structural analysis further confirms the coexistence of μ_2 -(1,1-azido) and μ_3 -(1,1,1-azido) bridging modes within the cluster. Electrochemical studies reveal that the Ni₄ cluster acts as a highly active and stable electrocatalyst for the hydrogen evolution reaction in 0.25 M acetate buffer at pH 3.8. The catalyst delivers a low overpotential of 287 mV at a current density of 10 mA cm⁻², along with a comparatively large double-layer capacitance of 0.34 mF cm⁻² and a low charge-transfer resistance of 17.6 Ω. Kinetic parameters, including a Tafel slope of 316 mV dec⁻¹, a turnover frequency of 1.82 s⁻¹ at 350 mV, and an exchange current density of 0.002 A cm⁻², indicate satisfactory intrinsic catalytic activity. Furthermore, the electrode demonstrates excellent operational stability, sustaining continuous hydrogen production for over 25 hours at a constant current density of -10 mA cm⁻², while achieving a Faradaic efficiency greater than 92%. Comparative electrochemical analyses confirm that this Ni₄ cluster exhibits enhanced activity, efficiency, and durability for hydrogen evolution, highlighting its promising potential for sustainable energy conversion applications.

Inhibiting Internal Sn²⁺ oxidation in Mixed Pb–Sn Perovskite Films Through Ionic Liquid Passivation

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Metal halide perovskite solar cells (PSCs) have emerged as a leading photovoltaic technology, achieving efficiencies of approximately 27%. However, the environmental impact of lead (Pb) content remains a significant challenge, necessitating the development of lead free/lead-reduced alternatives [1]. While these materials offer a desirable narrow bandgap, they suffer from poor stability due to the rapid oxidation of Sn²⁺ to Sn⁴⁺ which occurs throughout the film [2]. This work demonstrates the synergistic stabilization of mixed Pb–Sn perovskites using 1-butyl-3-methylimidazolium hexafluorophosphate (BMIMPF₆) as an ionic liquid additive. The stabilization mechanism is multi-faceted, wherein the BMIM⁺ cation coordinates with undercoordinated Sn²⁺ and Pb²⁺ ions, while the PF₆⁻ anion provides ionic shielding at grain boundaries and passivates tin vacancies. Furthermore, the hydrophobic nature of the BMIMPF₆ effectively blocks the diffusion of moisture and oxygen into the perovskite lattice. UV-Vis spectroscopy and Tauc plot analysis reveals a narrow bandgap of 1.25 eV, enhancing near-infrared light absorption. X-ray diffraction (XRD) analysis verified the formation of phase-pure perovskite films with improved crystallinity and strong structural integrity. The films also exhibited excellent thermal stability, as evidenced by the unchanged XRD patterns after aging at 85 °C. FTIR spectroscopy revealed clear chemical interactions between BMIMPF₆ and the perovskite film, indicating effective defect passivation. X-ray photoelectron spectroscopy (XPS) results show a significant suppression of the Sn⁴⁺ peak, confirming that the ionic liquid effectively inhibits tin oxidation. Moreover, the surface hydrophobicity was notably enhanced, as confirmed by the higher contact angle, demonstrating reduced hydrophilic character and improved resistance to moisture-induced film degradation. Overall, the incorporation of BMIMPF₆ delivers comprehensive improvements in the structural, optical, chemical, and environmental stability of mixed Pb–Sn perovskite films, providing a viable pathway towards high-efficiency, lead-reduced solar cells.

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Heterostructured CdS/WO₃/CoNb₂O₆ Visible-Light-Responsive Photocatalyst for High-Efficiency Solar Hydrogen Generation

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Sustainable Development Goals emphasise the urgent need to reduce dependence on fossil fuels by promoting environmentally friendly and renewable energy technologies. Fossil fuels, which currently account for the majority of the global energy supply, are not only finite but also significant contributors to greenhouse gas emissions and climate change. To address these challenges, the scientific community is increasingly focused on harvesting solar energy, which is both abundant and inexhaustible. Currently, only about 0.1% of the vast solar energy is harnessed for human use. So, a portion of that solar energy is being utilized to convert water into green hydrogen and is adopted as a promising strategy for harnessing renewable energy sources as it offers an energy-efficient approach. However, its practical application is hindered by major challenges such as low quantum efficiency, rapid charge carrier recombination, poor photocatalyst stability, and difficulties in large-scale implementation. To address these limitations, we developed a ternary composite photocatalyst system based on Cadmium Sulphide (CdS), Tungsten Trioxide (WO₃), and Cobalt Niobate (CoNb₂O₆). The CdS with a band gap of 2.2 eV, enables visible light absorption but suffers from photocorrosion. While, integrating with the WO₃ (band gap -2.6 eV) improves charge separation and stability through the formation heterostructure, achieving a hydrogen evolution rate of 79 mmol/h/g_{cat} with improved solar to hydrogen conversion efficiency. To further boost photocatalytic performance a low-cost CoNb₂O₆ (band gap of 2.5 eV) was synthesized hydrothermally and integrated into the system. The incorporation of CoNb₂O₆ enhanced charge carrier dynamics and broadened solar light utilization, resulting in a significant increase in hydrogen production efficiency. The strategic synthesis, structural and optical characterization, and photocatalytic evaluation of the CdS/WO₃/CoNb₂O₆ heterostructure, and scaling-up of hydrogen production will be discussed.

PP-103

Interface-engineered CdS/WO₃/NiNb₂O₆ Ternary Nanocomposite as a Visible-light-active Photocatalyst for Laboratory-scale to Large-scale Hydrogen Production

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Solar-driven hydrogen generation via photocatalytic water splitting is a straightforward and environmentally benign strategy for a sustainable hydrogen production. In this study, we developed a NiNb₂O₆-based ternary nanocomposite integrated with a CdS/WO₃ system to enhance photocatalytic hydrogen production, spanning from laboratory-scale investigations to large-scale demonstration. NiNb₂O₆, with a narrow band gap of ~ 2.2 eV and a 2D sandwich-like layered structure, exhibits excellent chemical and thermal stability, making it well-suited for visible-light-driven photocatalytic hydrogen production. CdS and WO₃ possess band gaps of ~ 2.21 eV and ~ 2.64 eV, respectively, which further contribute to their visible-light activity. The interface-engineered CdS/WO₃/NiNb₂O₆ ternary-nanocomposite exhibited significantly enhanced hydrogen evolution under both xenon lamp irradiation and natural sunlight. The optimized composition of CdS/WO₃/NiNb₂O₆ achieved a peak hydrogen evolution rate of 67.4 mmol/h/g_{cat}, along with outstanding stability over 4 consecutive days. This improved performance is attributed to the formation of a multi-heterostructure that facilitates efficient spatial charge separation across the distinct morphologies of the composite and enhances stability, as evidenced by VB-XPS analysis, UV-DRS measurements, and post-characterizations. To assess practical applicability, the system was further demonstrated using an indigenously developed photoreactor, under direct sunlight, achieving a hydrogen production rate of 151.8 mmol/h/g_{cat}, thereby demonstrating its potential for scalable hydrogen production. The detailed material synthesis, characterization, and photocatalytic performance will be discussed.

PP-104

Enhanced Hydrovoltaic Energy Conversion *via* Optimized Tubular MnO₂-activated Carbon Composites

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Recently, hydrovoltaic energy harvesting has emerged as a sustainable approach to convert water-solid interfacial interactions into usable electricity under ambient conditions. A systematic study

conducted here led to the fabrication and optimization of a tubular hydrovoltaic device composed of manganese dioxide (MnO_2) and activated carbon (AC) to enhance energy conversion efficiency. New insights into the structural and morphological characterizations, adapted to the hydrovoltaic mechanism, confirmed the uniform integration of crystalline MnO_2 within the activated carbon matrix, providing both hydrophilicity and a high surface area for effective water transport and electrokinetic activity. Justifying the critical role of physical dimensions, device geometry was first optimized using silicone tubes of varying lengths (2 cm, 3.5 cm, and 5 cm), in that the 3.5 cm device exhibited the most favorable balance between capillary-driven water flow and evaporation, thereby enabling continuous hydration-evaporation cycles and stable ion migration. In-depth tuning of the MnO_2 /AC ratio established that the 3:1 composition achieved the highest open-circuit voltage (1.12 V) and short-circuit current (0.19 mA), producing a peak power of 56 μW by leveraging the uniform MnO_2 dispersion within the AC framework to promote efficient electrical double layer (EDL) formation and sustained ion gradient establishment. The device demonstrated long-term operational stability over three months, scalability through series connections (up to 2.58 V with three devices), and practical utility by successfully charging capacitors of various capacitances and powering an LED. Highlighting the synergistic role of MnO_2 and AC in advancing hydrovoltaic energy harvesting, these findings bridge a critical gap in the application of composite materials, underscoring their promise for self-powered and sustainable electronic applications.

PP-105

Heterostructured Nanocomposites of BiFeO_3 - TiO_2 for Enhanced Photocatalytic Hydrogen Evolution

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Escalating consumption of fossil fuels poses dual threats of environmental pollution and an impending energy crisis. Efficient utilization of solar energy offers a viable pathway to mitigate fossil fuel dependence. A sustainable method for harnessing solar energy is photocatalytic hydrogen production, as it produces clean fuels and helps remediate environmental pollutants. It solely depends on sunlight and water. For water splitting, the photocatalyst must possess suitable band edge positions for hydrogen and oxygen evolution. In photocatalytic water splitting, a semiconductor absorbs photons with energy equal to or greater than its bandgap, exciting electrons from the valence band to the conduction band. These charge carriers then migrate to the photocatalyst surface, where electrons reduce protons (H^+) to hydrogen gas (H_2), and holes oxidize water to oxygen gas. However, practical application is limited by intrinsic drawbacks of photocatalysts, such as rapid charge recombination, poor light absorption, photo-corrosion, and low solar-to-hydrogen efficiency. Titanium dioxide (TiO_2), a widely studied stable photocatalyst, is often enhanced by co-catalyst loading, heterostructure formation, and doping to improve hydrogen production rates. Bare TiO_2 ,

initially prepared via hydrothermal synthesis followed by a calcination route, exhibits an H₂ evolution rate of 3.9 mmol/h/g_{cat}. To further improve the charge-transfer efficiency, BiFeO₃, a visible-active material synthesized through a modified Pechini route, was used to form heterostructures. It has a more negative conduction band edge compared to TiO₂, which favours H₂ production. To optimize the mass-loading effect, TiO₂ nanocomposites with tunable mass ratios of BiFeO₃ were prepared via impregnation. The optimized 10 wt.% BiFeO₃-loaded TiO₂ shows a maximum H₂ evolution rate of 70 mmol/h/g_{cat}. The structural, optical, and electronic properties were supported by various analytical tools, which confirmed the formation of BiFeO₃/TiO₂ heterostructure. The detailed synthesis strategy, structural/electronic characterization, and mechanistic insights into charge-transfer dynamics will be presented.

PP-106

Composition-Regulated Electronic Reconstruction in NiFe Hydroxide Heterointerfaces for Efficient Alkaline Oxygen Evolution Reaction

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The rational design of high-performance oxygen evolution electrocatalysts requires precise control over electronic structure and intrinsic reaction kinetics. Although NiFe layered hydroxides are among the most promising non-precious catalysts, establishing a clear composition-activity relationship remains challenging due to competing surface and electronic effects. Herein, we systematically engineer a series of Fe-Ni layered hydroxide heterostructures supported on nickel foam to elucidate the intrinsic role of Fe/Ni compositional modulation in alkaline OER. A controlled compositional series including Ni/Ni(OH)_x-NF, Fe(OH)_x-NF, FeNi₅/Ni(OH)_x-NF, FeNi₃/Ni(OH)_x-NF, FeNi/Ni(OH)_x-NF, and Fe₂Ni/Ni(OH)_x-NF was synthesised, enabling direct comparison of catalytic behaviour. Linear sweep voltammetry revealed a pronounced composition-dependent activity evolution, with FeNi₃/Ni(OH)_x-NF delivering the optimal performance among all investigated samples. Tafel analysis further demonstrates accelerated charge-transfer kinetics and favourable OER reaction pathways for the optimised composition. Electrochemical double-layer capacitance measurements were conducted to evaluate the electrochemically active surface area, and intrinsic activity normalisation confirms that the superior performance of FeNi₃ does not originate from surface area enhancement. Instead, the activity follows a volcano-type dependence on Fe fraction, highlighting a balanced electronic reconstruction effect induced by moderate Fe incorporation. At low Fe content, insufficient electronic perturbation limits catalytic activation, whereas excessive Fe incorporation dilutes active Ni centres and weakens synergistic interactions. The optimised FeNi₃ composition achieves a favourable electronic configuration that promotes Ni²⁺/Ni³⁺ redox transitions and optimises the adsorption energetics of oxygenated intermediates, thereby minimising reaction barriers. Long-term stability tests demonstrate negligible potential decay, confirming robust structural integrity under alkaline conditions. Moreover, when implemented in a two-electrode alkaline water electrolyser configuration, the optimised catalyst exhibits efficient overall water-splitting performance, underscoring its practical applicability.

PP-107

Defect-induced Electronic Modulation in Mo-substituted Double Perovskites for Efficient Bifunctional Water Splitting

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The development of efficient and robust bifunctional electrocatalysts for overall water splitting remains a critical challenge for sustainable hydrogen energy technologies. In this context, perovskite oxides have emerged as promising candidates due to their compositional flexibility and tunable electronic structures. Herein, we report the synthesis and electrochemical evaluation of Mo-substituted Fe-Co-based double perovskites, $A_2\text{Mo}_x\text{Fe}_{0.5-x}\text{Co}_{0.5}\text{O}_6$ ($A = \text{La, Sr}$), designed to investigate the effect of B-site compositional tuning on both the oxygen evolution reaction (OER) and hydrogen evolution reaction (HER). The introduction of high-valence Mo into the B-site lattice induces localized structural distortions and promotes oxygen vacancy formation, which effectively modulates the electronic environment of Fe/Co active centers. Electrochemical investigations in alkaline media demonstrate that the Mo-substituted perovskites exhibit significantly improved catalytic performance, delivers a (HER) overpotential of 240 mV and (OER) overpotential that is 180 mV lower than that of the state-of-the-art RuO_2 benchmark, both measured at a current density of 10 mA cm^{-2} under identical experimental conditions. Electrochemical impedance analyses reflect reduced charge transfer resistance and enhanced electroactive surface area, confirming improved intrinsic charge transfer kinetics. The catalysts further deliver excellent operational stability over prolonged electrolysis, and specifically validates the catalyst efficacy for high-performance OER. This work highlights the effectiveness of targeted B-site engineering in perovskites as a viable strategy to develop cost-effective, earth-abundant, and high-performance bifunctional electrocatalysts for overall water splitting.

PP-108

Unraveling the Synergistic Effect of Ionic Liquid AMIM-TFSI on the Structure and Performance of Triple-cation Perovskite Solar Cell

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Triple-cation perovskite solar cells (PSCs) have achieved impressive power conversion efficiencies, yet their practical deployment remains hindered by defect-induced nonradiative recombination and insufficient operational stability. Here, we report a multifunctional stabilization strategy employing the ionic liquid 1-allyl-3-methylimidazolium bis(trifluoromethanesulfonyl)imide (AMIM-TFSI) to simultaneously regulate crystallization, passivate defects, and enhance the intrinsic stability of $\text{Cs}_{0.05}\text{FA}_{0.81}\text{MA}_{0.14}\text{PbI}_{2.55}\text{Br}_{0.45}$ perovskite films. AMIM-TFSI incorporation yields improved morphology with enlarged grains and enhanced crystallinity without altering the perovskite bandgap. Fourier-transform infrared spectroscopy reveals successful ionic liquid integration through characteristic imidazolium and TFSI⁻ vibrational signatures, while X-ray diffraction confirms reduced lattice disorder at optimal concentrations. Photoluminescence analyses demonstrate that AMIM-TFSI effectively suppresses nonradiative recombination via hydrogen-bonding interactions and Pb-site passivation, resulting in enhanced PL intensity and prolonged carrier lifetimes. The modified PSCs exhibit superior performance with increased current density, improved fill factor, and reduced hysteresis. Critically, AMIM-TFSI-engineered films show excellent stability under continuous illumination and thermal aging at 85 °C, highlighting the ionic liquid effectiveness in mitigating degradation pathways. This work provides mechanistic insights into ionic liquid-perovskite interactions and establishes AMIM-TFSI as an effective multifunctional additive for developing stable and high-performance triple-cation perovskite solar cells.

PP-109

Mechanistic Insights into Transient Potential Oscillations during Cobalt Electrodeposition *via* Plasmon-enhanced *In Situ* Raman Spectroscopy

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Electrodeposition of cobalt plays a vital role in the fabrication of precise thin films with controlled thickness and uniform morphology, which are essential for advanced applications, including microelectronics, magnetic devices, and energy storage systems. The quality and performance of these films can be significantly improved by incorporating organic additives such as propargyl alcohol, 1,4-butanediol, and L-cysteine, which regulate nucleation, modify surface characteristics, and enhance overall film integrity [1]. However, during cobalt electrodeposition, transient potential oscillations frequently occur, influencing the electrochemical pathways and growth behavior of the deposited films [2]. A thorough understanding of these oscillations is crucial, as they directly impact film morphology and functional properties. In this work, symmetrical damped potential oscillations were observed during galvanostatic cobalt deposition in the presence of propargyl alcohol. To investigate the underlying mechanisms, time-resolved *in situ* shell-isolated nanoparticle-enhanced

Raman spectroscopy (SHINERS) was employed. This highly sensitive spectroelectrochemical technique enables real-time monitoring at subsecond temporal resolution, providing detailed insights into transient interfacial processes at the electrode–electrolyte interface (Figure 1). The information obtained from SHINERS provides a deeper understanding of the reaction dynamics governing cobalt electrodeposition, which will be further analyzed and discussed in light of the experimental findings.

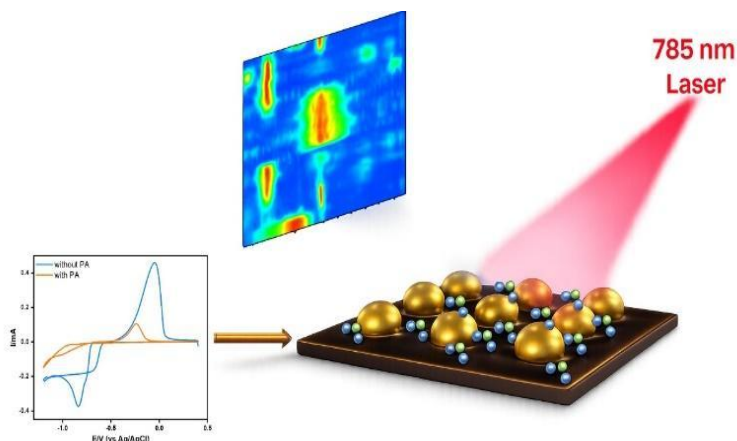


Figure 1. Representation on in situ Raman Spectral and electrochemical analysis of cobalt deposition.

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PP-110

Systematically Engineered Peroxidase-mimicking Nanoceria as Nanozyme for Electrochemical Detection of H₂O₂

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Nanozymes, a class of nanomaterials, have emerged as a robust alternative for the natural enzymes owing to the intrinsic catalytic activity, superior stability, and cost effectiveness. Several materials such as metal and metal oxide nanoparticles, carbon materials and metal organic frameworks (MOFs) are reported for their ability to act as these enzyme mimetics. Among them, MOFs known for their

highly porous nature with large surface area and excellent structural tuneability serve as a versatile precursor for the synthesis of metal and metal oxide nanoparticles. Herein, nanoceria (CeO_2 NPs) were obtained by calcination of a cerium-based metal organic framework (Ce-BTC MOF). Precisely, Ce-BTC MOF was synthesized via reflux condensation and the obtained MOF was subjected to calcination at $550\text{ }^\circ\text{C}$ to attain the CeO_2 NPs. The formation and structural characteristics of synthesized CeO_2 NPs were confirmed using spectroscopic and microscopic techniques, which prove that the as-synthesized CeO_2 NPs exhibit high surface area and abundant oxygen vacancies. This results in an increased number of active sites, which in turn enhances the catalytic efficiency of CeO_2 NPs and capability to scavenge reactive oxygen species. The enzyme mimicking activity of the MOF derived CeO_2 NPs was confirmed by the oxidation of the chromogenic substrate 3,3',5,5'-tetramethylbenzidine (TMB) in the presence of H_2O_2 using UV-Visible spectroscopy. The CeO_2 NPs nanozyme was utilized for the amperometric detection of H_2O_2 , where it demonstrated a good linear range and a very low detection limit. The fabricated sensor was also employed towards the detection of H_2O_2 in real samples, where it showed good recovery results.

PP-111

Impact of Additives in Electrodepositing CoNi Bimetallic Microstructures for Oxygen Evolution Reaction

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The growing demand for sustainable energy solutions has intensified interest in water electrolysis, a promising and commercially viable approach for clean hydrogen production. Electrolytic water splitting is gaining attention as a scalable and cost-effective method for generating hydrogen. Among various electrocatalysts, transition metal-based materials, particularly CoNi bimetallic systems, have shown excellent potential for the oxygen evolution reaction (OER) due to their abundance, tunable properties, and catalytic efficiency. CoNi-based materials have also been identified as stable and efficient catalysts for the OER in alkaline media. Electrodeposition, a highly versatile and scalable fabrication technique, enables the fabrication of binder-free, nanostructured electrodes with precise control over morphology and crystallinity. In this study, CoNi bimetallic films were obtained via potentiostatic electrodeposition, enabling the formation of binder-free, nanostructured electrodes with controlled morphology. The incorporation of additives in the electrolyte bath played a crucial role in regulating surface roughness and improving film quality. The presence of surfactants and additives in the electrolyte bath played a key role in optimizing the deposition process and improving the quality of the resulting bimetallic films. The additive has been used to control the surface roughness and texture of the CoNi layers. Furthermore, the synergistic interaction between cobalt and nickel enhanced the electrocatalytic performance. Overall, additive-assisted electrodeposited CoNi bimetallics demonstrate promising electrocatalytic activity toward OER in alkaline media.

Harmonizing Molecular Design and Interfaces for Efficient Organic Thermoelectrics

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To meet growing global energy demands, it is essential not only to develop alternative energy sources but also to utilize existing energy more efficiently. Heat is the most abundantly wasted form of energy, released from industrial processes, transportation, and everyday electronic devices. Soft organic thermoelectric (OTE) materials have emerged as promising candidates for harvesting low-grade heat due to their mechanical flexibility, low thermal conductivity, and compatibility with wearable and conformal surfaces. The efficiency of thermoelectric materials is governed by the dimensionless figure of merit, $ZT = (S^2\sigma T)/\kappa$, where S is the Seebeck coefficient, σ is the electrical conductivity, T is the absolute temperature, and κ is the thermal conductivity. Achieving a high ZT requires the simultaneous enhancement of electrical conductivity and Seebeck coefficient while suppressing thermal conductivity, which remains a fundamental challenge. In this study, functionalized triphenylamine (TPA)-based small molecules and polymers were designed for flexible thermoelectric nanocomposites with SWCNTs (Figure 1). The three-dimensional propeller architecture, electron-donating nature, and structural modulation via aryl substitution and TCNE/TCNQ moieties enable efficient charge transport through π - π stacking and hydrogen bonding. SWCNT incorporation enhances electrical conductivity while maintaining the Seebeck coefficient, and post-deposition ionic liquid (IL) doping introduces additional interfaces that promote energy filtering, suppress low-energy carriers, and decouple conductivity from Seebeck coefficient, leading to improved power factor and overall thermoelectric performance. The pristine SWCNT films exhibit an electrical conductivity of 670 S cm^{-1} and a Seebeck coefficient of $34.7 \text{ } \mu\text{V K}^{-1}$, resulting in a power factor of $79 \text{ } \mu\text{W m}^{-1} \text{ K}^{-2}$. The thermal conductivity is $0.194 \text{ W m}^{-1} \text{ K}^{-1}$, corresponding to a ZT value of 0.123. Incorporation of TPA-based molecules is expected to further enhance the thermoelectric performance, which can be further improved via post-deposition ionic liquid (IL) treatment. The resulting composites will be fabricated into free-standing thin films, and flexible thermoelectric modules will be constructed on suitable substrates to harvest waste heat from any conformal surface.

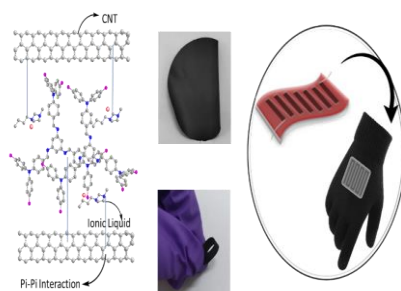


Figure 1. Graphical representation on design of thermoelectric nanocomposite.

PP-113

Designing Co₃O₄ Anchored N-doped Porous Carbon as an Efficient Electrocatalyst for Electroreduction of CO₂ to Multicarbon Products

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Electrochemical CO₂ conversion is promising approach for a sustainable economy which play an important role in lowering CO₂ emissions in various industrial activities. It also provides another way of storing energy from renewable electricity as it converts CO₂ into multicarbon products. In addition, such methodologies provide enormous possibility of large-scale chemical production along with concomitant decrease in carbon footprint such area increases significant research and commercial interest. In this work, we developed a catalyst through hard template method where Co₃O₄ anchored in Nitrogen-doped porous carbon is produced with good yield. This material achieved multicarbon products like Methanol, Acetate and Ethanol of Faradic Efficiency 12%, 16% and 20% respectively, under current density of 7 mA cm⁻² in 0.5 M KHCO₃ electrolyte. From NMR, FESEM and XPS analysis, we have found that the mixture of product is due to synergistic electronic interaction between graphitic and pyridinic nitrogen species. It enriches the local CO₂ concentration near the electrode surface and also lowering the CO dimerization barrier, which is challenging due to high energy barrier and stabilize the intermediates like *CO and *CHO.

PP-114

Synergistic Phase Conversion and Interface Engineering of MoS₂ via Cation Intercalation on N, S-Doped Hollow Carbon Spheres for Efficient Hydrogen Evolution

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Molybdenum disulfide (MoS₂) has emerged as an attractive electrocatalyst for the hydrogen evolution reaction (HER); however, its intrinsic semiconducting 2H phase and the scarcity of exposed active sites limit catalytic efficiency. Herein, we report an in-situ dual-modulation approach to address these

challenges by concurrently engineering both the phase and interfacial structure of MoS₂. Phase-modified MoS₂ hollow spheres were prepared via a controlled hydrothermal route, in which NH₄⁺ ions and N, S-doped hollow carbon worked synergistically to induce and stabilize the 2H→1T phase conversion. The heteroatom-enriched carbon scaffold improved electrical conductivity, preserved the metallic 1T phase, and facilitated rapid electron transport, while also serving as a high-surface-area substrate to ensure uniform dispersion of MoS₂ nanosheets. Through careful control of heteroatom content and optimization of the MoS₂–intercalant ratio, the catalyst achieved enhanced charge-transfer dynamics and a greater density of electrochemically available active sites. Consequently, the optimized catalyst delivered remarkable HER activity, requiring an overpotential of only 184 mV to achieve 10 mA cm⁻² in acidic medium, along with excellent durability over 72 h of continuous operation. Comprehensive structural and electrochemical investigations uncover the superior performance originates from the combined effects of phase transformation and improved stability arising from strong interfacial interactions with the doped carbon network. This study offers a practical and scalable strategy for developing efficient and economical MoS₂-based electrocatalysts for clean hydrogen generation.

PP-115

Eco-Friendly Halogen-free Coatings for Fire Mitigation in Cotton Fabrics

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The global ban on halogenated flame retardants has accelerated the development of non-toxic alternatives for cotton, which is inherently flammable due to its low Limiting Oxygen Index (LOI). This work introduces an environmentally benign coating that enhances cotton's fire resistance through a phosphorus-nitrogen (P–N) synergistic effect (Figure 1). The treated fabric operates via a dual-action mechanism: in the condensed phase, phosphorus promotes a protective char layer that restricts oxygen access, while in the gaseous phase, nitrogen releases non-flammable gases like ammonia to dilute volatile combustibles. This synergistic approach resulted in a significant LOI value of 36.5% and demonstrated robust self-extinguishing behavior during vertical flammability tests. Ultimately, this P–N based coating offers a high-performance, eco-friendly solution to suppress combustion and improve the safety profile of cotton fabrics.

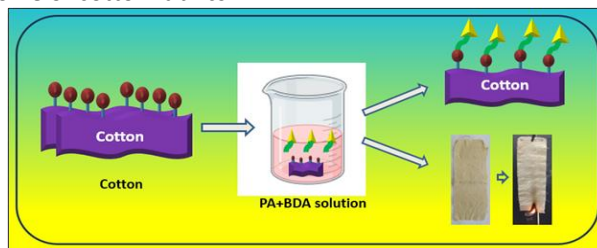


Figure 1. Schematic for coating P-N based coating.

PP-116

Nickel Selenide/rGO Composite Electrodes for Supercapacitor Application

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As the demand for efficient and sustainable energy increases, energy storage devices have gained more attention. This work focuses on the development of rGO-incorporated nickel selenide composite electrodes for positive electrodes in asymmetric supercapacitor applications. Nickel selenide was chosen as the active material because of its high theoretical capacity, multiple oxidation states, and high conductivity compared to other oxides in an alkaline medium. Composites were synthesized with varying rGO concentrations (0-1 wt %) to further enhance conductivity and stability. The electrochemical performances were evaluated in a three-electrode setup in an alkaline medium. A specific capacity of ~ 200 mAh g⁻¹ was observed for the optimized electrode in a half-cell configuration. Further, an asymmetric capacitor was fabricated with this optimized electrode as the positive electrode and activated carbon as the negative electrode. It exhibited enhanced electrochemical performance, with high power density and excellent cycling stability. Hence, these results clearly demonstrate that the fabricated asymmetric supercapacitor with the optimized rGO weight percentage in nickel selenide exhibits strong potential for practical energy storage applications.

PP-117

Near-Infrared Cyanine Dye-driven Crystallization Control and Grain-boundary Passivation in Triple-cation Perovskite Solar Cells

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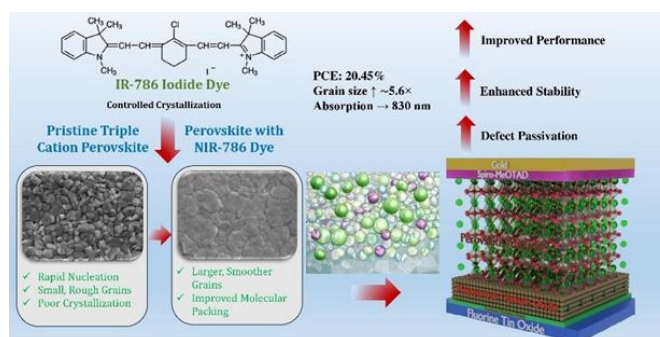
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Metal halide perovskite solar cells have achieved remarkable evolution in the photovoltaic industry. The trap states at the surface and grain boundaries of perovskite films are major bottlenecks to device performance. Herein, we introduced NIR dye (IR-786) molecules as multifunctional defect-passivating

additives within a perovskite precursor system. The dye's delocalized π -conjugated structure and ionic functional groups promote strong interactions with under-coordinated $\text{Pb}^{2+}/\text{I}^-$ surface sites, thereby reducing deep-level trap states and encouraging uniform grain growth. The NIR dye molecule forms a perovskite–dye complex in the precursor solution, promoting larger grain growth and improved film crystallinity by slowing the crystallization process. XRD and FTIR analyses confirm that the NIR dye molecules are not incorporated into the perovskite crystal lattice but are localized at the film surface and grain boundaries. Furthermore, the light absorption of the perovskite film with the NIR Dye was in the NIR region, which is beneficial for photocurrent enhancement. The devices with the dye additive achieved a power conversion efficiency of 20.4%, surpassing the control device (14.58%) and demonstrating improved stability for over 30 days. This study demonstrates that organic dye molecular engineering is a feasible method for improving the performance and stability of perovskite technologies.



hydrovoltaic devices are particularly noteworthy, as they mimic earth's natural water cycle to transform ambient thermal energy into electricity. This approach has garnered significant attention for its potential to power self-sustaining systems, particularly in remote or off-grid locations, where low-energy devices can operate independently of external power sources. Recent advancements in hydrovoltaic energy harvesting emphasise the critical role of material innovation in enhancing conversion efficiency. In this study, commercially available carbon powder was chemically oxidised in acidic medium to tailor its surface properties for improved energy generation. The functionalization process imparted advantageous attributes including increased surface area, enhanced hydrophilicity, superior porosity, and improved wettability, thereby facilitating more effective water absorption and charge generation. The surface modified materials were systematically characterised through various characterisation techniques like XRD, FESEM, FT-IR, XPS and Raman spectroscopy to investigate its crystallinity, morphology, and to analyse surface chemical functionalities. Contact angle measurement was also carried out to further assess its surface wettability. The multipronged design and evaluation strategy underscores the potential of chemically engineered carbon materials in enabling scalable and efficient hydrovoltaic systems. By optimizing water–surface interactions at the nanoscale, this work contributes to the advancement of next-generation energy harvesting platforms that are sustainable, environmentally benign, and adaptable for diverse real-world applications. The findings highlight not only the fundamental material–property relationships critical for hydrovoltaic energy conversion but also the broader role of nanostructured carbon-based systems in shaping the future of renewable energy technologies.

PP-119

Electronic Structure Modulation of Borophene *via* N, S Modification and Iridium Infusion for Superior Oxygen Evolution Reaction

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Borophene, a newly emerging two-dimensional boron allotrope, holds promise for electrocatalysis but suffers from limited conductivity, partial metallicity, and structural instability during the oxygen evolution reaction (OER). In this study, we developed a facile synthesis approach combining heteroatom (N, S) doping and Iridium infusion to engineer borophene nanosheets (Figure 1). The resulting catalysts (BPN, BPNS, BPN–Ir, and BPNS–Ir) exhibited enhanced OER performance, with BPN–Ir and BPNS–Ir achieving the lowest overpotential (278 mV and 281 mV at 10 mA cm⁻²), a Tafel

slope of 83 mV dec⁻¹ and 104 mV dec⁻¹, over multiple trials and excellent durability over 12 hours. These improvements are attributed to electronic structure modulation, increased conductivity, and abundant active sites enabled by synergistic functionalization. This work highlights an industrially efficient synthesis pathway to engineer borophene and provides a doping and functionalisation technique for OER application.

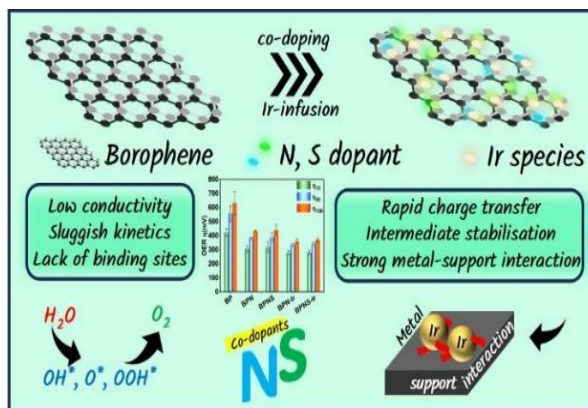


Figure 1 Graphical illustration on synthesis route to engineer borophene with dopants.

PP-120

Design of Sulfonated Polyphenylene Membranes with PTA-encapsulated MOFs for Improved Proton Transport and Stability in Fuel Cells

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The development of high-performance proton exchange membranes (PEMs) is critical for advancing fuel cell technologies. In this work, a novel composite membrane is designed based on sulfonated polyphenylene (SPP) integrated with phosphotungstic acid (PTA)-encapsulated metal-organic frameworks (MOFs) to achieve enhanced proton conductivity and stability (Figure 1). The SPP polymer provides a robust hydrocarbon backbone with excellent chemical and thermal stability, while the incorporation of PTA within the porous MOF structure facilitates efficient proton transport through the formation of continuous proton-conducting pathways. Encapsulation of PTA inside the MOF matrix effectively mitigates its leaching, a common limitation in heteropolyacid-based systems, thereby improving long-term durability. The resulting composite membranes are systematically characterized for their physicochemical, thermal, and electrochemical properties. The synergistic

interaction between SPP and PTA@MOF significantly enhances proton conductivity under varying humidity conditions while maintaining dimensional and mechanical stability.

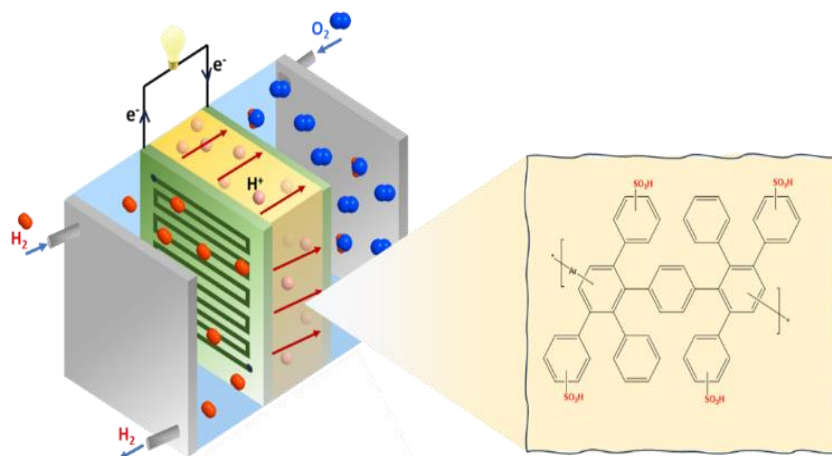


Figure 1. Hydrocarbon based Polymer electrolyte membrane Fuel cell.

PP-121

Judiciously Designed Pd-doped Ni₃S₂ Electrocatalyst towards Efficient Electrocatalytic Oxidation of Methanol

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Fuel cells convert chemical energy to electrical energy, which can be utilized to overcome the worldwide energy demand. The development of a highly efficient electrocatalyst with stable performance on the anodic side of a direct methanol fuel cell (DMFC) remains a significant challenge. Palladium (Pd)-based electrocatalysts have gained huge attention in electrochemical studies, since their electrochemical performance is similar to platinum, which is considered the state-of-the-art electrocatalyst. Herein, we followed a two-step synthesis method to reduce the consumption of noble metal and cost. Initially, Ni₃S₂ was synthesized in-situ on nickel foam (NF) hydrothermally, followed by the electrochemical deposition of Pd metal to enhance the electrochemical performance. The obtained Pd/Ni₃S₂/NF was utilized as an electrode towards MOR, and other electrodes, viz., Pd/NF and Ni₃S₂/NF was also synthesized for comparison. The prepared electrocatalytic materials were thoroughly characterized using different spectroscopic and microscopic studies. The electrocatalytic activities of the synthesized materials were examined by cyclic voltammetry. Further, the

electrochemical resistance and stabilities of the fabricated electrodes towards oxidation of methanol in alkaline media were measured using electrochemical impedance spectroscopy, and chronoamperometry measurements, respectively. The obtained results show that Pd/Ni₃S₂/NF exhibits higher stability and greater activity, which could be due to the high active surface area that facilitates the ion transport during MOR.

PP-122

Highly Durable Partially Fluorinated Anion Exchange Membrane *via* Free Radical Polymerisation Approach

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Hydrogen is considered to be the promising energy vector and water is regarded as a long-term source for hydrogen generation due to its widespread availability. Anion exchange membrane water electrolyser (AEMWE) has the advantages of both alkaline and PEM electrolysis, however, it is still in its premature stages of development. AEM is composed of a polymer backbone with cationic groups that are anchored and provide anionic conduction with selectivity. The anion exchange group is typically made up of quaternary ammonium salts and it can be connected to the expanded side or the main chain of the backbone. The chemical and physical stability of the membrane is enhanced by cross-linking the polymer units. This cross-linked structure improves both ionic conductivity and overall stability of the AEM. This work mainly discusses the synthesis of AEM membranes using fluorocarbon and aromatic hydrocarbon moieties in the polymer backbone via free radical polymerization and further characterization (structural, morphological and physicochemical) using various analytical techniques. The optimized anion exchange membrane, prepared with an appropriate ratio of anion exchange polymer (partially Fluorinated) with PVDF exhibited a high ionic conductivity of $1.0 \times 10^{-2} \text{ S cm}^{-1}$ and an ion exchange capacity of 1.7 mmol g^{-1} .

PP-123

Hydroxyl-functionalized C_3N_5 as a Surface-engineered Electrocatalytic Platform for Detection of Antimony in Occupational Biomonitoring

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Antimony (Sb) is extensively used in industrial processes such as plastic manufacturing and flame-retardant production, leading to potential occupational exposure. Chronic Sb exposure has been associated with respiratory irritation, pneumoconiosis, cardiovascular effects, gastrointestinal disturbances, and potential carcinogenicity. Monitoring Sb levels in biological fluids such as urine or blood is therefore essential for effective occupational biomonitoring. Urinary Sb concentrations in the general population are typically below 1 $\mu\text{g/L}$, while levels exceeding 5 $\mu\text{g/L}$ have been associated with occupational exposure. In this study, a stripping voltammetric electrochemical sensor based on hydroxyl-functionalized C_3N_5 was developed for the ultra-trace detection of Sb (III). C_3N_5 , a nitrogen-rich graphitic carbon nitride framework, provides abundant coordination sites, high surface area, and enhanced electron transport, enabling improved adsorption and electrocatalytic performance compared to conventional carbon materials. The synthesized $C_3N_5\text{-OH}$ was characterized using FESEM, XRD, ATR-FTIR, TGA, and BET analysis. Electrochemical parameters, including supporting electrolyte pH, deposition time, and stripping potential, were systematically optimized. Under optimized conditions, the sensor exhibited a well-defined stripping response with good linearity. The calculated limit of detection was 0.159 nM (0.019 $\mu\text{g/L}$), significantly lower than biologically relevant exposure levels. These findings demonstrate the potential of $C_3N_5\text{-OH}$ for sensitive Sb detection in occupational biomonitoring applications.

PP-124

Interfacial Charge Modulation in Sputtered $\text{CuO-Al}_2\text{O}_3$ Bilayer Thin Films for Enhanced Formaldehyde Sensing

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Formaldehyde is a vital chemical compound widely used in household products, laboratories, and industrial settings. Prolonged exposure to formaldehyde gases poses serious health risks, including

respiratory disorders and even carcinogenic effects [1]. Therefore, developing a reliable and high-sensitivity sensor to detect formaldehyde gases at low ppm levels ensures safety in various environments [2]. In this study, CuO-Al₂O₃ thin film electrodes were fabricated using the reactive DC magnetron sputtering method to investigate the capability to detect formaldehyde gas efficiently. Identification and the structural characterization of the fabricated CuO-Al₂O₃ film was analyzed using X-ray diffraction. The results confirmed the presence of a monoclinic crystalline structure for CuO and a hexagonal crystalline structure for Al₂O₃. Scanning electron microscopy images of the fabricated sensing electrode showed a highly porous surface morphology. The porous nature of the material is advantageous for gas sensing applications, as it increases the surface area, thereby allowing more gas molecules to be adsorbed. The selectivity test for the CuO-Al₂O₃ electrode was evaluated using five different volatile organic compounds (VOCs) at a constant concentration of 50 ppm. Initially, five different VOC gases were tested. The sensor exhibited a strong and specific response to formaldehyde compared to the other VOC gases, indicating its good sensing response and recovery. Furthermore, gas sensing experiments were performed at different operating temperatures, from 25-100 °C. The study also examined various concentrations of formaldehyde gas, ranging from 5 to 150 ppm. The results demonstrated that the sensor exhibited a rapid response, recovery, and high sensitivity across the various concentration ranges, with enhanced response at higher temperatures due to increased molecular interaction and diffusion. In addition to its high sensitivity and selectivity, the sensor demonstrated remarkable stability and repeatability over multiple testing cycles.

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PP-125

In-situ Growth of Binder-free NiCoP Nanosheets: A Two-way Strategy for Electrocatalytic Hydrogen Evolution Reaction (HER)

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The pursuit of efficient, stable, and self-supported electrocatalysts derived from earth-abundant non-noble metals through simple and scalable synthesis routes remains a critical challenge for efficient water electrolysis driven hydrogen generation. Herein, a two-way strategy, hydrothermal method followed by low temperature phosphorization method to synthesize a series of highly active and robust bimetallic nickel cobalt phosphide nanosheets (NiCoP NSs) thin film electrodes. Among various

conductive substrates, stainless steel (SS) has garnered significant attention as an electrode for energy conversion applications. Binder-free bimetallic nickel cobalt phosphide electrocatalyst grown on a SS conductive substrate (NiCoP/SS) to decrease the overpotential and shows high-performance and stable electrocatalysts in alkaline media for hydrogen evolution reaction (HER). The (NiCoP NSs/SS@8) electrocatalyst achieves a low overpotentials of 99 mV and at 10 mA cm⁻² current density in 1 M KOH and Tafel slope of 58 mV dec⁻¹ electrolyte for driving HER, a relatively large electrochemical active surface area (ECSA), small charge transfer resistance, and sustained operational stability exceeding 20 hours at ambient temperature. This work opens up a simple and new way of constructing low-cost, efficient, and applicable for self-supported electrocatalytic HER.

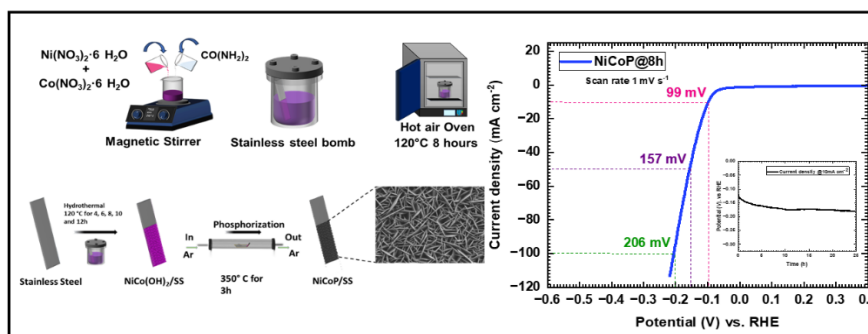


Figure 1. Synthesis of bimetallic nickel cobalt phosphide nanosheets and its electrocatalytic performance.

PP-126

Beyond Octahedral and Tetrahedral: Unprecedented Coordination Motifs in Vacancy-engineered LLZO Revealed by DFT

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The solid electrolyte Li₇La₃Zr₂O₁₂ (LLZO) is being widely investigated for its high lithium-ion conductivity. In its pristine form (Li₅₆La₂₄Zr₁₆O₉₆, a unit cell of Li₇La₃Zr₂O₁₂ with 8 formula units), Li occupies two coordination sites, such as 24 reside in ideal tetrahedral sites, while 32 in octahedral sites; Zr and La occupy octahedral and dodecahedral sites, respectively. To investigate the influence of vacancy engineering on lithium coordination in LLZO, a Li vacancy was introduced by doping Ta/Nb at Zr site, resulting in the formation of Li₅₅La₂₄Zr₁₅Ta₁O₉₆/Li₅₅La₂₄Zr₁₅Nb₁O₉₆ compositions, correspondingly. Density functional theory (DFT) calculations reveal that the removal of Li from either

tetrahedral or octahedral positions leads to the emergence of unprecedented coordination geometries. When a vacancy is introduced at a tetrahedral Li site, both Ta- and Nb-doped systems exhibit distorted tetrahedra, trigonal bipyramids, and trigonal pyramids. In contrast, a vacancy creation at an octahedral Li site results in new environments such as distorted tetrahedra, octahedra, and trigonal bipyramids. These findings demonstrate that vacancy-dopant interplay can substantially alter local lithium coordination, inspiring the traditional view of fixed geometries in LLZO and opening new paths for structural design in complex oxides.

PP-127

Transition-metal and Graphene-based Electrode Architectures for Direct Bioethanol Fuel Cells Applications

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The development of noble-metal-free electrocatalysts for bioethanol electrooxidation is essential for advancing sustainable bio-ethanol fuel cells (Bio-EFCs) with clean and sustainable energy generation. In this work, two independently fabricated transition-metal electrode systems—graphene oxide-modified nickel mesh (GO@Ni-m50) and copper–cobalt-modified copper foil (Cu–Co@Cu-F)—were developed via electrochemical deposition strategies for efficient biomass-derived bioethanol oxidation in alkaline medium (Figure 1). The GO@Ni-m50 electrode, fabricated through cyclic voltammetric deposition of graphene oxide onto Ni-mesh, delivered a current density of ~ 15.37 mA/cm² at 1 M ethanol in 0.1 M KOH with an onset potential of 0.45 V vs. Hg/HgO. The enhanced performance arises from the synergistic interaction between GO functional groups and the Ni(OH)₂/NiOOH redox couple, leading to reduced charge-transfer resistance ($R_{ct} \approx 4.5$ Ω/cm²), diffusion-controlled kinetics, and stable operation over 50 cycles. A low activation energy of 21.75 kJ/mol confirms favorable reaction kinetics, while density functional theory (DFT) calculations reveal a direct ethanol-to-acetaldehyde oxidation pathway with an adsorption energy of -0.77 eV. Bioethanol synthesized from potato peel waste achieved current densities exceeding 10 mA/cm² validating its applicability in alkaline bioethanol-driven systems. Complementarily, the Cu–Co@Cu-F25 electrode synthesized via chronoamperometric electrodeposition (shorter deposition time) exhibited a current density of ~ 21 mA/cm² at 1 M ethanol in 0.1 M KOH with an oxidation potential of 0.4 V. The electrode demonstrated a remarkably low charge-transfer resistance ($R_{ct} = 2.178$ Ω/cm²) and a low activation energy of 22.64 kJ/mol, indicating accelerated interfacial kinetics and efficient redox mediation. The engineered Cu–Co interface promotes Cu(I)/Cu(II) transitions and enhanced hydroxyl adsorption, enabling stable ethanol electrooxidation. Bioethanol derived from overripe banana pulp displayed comparable electrochemical activity, confirming robustness toward biomass-derived fuels. Collectively, these transition-metal-based electrode architectures demonstrate efficient and stable ethanol and bioethanol electrooxidation without reliance on precious metals. By integrating biomass valorization with rational electrocatalyst design and mechanistic understanding,

this work advances scalable and sustainable platforms for next-generation bioethanol fuel cell technologies.

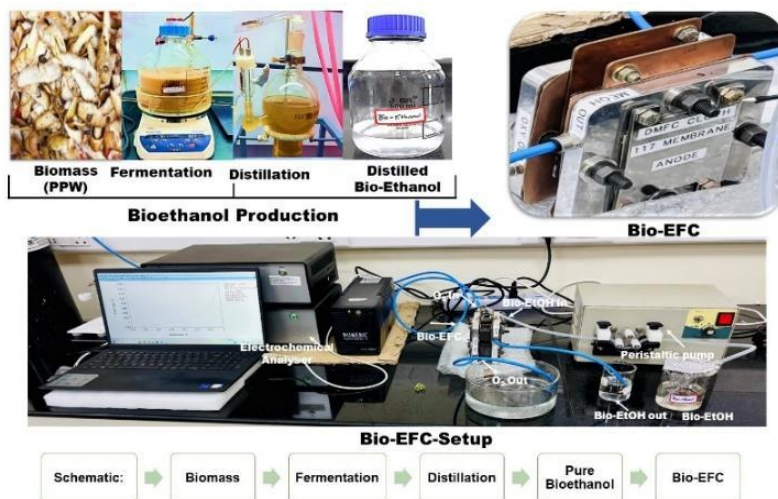


Figure 1. Steps for bioethanol production and its fuel cell setup.

PP-128

Unveiling the Role of the MoN/MoP₂ Heterostructure on the Ni₃N Surface for Sulfide-Assisted Water Splitting

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The importance of hydrogen as a green energy source for a sustainable future is becoming more widely accepted. Industrial refineries produce a large amount of hydrogen sulfide (H₂S) as an undesirable waste by-product during the processing of petroleum products, which pollutes the environment. The conventional Claus method used to treat H₂S is expensive, inefficient in terms of energy, and produces low-value byproducts. Catalytic hydrogen (H₂) synthesis through electrochemical splitting of water is an effective approach to meeting the energy demands because of the significant benefit of carbon-free emissions. However, its efficiency is constrained by the slow anodic oxygen evolution reaction (OER), which necessitates a significant overpotential. A feasible substitute is the electrochemical conversion of H₂S via the sulfide oxidation reaction (SOR), which allows for the simultaneous recovery of elemental sulfur and pure H₂ in a more sustainable manner.

This method lowers hazardous H₂S emissions while providing an economical and environmentally favorable way to produce H₂. In this work, a hydrothermal method was used to fabricate the MoN/MoP₂ heterostructure on the Ni₃N-NF substrate. In a 1.0 M Na₂S + 1.0 M NaOH solution, the Ni₃N-MoN/MoP₂ heterostructure showed an exceptionally low potential of 0.232 RHE at a current density (j_{SOR}) of 100 mA/cm². The ultralow power consumption (9.83 kWh/kg H₂) may have been reduced by the heterostructure with laterally grown nanorods resisting S₈ deposition. With a cell voltage of 0.37 V at j_{SOR} of 100 mA/cm², the two-electrode arrangement demonstrates efficacy and the outstanding SOR stability of over 350 hours in 1.0 M Na₂S + 1.0 M NaOH solution, 120 hours in (NH₄)₂S, and 90 hours in sour water. This process reduces the release of dangerous H₂S gas and produces H₂, a clean energy source, which helps to address safety and environmental concerns.

PP-129

From Lab to Production: Evaluating Coating Techniques for Catalyst Coated Membrane Fabrication for Scale-up

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As the demand for high-performance, cost-effective hydrogen fuel cells and water electrolyzers grows, scalable fabrication of catalyst-coated membranes (CCMs) has become a critical challenge and the fabrication method of CCMs plays a crucial role in determining the performance, reproducibility, and manufacturability of polymer electrolyte membrane fuel cells (PEMFCs) and PEM-electrolyzers. The coating method used significantly influences not only electrochemical output but also manufacturing viability. In this study, we compare three primary CCM fabrication methods: decal transfer, spray coating, and slot-die coating based on their coating uniformity, practicality, material efficiency, choice of substrate, equipment maintenance and scale up viability. At laboratory scale, decal transfer is valued for its high control over uniformity but is limited by its multi-step processing, low throughput, operator dependency and significant material losses. Spray coating offers versatility and control at small scale but requires elaborate setup, frequent maintenance and suffers from high catalyst ink wastage. On the other hand, the slot die coating can be a good alternative technique for the direct coating of a catalyst on the membrane surface and also is suitable for the mass-manufacturing of CCMs. Slot-die coating demonstrates compatibility with roll-to-roll platforms, offering higher material utilization and speed, but introduces new challenges at scale such as the need for precise control of rheology, web tension, and drying parameters. A detailed comparison was made of coating time per CCM, ink consumption, adhesion to substrate, wettability and drying, scale up viability, ink rheology, post coating processing and reproducibility across the aforementioned three methods. Additionally, cost per CCM, process integration complexity, and the need for in line quality monitoring were also compared in this study. This work provides a comprehensive view of the trade-offs involved and establishes a practical framework for selecting coating technologies for scaling up to achieve manufacturing goals.

Electrochemical Sensors

PP-130

Lytic Bacteriophage Assisted Selective Electrochemical Detection of *Klebsiella pneumoniae* using Er₂O₃/Co₃O₄/Au/PEI Modified SPCE

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Rapid and selective detection of pathogenic bacteria is essential for timely clinical diagnosis and environmental surveillance [1,2]. In this work, we report a bacteriophage-assisted electrochemical sensing platform for the selective detection of *Klebsiella pneumoniae* using an Er₂O₃/Co₃O₄/Au/polyethylenimine (PEI) modified screen-printed carbon electrode (SPCE). The hierarchical nanocomposite was engineered to provide high surface area, enhanced charge-transfer kinetics, and abundant functional sites for efficient phage immobilization. PEI served as a cationic linker to facilitate stable electrostatic attachment of lytic bacteriophages while maintaining their biological activity and host specificity. Upon target recognition, phage–bacteria binding at the electrode interface produced pronounced impedance changes due to interfacial blocking and altered electron-transfer dynamics. The proposed biosensor exhibited high selectivity toward *K. pneumoniae* over non-target bacteria and was able to classify live and dead bacterium. The sensor showed a wide linear detection range from 10¹ – 10⁷ CFU/mL with a low detection limit of 7.8 CFU/mL. The sensor also displayed a satisfactory performance in spiked real water samples, highlighting its practical applicability. This work establishes a robust nano-bio hybrid strategy that integrates rare-earth/transition metal oxide electrocatalysts with phage biorecognition on disposable SPCE platforms. The developed system shows strong potential for point-of-care pathogen monitoring in clinical, environmental, and food safety applications.

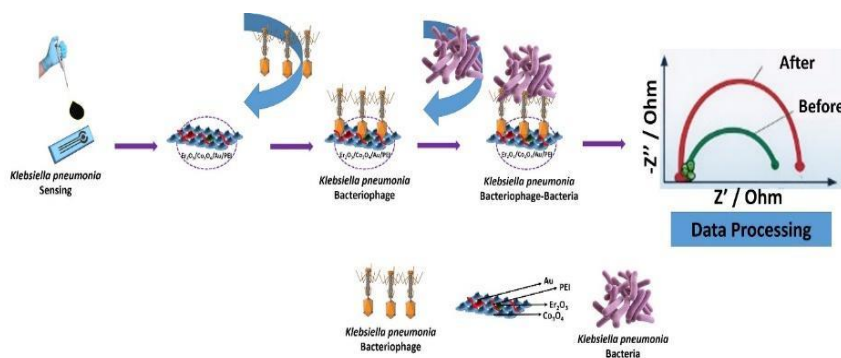


Figure 1. Steps involved in biosensor fabrication and detection of *K. pneumoniae*.

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PP-131

Ulva compressa Derived Chlorophyll *a* and Cellulose Nanostructures for Healthcare Applications

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Biodegradable pigment and polymer membrane are extremely interesting for healthcare and environmental applications including anti-oxidant, drug delivery, hydrogel and food packaging materials [1,2]. In this work, chlorophyll *a* and cellulose nanocrystals are processed from *Ulva compressa*, a naturally abundant marine algae via solid-liquid extraction. Isolates of *Ulva compressa* were carefully pre-treated with sequential alkali, bleaching and acid treatment to separate cellulose. As-prepared bulk cellulose was transformed into cellulose nanocrystals (CNC). Optical absorbance and electrochemical oxidation-reduction property of the isolated chlorophyll *a* was comprehensively studied to correlate the opto-electrochemical function, useful for biocompatible sensor application, in vivo studies. Radical scavenging and anti-bacterial function of the chlorophyll *a* was also investigated using DPPH assay and growth curve analysis. Similarly, the role of CNC in enhancing the

biodegradability of polymer film was tested using κ -carrageenan, a known thickening agent deployed in food industries. Ratiometric effects of CNC concentration in film stability or hydrogel behavior with κ -carrageenan are studied for potential application in transdermal drug delivery system.

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PP-132

Copper Decorated Exfoliated Boron Oxycarbide for Enzymeless Electrochemical Creatinine Detection Towards Point-of-Care Diagnostics

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Creatinine is a vital biomarker used to evaluate renal function and monitor kidney related disorders. Therefore, the development of a point-of-care testing device for rapid and early detection of creatinine is of significant importance. In this work, boron oxycarbide is synthesised using a hydrothermal method and exfoliated by simple bath assisted sonication. The exfoliated boron oxycarbide exhibits excellent conductivity, electrocatalytic properties and provides large active surface area. The copper decorated exfoliated boron oxycarbide electrode was fabricated using a simple one-step electrochemical potentiodynamic technique and applied for the electrochemical sensing of creatinine based on the formation of copper-creatinine complexes. Upon addition of creatinine, the oxidation current response increases due to the formation of a soluble copper-creatinine complex, thereby exposing fresh copper active sites. The sensor exhibited linear detection range from 0 μM to 100 μM with a LOD of 6.30 μM and sensitivity of 0.57 $\mu\text{A } \mu\text{M}^{-1} \text{cm}^{-2}$ in the biological pH (7.4, PB). The sensor demonstrated good selectivity in the presence of potential interferents in their physiological concentrations including glucose (5 mM), uric acid (125 μM), ascorbic acid (125 μM) and dopamine (5 μM). The developed sensor is promising for the development of wearable creatinine sensors for monitoring creatinine levels in non-invasive biofluids like sweat.

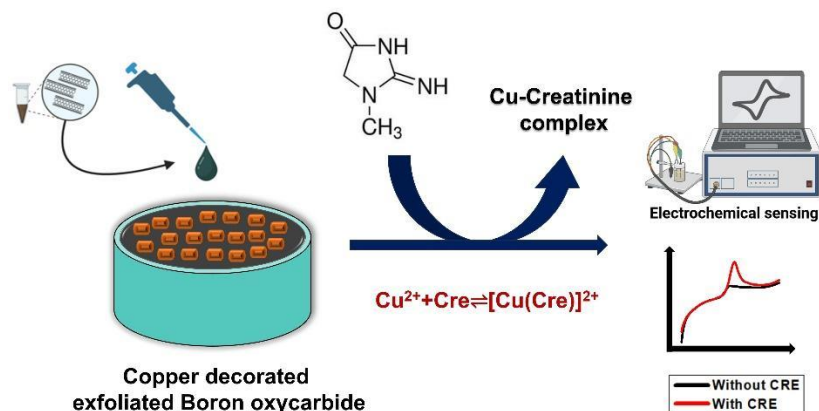


Figure 1. Graphical abstract.

PP-133

Electrochemical Point-of-Care Detection of Whole-cell Bacteria in Human Urine Samples

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Growing clinical and mechanistic evidence indicates that maternal infections, particularly urinary tract infections (UTIs), act as critical triggers for preeclampsia (PE). Bacterial antigens can mimic placental proteins, inducing immune dysregulation and autoimmune-like endothelial injury. As the UTIs are often silent and preeclampsia is diagnosed late, timely detection of biomarkers in urine samples offers a promising preventive strategy to reduce maternal and neonatal mortality. In this work, we report a nanostructured electrochemical biosensor based on carboxyl-functionalized multi-walled carbon nanotubes (MWCNTs) for the direct detection of *Pseudomonas aeruginosa* in urine samples. The electrode surface was modified with MWCNTs to enhance conductivity and surface area, followed by covalent immobilization of a species-specific DNA aptamer for selective bacterial recognition. Electrochemical impedance spectroscopy (EIS) and cyclic voltammetry (CV) were employed to characterize surface modification and sensing performance. The developed biosensor exhibited excellent sensitivity with a wide linear detection range (1×10^1 to 1×10^7) CFU/mL and a low limit of detection (1 CFU mL^{-1}) in buffer and spiked human urine samples. High selectivity of the proposed system was confirmed against other non-target bacterial strains. The sensor demonstrated good

reproducibility, stability, and rapid response, requiring minimal sample preparation. Importantly, the platform successfully detected *Pseudomonas aeruginosa* in clinical urine samples, validating its real-world applicability. Owing to its simplicity, portability, and low cost, this electrochemical aptasensor offers a promising point-of-care diagnostic tool for early UTI detection and may contribute to timely clinical intervention, particularly in resource-limited healthcare settings.

PP-134

Printed Nanotube Inks for Next-Generation Wearable Electronics

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Conductive inks play an important role in the development of printed electronics, exhibiting considerable promise within the realms of wearable devices. Among them, multi-walled carbon nanotubes (MWCNTs) are favoured for their low cost, scalability, and mechanical robustness. Yet, their strong van der Waals interactions (~ 500 eV/ μm) hinder dispersion, making the printable formulations difficult [1]. To address these challenges the reliable dispersion of carbon nanotubes (CNTs) remains a critical bottleneck in the advancement of conductive inks for wearable electronics. In this study, we present a sustainable approach that leverages chitosan (CS) based natural dispersant to stabilize multi-walled carbon nanotubes (MWCNTs) in aqueous media [2]. Through synergistic non-covalent interactions including electrostatic attraction, π - π stacking, and hydrophobic effects CS effectively prevents CNT aggregation, yielding a dispersion efficiency of 90.5%. The resulting CS-based MWCNTs ink exhibit high electrical conductivity (~ 1205 S/m), robust printability across diverse substrates, and excellent thermal stability. Additionally, we optimized rheological properties of the CS-based MWCNTs ink for dispenser printing, achieving high conductivity and reliable durability. The biocompatibility nature of Chitosan (CS) significantly enhances the potential application of these inks for the direct skin-contact applications [3]. A wearable strain sensor is fabricated with CS-based MWCNT inks to track human motion for health management, soft robotics and human-machine interfacing.

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PP-135

Chemical Reduction of Bicarbonate to Value Added Product at Liquid-liquid Interface

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Industrialization and other developmental activities had been accompanied by emission of greenhouse gases such as CO₂ which disrupts climate change by global warming and negatively impacts our environment. Due to these, conversion of CO₂ into products of industrial significance has attracted the attention of researchers and one such method is the electrochemical CO₂ reduction. Interface between two immiscible electrolyte solutions (ITIES) offers significant advantages for the reduction of carbon dioxide (CO₂) into value-added products such as formate, carbon monoxide, and methanol. Traditional solid/liquid interface system suffers from limitations such as, limited CO₂ catalyst leaching in electrolyte media, surface fouling and competing hydrogen evolution reactions which often restricts the catalytic efficiency and selectivity. To overcome the stability and scalability limitations of the solid/liquid interface systems, we have utilized electrode-less liquid/liquid interface systems for efficient electron transfer and improved catalytic performance. In this work, reduction of CO₂ (in the form of bicarbonate) at water/1,2-dichlorobenzene (H₂O/DCB) interface was studied in presence of the lipophilic electron donor, tetrathiafulvalene (TTF). The product formed by chemical reduction of bicarbonate at liquid/liquid interface was analyzed by NMR spectroscopy and ¹H-NMR spectra exhibit a peak at 3.24 ppm which corresponds to the formation of methanol. It suggests the successful reduction of bicarbonate to methanol *via*. 6e⁻ transfer process at the H₂O/DCB interface. These results indicate that liquid/liquid interface as a promising strategy for the conversion of CO₂ to value added products.

PP-136

Development of MWCNT-Fucoidan-integrated Iron Hybrid Matrix for Label-free Electrochemical Detection of Polydatin

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User-friendly, reliable, and sensitive electrochemical sensor probes for point-of-need analysis of pharmaceuticals/nutraceuticals are valuable, particularly for therapeutic drug monitoring. Here, we develop a novel label-free sensor platform using a multi-walled carbon nanotube-integrated iron-

fucoidan (MWCNT-Fe-Fu) hybrid matrix for the detection of polydatin. Polydatin is a polyphenolic stilbene derived from grapes, possessing potential immunomodulatory, anti-inflammatory, and antioxidant properties. The MWCNT-Fe-Fu matrix was synthesized using an ultrasonochemical method without a harsh environment/solvent. Its physicochemical properties were characterized using UV-Vis, FT-IR, XPS, FE-SEM, and XRD. Electrochemical studies confirmed the strong coordination between Fe(II) ions and sulfate-rich fucoidan, enabling a mediator-free hybrid electrochemical sensor matrix. The existence of MWCNT substrate sensitizes the Fe-Fu platform with superior activity for polydatin oxidation, displaying two distinct anodic peaks, at +0.61 V and +1.1 V (vs Ag/AgCl) in cyclic voltammetry. Efforts are in progress to optimize ultralow detection limit and wide linear detection range, without compromising sensitivity. Preliminary results suggest that the prepared hybrid matrix shows potentiality of this sensor probe for QC/QA application of polydatin, a herbaceutical in commercial samples and other similar polyphenols in polyherbal formulation, useful for therapeutic drug monitoring studies.

PP-137

Ion-selective Electrodes for Regolith Sample Analysis

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In this work, an ion-selective electrode (ISE) based on MOF (ZIF-8) as sensors for the detection of Li⁺ ions in the regolith sample is proposed. Herein, micro porous Metal–Organic Framework (MOF), ZIF-8 (Zeolitic Imidazolate Framework-8), is deposited on GCE, which is further modified with Li ionophore serving as the ion-selective membrane (ISM) for the Li⁺ detection. Advantages of MOF in this work include its good conductivity, high surface to volume ratio, and porous structure. Further, upon modification with the Lithium ionophore creates appropriate cavity sizes to accommodate plentiful Li⁺ enabling a highly sensitive detection. Moreover, the ionophore contains binding sites which play the role of transportation of Li⁺ from the sample to the ISE. Furthermore, the hydrophobic nature of Lithium ionophore promotes dehydration of Li⁺ at the membrane interface, enabling selective extraction and stabilization of Li⁺ within the membrane. The advantages of the proposed ISE based sensors include rapid response, cost-effective and wide linear range of detection.

SiOC Ceramic Coating Incorporated with WS₂ Nanosheets for Enhanced Room Temperature Gas Sensing Applications

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Silicon oxycarbide (SiOC) is a promising material with significant use in hardness, wear resistance, and corrosion protection, and it can be used in extreme environments. There is also a considerable industrial interest in SiOC as a material for electronics, such as power electronics, harsh environment electronics, and sensors. In an unconventional approach, the SiOC coating was produced by high-temperature pyrolysis of a polymer-derived ceramic material (PDC) [1]. The coating was initially characterized by Fourier Transform Infrared Spectroscopy and Raman spectroscopy. The surface morphology and elemental composition were analyzed using Field Emission Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy (EDX), respectively. Owing to the high bandgap and high-temperature stability of SiOC devices, we can use this as a sensing material even at high temperatures. However, SiOC alone (a p-type semiconducting material) exhibits good sensing performance only at high temperatures, such as 300 °C [2]. To improve the sensing behavior of SiOC at room temperature, WS₂ nanosheets (NS) (an n-type material) [3] was introduced on the SiOC substrate to form a p-n heterojunction between them (Figure 1). A p-n junction creates a depletion region at the interface, generating a built-in electric field that enables efficient charge separation without the need for external thermal activation. From this, we can use this as an exceptional sensing material for the detection of NO₂ gas at room temperature.

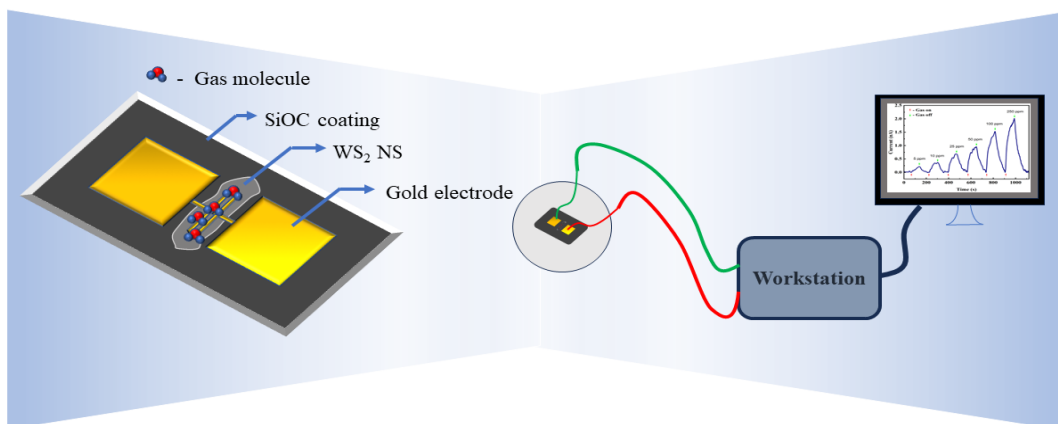


Figure 1. Graphical illustration depicting sensor and its measurement.

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PP-139

Study of High-kinetics Alkanolamine Coreactant for Enhanced Electrochemiluminescence in Visualising Latent Fingerprint

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Electrochemiluminescence (ECL) is a unique phenomenon that exerts luminescence triggered by electrical potential. Coreactant pathway has emerged as a pivotal method for boosting ECL efficiency and versatility in application. With such merits Ru(bpy)₃²⁺/TPrA (Tripropylamine) has become the most explored system for ECL assays including the commercial ones for clinical diagnosis. This tertiary amine based TPrA electro-oxidises to form a potent reducing agent that readily donates electrons to luminophores. Albeit, the hydrophobic TPrA shows poor biocompatibility, toxicity, and requires high doses (>100 mM) to generate sufficient ECL signals for imaging. Thus, numerous aliphatic amine based hydrophilic coreactants are under quest for promising replacements of TPrA in ECL based sensor and imaging applications. 1-[Bis[3-(dimethylamino)propyl]amino]-2-propanol (BAPAP), is an alkanolamine with three tertiary amine and a secondary alcohol functionality. The three tertiary amine groups in BAPAP, makes it a potent coreactant for Ru(bpy)₃²⁺ based anodic ECL. Notably BAPAP exhibited ECL signals that are >10-fold higher than that observed with TPrA. Further electrochemical studies showed that under anodic potential, the electro-oxidation of BAPAP initiates deprotonation and involves two protons and two electrons for ECL generation. In addition, BAPAP exhibits 85% and 117.9% relative efficiency in GCE and gold electrodes, respectively. The significantly higher electron transfer kinetics of BAPAP than other competent coreactants makes it a viable coreactant for ECL based imaging application. Here we utilized Ru(bpy)₃²⁺/BAPAP based anodic ECL system for imaging latent fingerprints using home-made cell setup and smartphone camera (Figure 1). The captured ECL images of latent fingerprint exhibited level three details making this a potential technique for future bioanalysis and imaging applications.

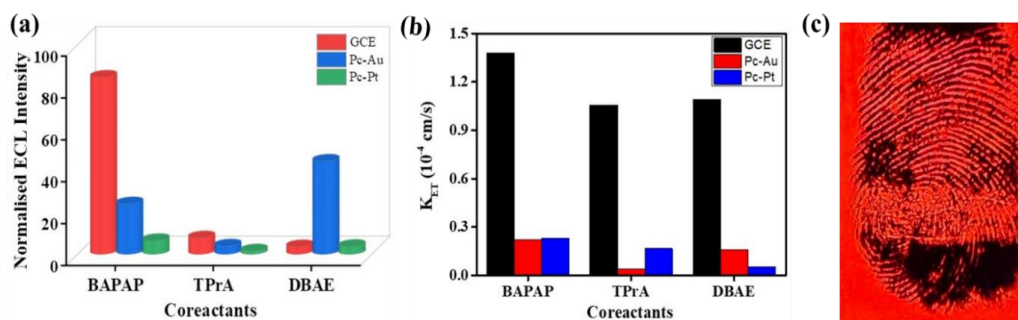


Figure 1. (a) Comparison plots of normalized ECL intensity for 0.1 mM $Ru(bpy)_3^{2+}$ in 0.1 M PBS (7.4) with 10 mM of various coreactants using different working electrodes. (b) Bar Chart representing the heterogeneous electron transfer rate constant (K_{ET}) of coreactants (BAPAP/TPrA/DBAE) in 0.2 M PBS at 0.9 V using GCE or Pc-Au or Pc-Pt as working electrodes. (c) ECL image of latent fingerprint in $Ru(bpy)_3^{2+}$ /BAPAP system by applying constant potential of 1.3 V for 30 s.

PP-140

Aptamer-based Electrochemical Sensor for Point-of-Care Detection of Botulinum Toxin A

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Detecting biological warfare agents rapidly and accurately remains a global challenge for biodefense and public health security. Botulinum neurotoxin type A (BoNT/A), produced by *Clostridium botulinum*, is recognised as a high-risk biological agent. BoNT/A exhibits lethal and severe neurotoxic effects at its extremely low dose (LD_{50} ; oral ~ 1 μ g, inhalational ~ 0.7 – 0.9 μ g, and intramuscular ~ 0.09 – 0.15 μ g for a 70 kg adult). In this work, an aptamer-based electrochemical sensing platform for the point-of-care detection of BoNT/A is demonstrated using a screen-printed electrode architecture. Forty-four potential aptamers were evaluated for the binding affinity of the BoNT/A light chain (BoNT/A-LC). Among them, 3 aptamer sequences, namely AptA, AptB, and Apt27, showed stronger binding affinity and were selected for further optimization by molecular docking. The docking studies performed with AutoDock, ZDOCK, and HADDOCK identified aptamers with enhanced binding affinities or free energies (ΔG) (AptB = -7.1 kcal/mol, AptC = -7 kcal/mol, and AptB27 = -10 kcal/mol).

The selected optimized aptamers with higher binding affinities were immobilized on screen-printed gold electrodes and characterized by cyclic voltammetry and square-wave voltammetry. The influence of key physical factors such as pH, temperature, and ionic strength on the efficacy of the aptamer-based sensor was evaluated. The sensitivity and selectivity of each aptamer sensor to BoNT/A-LC were assessed. Additional validation experiments employing spiked lab samples revealed reliable toxin detection. Overall, the proposed electrochemical aptasensor offers a compact, sensitive, and expandable botulinum detection platform that has significant potential for point-of-care diagnostics and global biodefense applications (Figure 1).

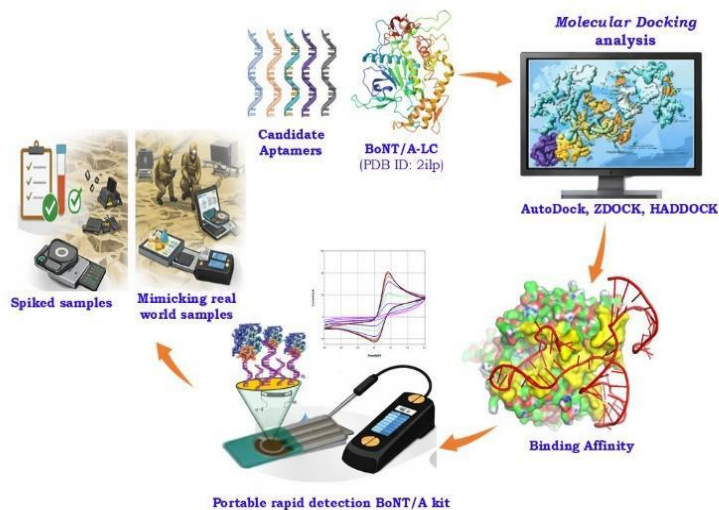


Figure 1. Graphical illustration showing Aptasensor and sensing application.

PP-141

Organic-inorganic Hybrid 2D WS₂@PEDOT:PSS p-n Heterojunctions for High-performance Carbon Monoxide Sensing Probed by *In situ* Raman Spectroscopy

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Continuous and reliable monitoring of carbon monoxide (CO) at room temperature is crucial due to its high toxicity and stringent exposure limits, particularly for portable and low-power environmental sensing applications [1]. However, most commercially available and metal oxide-based CO sensors

require elevated operating temperatures, resulting in high power consumption, complex circuitry, and limited suitability for continuous real-time monitoring [2]. To address these limitations, a novel organic-inorganic p-n junction nanocomposite comprising tungsten disulfide nanosheets (WS₂ NSs) and poly(3,4-ethylenedioxythiophene): poly(styrenesulfonate) (PEDOT:PSS) is developed for ultra-sensitive room-temperature CO gas sensing, with mechanistic insights obtained through *in situ* Raman spectroscopy. The hybrid nanocomposite is synthesised via ultrasonic exfoliation of WS₂ followed by uniform dispersion within the PEDOT:PSS matrix, forming an efficient p-n heterojunction. A chemiresistive sensor fabricated using this composite exhibits an outstanding linear response ($R^2 = 0.9969$) over a wide CO concentration range of 1-600 ppm, with a sensitivity of 0.91 $\mu\text{A/ppm}$ at room temperature. At 25 ppm CO, the sensor demonstrates excellent repeatability along with rapid response and recovery times. In situ Raman analysis reveals that CO exposure modulates the carrier concentration at the WS₂@PEDOT:PSS interface, leading to reduced depletion layer thickness and enhanced interfacial charge transport. The proposed sensing platform offers a promising pathway toward energy-efficient, room-temperature CO sensors suitable for practical environmental monitoring.

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PP-142

Functionalized Graphene Nanoplatelets Based Electrochemical Immunosensor for Quantification of Thyroid Stimulating Hormone

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Thyroid-stimulating hormone (TSH) is regarded as the most accurate biomarker for the diagnosis of thyroid disorders. The present study describes a method to develop an electrochemical label free immunosensor for the sensitive detection of TSH. This is achieved by employing polyethyleneimine functionalised graphene nanoplatelets to modify the working area of a screen-printed carbon

electrode, where the 2D-sheetlike morphology of graphene nanoplatelets provided high surface area for anchoring the TSH antibodies. The modification also enabled a facile electron transfer between electrode-electrolyte interfaces thereby enhancing the electrocatalytic activity. The polyethyleneimine functionalisation aided in the antibody immobilisation by forming covalent interactions between its amine branches and the carboxyl groups present in the antibody. The performance of the immunosensor was evaluated using electrochemical impedance spectroscopy and the sensor exhibited a good detection range from 0.001 to 100 $\mu\text{U/mL}$, with excellent selectivity. The immunosensor developed in this work is promising for the development of point-of-care testing platforms for TSH quantification.

PP-143

Laser-scribed Flexible Interdigitated Electrodes with Polyaniline and Silver, Fabricated Using a DIY Laser Engraver, for pH Sensing

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Considering the complexity of the wound healing process, an objective and reliable indicator is essential for assessing healing progression. Sensitivity, repeatability and accuracy are key criteria for such measurements, along with minimizing patient discomfort [1]. In this study, a flexible pH sensor was developed through the electrodeposition of polyaniline and silver on laser-scribed interdigitated electrodes (Figure 1). Furthermore, the development of laser-induced graphene (LIG) interdigitated electrodes using an affordable do-it-yourself (DIY) diode laser engraver was demonstrated, along with a critical strategy to improve electrical conductivity. Subsequently, polyaniline (PANI) was electropolymerized on LIG by cyclic voltammetry, through a potential range of -0.1 to 1.2 V at a scan rate of 100 mV/s [2]. The Ag/AgCl pseudo-reference electrode was also electrodeposited on the interdigitated LIG pattern via galvanostatic conditions, followed by electrochemical chlorination [3]. The fabricated sensor showed an average sensitivity of 47.9 mV/pH, comparable to the Nernstian value (59.0 mV) within the pH range of 4.0 – 8.0 . The response time, cyclical and temporal stability of the sensor were evaluated, revealing a rapid and stable response [4]. Overall, the developed sensor allows precise pH measurement within the physiologically relevant range for wound healing and provides the added benefit of low capital cost, making it a cost-effective option.

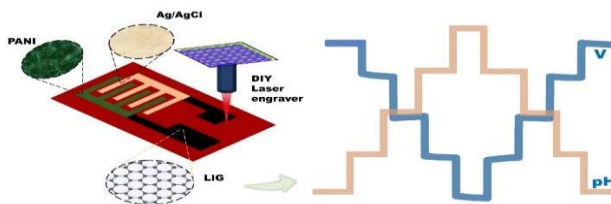


Figure 1. Fabrication of laser scribed interdigitated electrodes.

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PP-144

Advancing the Diagnostics of Neurological Disorders: A Molecular Imprinted Polymer-based Microneedle-strip Electrochemical Sensor for Label-free Dopamine Monitoring

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Dopamine (DA) is a critical neurotransmitter in the brain, and its aberrant levels are linked to a variety of neurological illnesses, including Parkinson's disease. This research introduces a unique integrated microneedle-strip-based biomimetic sensor for fast and label-free detection of dopamine. Here, we have prepared molecular imprinted polymers and used them as biomimetic recognition matrices for the selective and sensitive detection of dopamine. α -cyclodextrin (α -CD) was employed as the functional monomer to create specific recognition sites for dopamine via electro-polymerization within the imprinted polymer matrix. The sensor exhibited high selectivity for dopamine over structurally similar interfering substances due to the chemical recognition properties of its imprinted cavities. Structural and morphological characterization of MIP-electrode surfaces were done with X-ray photoelectron spectroscopy and scanning electron microscopy. Electro interfacial properties were studied with cyclic voltammetry and electrochemical impedance spectroscopy. Electroanalytical performance of the sensor was tested with amperometry and square wave voltammetry methods. The sensor demonstrated high sensitivity and selectivity for dopamine in a wide linear range of 5 nM

to 100 μM (buffer) and 0.5 to 100 μM (in artificial ISF). A remarkable Limit of Detection (LOD) of 0.58 nM was achieved. Various interactions between α -cyclodextrin and dopamine was studied with the help of Docking and Density Functional Theory. Different types of hydrogen-bonded interactions were identified between CD and Dopamine and found that upon the application of potential, only dopamine detaches from the α -cyclodextrin layer and the α -cyclodextrin layer remains intact. The integrated design combining the microneedle platform with screen printed electrodes (SPCE) enables continuous monitoring of dopamine levels. The integration of cyclodextrin-functionalized molecularly imprinted polymers (MIPs) into wearable microneedle-SPCE sensors demonstrates significant potential for sensitive and selective dopamine detection, particularly in therapeutic and diagnostic applications (Figure 1).

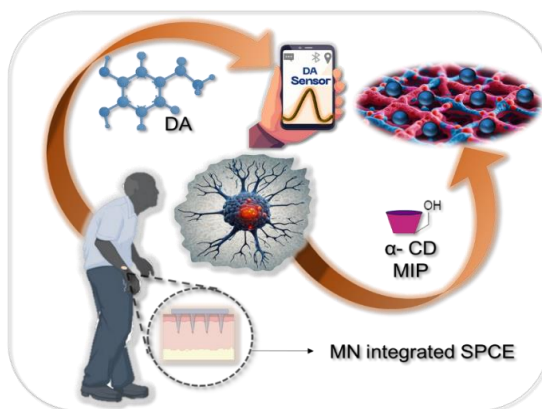


Figure 1. Graphical illustration showing Microneedle strip based electrochemical detection of Dopamine.

PP-145

Electrochemical Sensing of Ca^{2+} Ions Using Adsorptive Stripping Voltammetry at Electrified Liquid–liquid Interface

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Electrochemical sensing of Ca^{2+} ions at interface between two immiscible electrolyte solutions (ITIES) was investigated using adsorptive stripping voltammetry (AdSV). The electrochemical study was performed at water/1,2-dichloroethane interface, where the aqueous phase contained the target divalent metal ions and the organic phase contained ion-selective ligands. Due to the difference in

hydration energy, the alkaline-earth metal ions exhibit distinct ion transfer responses across the liquid–liquid interface. However, the transfer of divalent metal ions requires higher transfer energies. To overcome this limitation, facilitated ion transfer was proposed using polymeric ionophores, especially poly vinyl chloride (PVC), which form stable metal–ligand complexes in the organic phase and it lowers the Gibbs energy for transfer metal ions and enhances the selectivity. Further, AdSV was employed to enhance the sensitivity and attained well-resolved distinct metal ion transfer at ITIES. These results demonstrate that the ITIES platform is an effective tool for understanding ion–ligand interactions and selective transport mechanisms of divalent cations.

PP-146

Microcontroller-based Portable Nitrite Analyzer using Chronoamperometry

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A portable, microcontroller-based nitrite analyzer employing the chronoamperometry technique has been designed and implemented. The system is built around a low-power ARM Cortex-M4 microcontroller programmed using a dedicated embedded development environment. The analog front-end uses a low-noise precision operational amplifier configured as a potentiostat [1], interfaced with a three-electrode cell comprising carbon screen-printed electrodes (SPCE). A controlled excitation potential (0.8 V) is applied via the onboard 12-bit DAC, and the resulting current response is conditioned through a transimpedance amplifier and digitized using the integrated 12-bit ADC. Passive filtering components are incorporated to reduce noise and improve signal integrity. A firmware-based calibration routine acquires current responses from known nitrite concentration standards [2] and stores them in the internal flash memory of the microcontroller for reference. Unknown sample concentrations are then determined in real time by comparing measured responses against the stored calibration data. Results are displayed on an OLED screen *via* i2c interface (Figure 1). The proposed system offers a compact, cost-effective, and field-deployable solution for on-site nitrite detection.

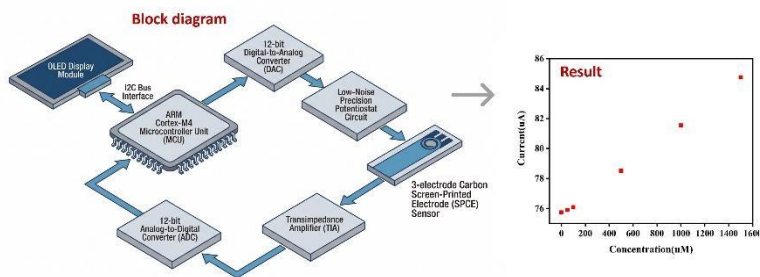


Figure 1. Schematic representation of Microcontroller based nitrite analyzer.

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PP-147

Point-of-care Electronic Devices for Electrochemical Sensing

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This work focuses on the development of a portable and wearable electrochemical point-of-care (PoC) device for the detection of nitrite. The proposed device is designed to perform cyclic voltammetry technique for sensitive and selective measurement of nitrite (Figure 1). Pre-programmed STM32 L432KC microcontroller and low-power, low noise quad-operational amplifier (op-amp), OPA4316 are used to create the portable potentiostat circuit. The microcontroller is programmed to produce the triangular waveform input because the potential must be swept forward and backward between two voltage limits. Screen printed electrodes in three electrode configurations were integrated with the portable potentiostat for nitrite measurement. The sensor output is filtered through an analog RC filter (low-pass filter) to remove the unwanted noise from the signal and the resulting current signal is amplified and converted to voltage by a trans-impedance amplifier (TIA). The signal is then converted into a digital value for further processing by the microcontroller and is transmitted wirelessly through the HC-05 Bluetooth module. The developed device is compact, low-cost, and suitable for portable point-of-care and environmental monitoring

applications. The proposed device will be integrated with an LCD module and self-calibrating algorithms for practical implementation.

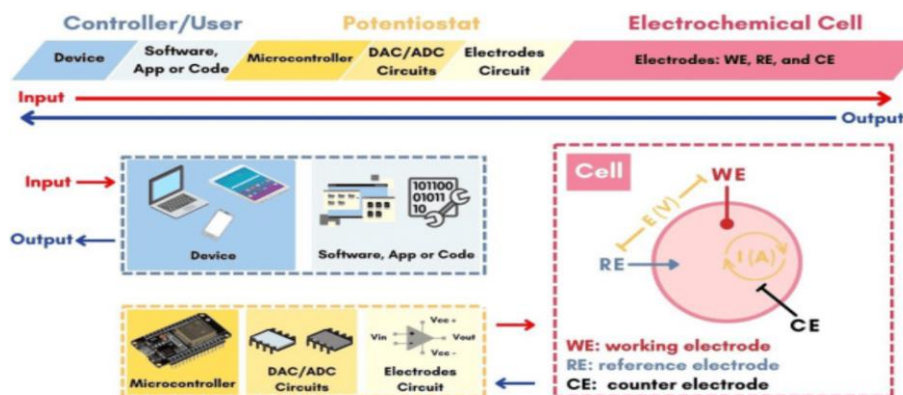


Figure 1. Schematic representation of a potentiostat operation.

PP-148

Marine Algae-derived Phloroglucinol modified Molybdenum Trioxide Structure: A Bionanosystem for Theranostics

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Phlorotannins are potential bioactive polyphenols derived from brown seaweeds, exhibiting anti-oxidant, anti-microbial, neuroprotective, hepatoprotective and cardiovascular benefits. Despite their potential to outperform synthetic alternatives, their clinical application is hampered by bioavailability challenges and a lack of extensive *in vivo* data. To overcome these hurdles, herein, surface conjugation strategy is attempted with metal oxide structure. Integration of size/shape-controlled metal oxide systems can retain stable structural and functional properties of polyphenol. Molybdenum trioxide (MoO_3) nanostructures are recently emerging as promising candidates for bioconjugate preparation excelled in opto-electrochemical sensing and therapeutic function such as anti-oxidant and neuroprotection [1-3]. Amongst various phlorotannins, phloroglucinol is one of the underexplored polyphenols from brown seaweeds. In this study, a stable structural hybridization is formed consisting of MoO_3 and phloroglucinol (MoO_3 -PG) using sulfated polysaccharide as linker molecule. Conjugation chemistry, optical absorbance, crystalline pattern and morphological characterization of the prepared hybrid structure is comprehensively investigated using FT-IR, UV-

visible, XRD and SEM techniques. Therapeutic function of the MoO₃-PG structure toward hepatoprotection is under investigation. Presuming the pH responsiveness of the prospective hybrid, a viable theranostic application would be designed to monitor oxidative damage and healing function through in vitro assay methods.

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PP-149

Exploring the Potential of ZIF-67-decorated Copper Nanowires Towards Sensing of Glucose in Alkaline Medium

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Metal-organic frameworks (MOFs) are an emerging class of microporous materials that has gained researchers' attention. They have a supramolecular structure made up of metal centers/clusters and multidentate organic linkers. MOFs are of great interest to current research because of their high porosity, surface area, and tunable properties. This work reports the *in-situ* growth of cobalt MOF on the copper nanowires. The synthesized composite was employed for non-enzymatic glucose detection in an alkaline medium. The morphology of the composite was characterized using various microscopic techniques such as FESEM and HRTEM. The crystallinity and elemental composition were elucidated using XRD and XPS. The enhanced surface area of the composite is expected to aid the electrochemical characteristics. The electrochemical properties of the composite towards glucose were evaluated using voltammetry and amperometric techniques. Glucose exhibited a relatively low oxidation overpotential of 0.45 V on the screen-printed electrode modified with the composite. The sensor exhibited two linear ranges between 50 μM – 1 mM and 1 mM – 9 mM with sensitivities of 2.03 $\mu\text{A } \mu\text{M}^{-1} \text{ cm}^{-2}$ and 0.61 $\mu\text{A } \mu\text{M}^{-1} \text{ cm}^{-2}$, respectively, with a detection limit of 0.4 μM . The developed sensor was successfully tested in serum samples to evaluate its practical applicability.

RuO₂ Decorated Laser Induced Graphene Sensor for Ultrasensitive Detection of Lead and Cadmium

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Lead and Cadmium contamination in edible items pose serious risks to health, necessitating an urgent need for rapid, scalable and field deployable sensing platforms beyond conventional techniques. However, existing electrochemical sensors for Pb²⁺ and Cd²⁺ often require complex surface functionalization and rigid substrates, limiting portability, and ease of fabrication. Herein, RuO₂ decorated laser induced graphene (RuO₂@LIG) is developed via a scalable, mask free, CO₂ laser writing technique and simple drop-casting approach. The microscopic and spectroscopic characterizations show the 3D porous architecture along with uniform distribution of RuO₂ onto the LIG surface. The electrochemical studies present the enhanced electroactive surface area compared to bare LIG due to synergistic interaction between RuO₂ nanoparticles and the porous graphene network. The RuO₂ nanoparticles provide abundant electrocatalytic active sites, resulting in amplified stripping currents and improved analytical performance. Using, square wave anodic stripping voltammetry (SWASV), under optimized condition in 0.1 M acetate buffer, RuO₂@LIG achieved a low detection limit, 18.1 nM for Cd²⁺ and 11.2 nM for Pb²⁺, simultaneously in the linear range of 1 to 10 μM with well resolved stripping peaks (Figure 1). The calibration sensitivity of RuO₂@LIG for Cd²⁺ and Pb²⁺ is 9.66 μA. μM⁻¹ and 8.01 μA, respectively μM⁻¹. Furthermore, the RuO₂@LIG electrode detects Cd²⁺ and Pb²⁺ in a linear range of 2–10 μM for milk powder samples, with a recovery rate of nearly 100%. The fabricated RuO₂@LIG electrode exhibits good selectivity in the presence of potential interferents thereby demonstrating practical applicability for onsite analysis. These results indicate that the proposed RuO₂@LIG electrode can serve as a scalable, and for decentralized water quality surveillance, while the direct laser writing approach eliminates complex surface functionalization and offers a versatile route for real time environmental monitoring and regulatory compliance assessment.

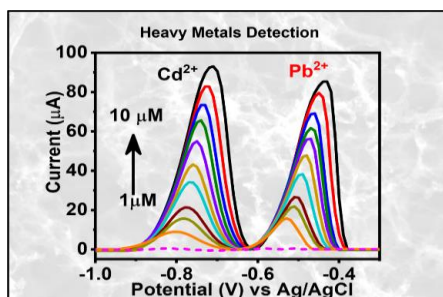


Figure 1. RuO₂@LIG based sensing of Cd²⁺ and Pb²⁺.

PP-151

Defect Engineered Metal Organic Framework CeM–mlm (M = Mn, Fe, Co, Ni, Cu) for Dopamine Sensing

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Dopamine is a crucial neurotransmitter that plays an important role in controlling one's movements, cognition, and emotions. Hence a sensitive and reliable detection of dopamine is essential for early diagnosis of neurological disorders and real-time biomedical monitoring. The study investigates the synergistic effects of solvothermally synthesized defective metal–organic framework, by introducing transition metal (M = Mn, Fe, Ni, Co and Cu) in CeM–mlm MOF. All of the defective MOFs were tested for electrochemical DA detection. From which CeCu–mlm was selected and integrated with conductive polypyrrole for conductivity enhancement using a facile method ensuring uniform distribution of PPy on CeCu–mlm, and the resulting composite (CeCu–mlm@PPy) was fabricated on glassy carbon electrode and developed as an efficient electrochemical sensing platform. The electrocatalytic composite's morphology was examined via FESEM and HRTEM, while its structure was analyzed using XRD, XPS, and IR spectroscopy. Electrochemical catalytic performance of CeCu–mlm@PPy was evaluated for dopamine detection in neutral medium. It shows a wide detection range for higher concentrations of dopamine 25 μM to 900 μM . The limit of detection and limit of quantification, were found to be 1.26 μM and 4.21 μM respectively with a sensitivity of 94.63 $\text{nA } \mu\text{M}^{-1} \text{cm}^{-2}$. The developed sensor was reproducible and was selective towards dopamine. This research highlights the promising application of CeCu–mlm@PPy composites as advanced materials for the development of sensitive and selective electrochemical sensors for dopamine detection.

PP-152

Copper Selenide (Cu_3Se_2) as a Redox Mediator for Sensing of 5-hydroxymethyl Furfural in Honey Samples

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Long-term storage of honey at inappropriate places leads to the formation of 5- Hydroxymethyl furfural (5-HMF). The consumption of 5- HMF exceeding the specified limits acts as a cytotoxic agent to the human body, because it will convert to 5-sulfoxide methyl furfural (carcinogenic agent) and long-term accumulation in our body. Chromatographic and spectrometric techniques are expensive and available only in centralised, well-equipped labs, which makes routine analysis impossible. Electrochemical sensors are desirable candidates for sensing as they are portable and operable with minimal inputs. Due to this reason, this study aims to fabricate a highly sensitive Cu_3Se_2 nanoflakes modified electrode platform for the detection of 5-HMF in honey samples. Cu_3Se_2 nanoflakes have been prepared *via* co-precipitation method and characterised using physicochemical techniques. The prepared Cu_3Se_2 has been employed at the solid-liquid interface through drop-casting for sensing of 5-HMF in honey samples. Electrochemical techniques such as cyclic voltammetry and EIS have been utilized to understand the redox nature and sensing ability of prepared Cu_3Se_2 nanoflakes. The results indicated a linear relationship between 5-HMF concentration and current in the range of 10^{-6} – 10^{-3} M, and the limit of detection was found to be 50 μM .

PP-153

Design of Copper Cobalt Oxide Anchored N, S-doped Hollow Carbon Sphere Nanocomposite for Enhanced Electrochemical Hydrazine detection

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In this work, the electrochemical detection and quantification of hydrazine in 0.1 M PBS (pH 7.0) were performed using a $\text{CuCo}_2\text{O}_4/\text{NSCS}$ electrocatalyst prepared via the hard-template method. The crystallographic nature, morphology, elemental distribution, oxidation states, and chemical bonding characteristics of the synthesized $\text{CuCo}_2\text{O}_4/\text{NSCS}$ materials were examined using XRD, Raman, TGA, XPS, FESEM and HRTEM techniques. For electrochemical evaluation, cyclic voltammetry was employed, revealing the oxidation of hydrazine at a lower potential (0.32 V vs. SCE) and confirming a diffusion-controlled process. Differential pulse voltammetry was further used for quantitative analysis, demonstrating excellent electrocatalytic performance of the $\text{CuCo}_2\text{O}_4/\text{NSCS}$ -modified GCE toward hydrazine detection, with a linear detection range from 50 μM to 6000 μM and a limit of

detection of 19.57 μM (Figure 1). Based on these results, the $\text{CuCo}_2\text{O}_4/\text{NSCS}$ -modified GCE shows strong potential for practical applications, including the analysis of hydrazine in real water samples.

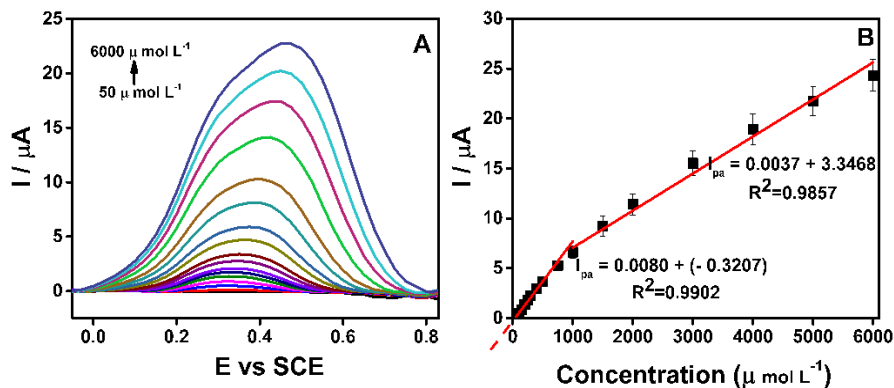


Figure 1 (A) Differential pulse voltammograms of $\text{CuCo}_2\text{O}_4/\text{NSCS}$ -modified GCE for hydrazine detection and (B) its corresponding calibration plot.

PP-154

A Custom-made 3D-printed Batch Injection Analysis Device for Rapid Microlitre-volume Detection of Vitamin C in Real Samples

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Batch Injection Analysis (BIA) is a rapid and user-friendly electroanalytical technique designed for the direct introduction of microliter-scale sample volumes into a detector-containing solution [1]. It offers a compact, portable, and cost-effective alternative to traditional flow systems, eliminating the need for complex tubing or pumps [2]. Unlike conventional systems, developing a low cost, 3D-printed BIA model is crucial for enabling affordable and easily accessible electrochemical sensing solutions. In this work, an acrylonitrile Butadiene Styrene (ABS) polymer-made BIA system was developed for practical electrochemical sensing applications. The BIA cell, often 3D-printed for customization, includes a strong Neodymium magnetic closing mechanism and an O-ring-enclosed electrochemical cell. A Teflon-based stirring rod allows for adjustable stirring speeds (500–3000 rpm), enhancing sample mixing and reducing electrode fouling. The technique is especially effective for trace analysis, providing fast response times and high sensitivity. A low-cost carbon ink was developed for the electrochemical oxidation of ascorbic acid (AA, Vitamin C) using a Zensor® three-electrode system in

phosphoric buffer solution PBS (pH 3). Chronoamperometry revealed a distinct oxidation peak at different intervals for applied potential of 0.05 V vs Ag/AgCl. The carbon ink modified SPE was characterized using Raman, IR, and TEM, demonstrating high sensitivity and selectivity for AA with minimal interference. This system offers a cost-effective, customizable, and portable alternative to traditional flow injection setups. The sensor demonstrated effective electrochemical detection of AA, with linear detection ranges of 10-50 μM , and a low detection limit of 10 μM ($S/N = 3$). Validation with real samples, including vitamin C tablets, Lemon juice confirmed the sensor's practical applicability.

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PP-155

Electrochemical Tweaking: Unfolding the Relationship between Surface Changes and NADH Oxidation

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Cathodic pretreatment of a glassy carbon electrode (GCE) is carried out to study its effect on the electrochemical oxidation of nicotinamide adenine dinucleotide (NADH). Pretreatment conditions are optimized with respect to applied potential, duration and electrolyte composition (Figure 1). Cathodic polarization performed at -0.8 V (vs. SCE) in 0.1 M NH_4Cl for 60 seconds is found to be very effective in improving the electrocatalytic performance towards NADH oxidation. Surface wettability analysis revealed a change in the contact angle following cathodic treatment, indicating a modification of GCE surface properties. Unlike anodic pretreatment, which introduces inhibitory surface layers, the cathodic activation restructured the carbon surface towards a defect rich, edge plane dominant morphology. This transformation is confirmed by Raman spectroscopy, showing an increase in I_D/I_G ratio. XPS and Raman analyses revealed the formation of carbonyl, carboxylic, and nitrogen-containing functional groups during the pre-treatment. From these results it is confirmed that electrochemical pretreatment leads to predominance of carboxylic acid groups as the active sites on

the surface. Furthermore, the negatively charged carboxylate groups promote NADH oxidation by stabilizing hydrogen bonded intermediates and facilitating better NADH interaction at the electrode–electrolyte interface. They also promoted a two electron, one proton transfer mechanism, while significantly lowering the oxidation potential, dimer formation, and suppressing the surface fouling. The electrochemically activated GCE (ECA GCE) sensor exhibits a linear response towards NADH concentrations ranging from 0.01 mM to 5 mM, with a lower detection limit of 14 μ M and a correlation coefficient of $R^2 = 0.9810$. It has been demonstrated that GCE with minimal electrochemical treatment can be employed for bio-electrochemical sensing and biofuel cell applications.

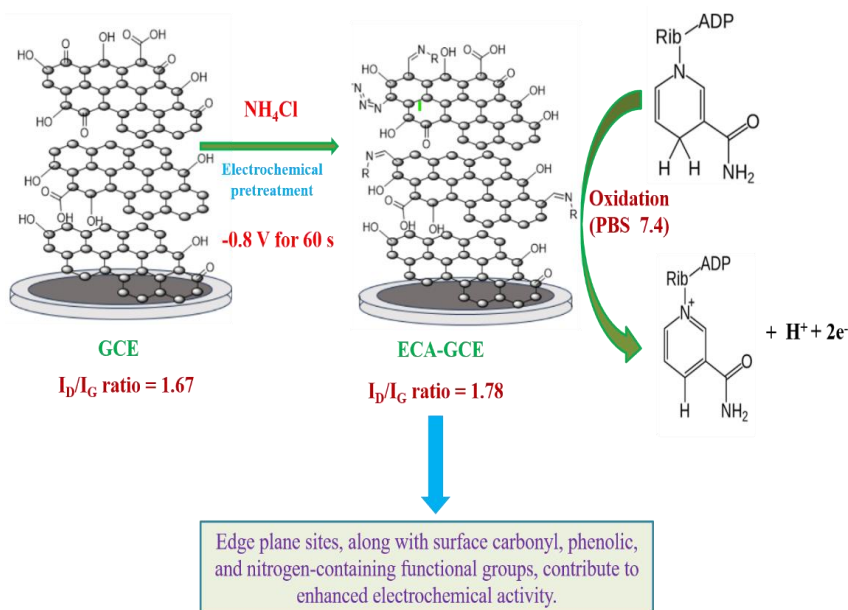


Figure 1. Surface treatment of electrode for enhanced sensing of NADH oxidation.

Direct Printing of Metal-organic Decomposition Ink for Wearable Electronics Application

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In the realm of printed electronics, Metal-MOD (Metal Organic Decomposition) ink represents a particle-free alternative to traditional nano-carbon and nanoparticle (NP) inks. While carbon and NP inks suffer from nozzle clogging and require more time to remove stabilizers, MOD inks offer true solutions where the metal layer is deposited by evaporating its organic ligands. Among the various types of metals, nickel (Ni) is specifically prized for its low cost, and high oxidation resistance, making it a vital candidate for conductive film fabrication. This present study investigates the synthesis and printing of particle-free Ni-MOD complex ink on a flexible polyimide (PI) substrate. Thermogravimetric analysis (TGA) and Differential thermal analysis (DTA) confirmed a multi-stage decomposition pathway, with the nickel complex undergoing complete reduction to form metallic Ni network in the range of 210°C to 250°C. The resulting films exhibit a continuous polycrystalline structure with an average grain size of about 150 nm, the sintering process promotes homogeneous nucleation. While XPS confirms the oxidation states and metallic nature of Ni, the XRD pattern reveals lattice parameters. The electrical studies revealed the sheet resistance value in the range of ~11-12 Ω/sq with negligible change when exposed into the open atmosphere. The rheological properties of the Ni-MOD ink have been optimized for dispenser printing to achieve high conductivity and durability. The direct formation of nickel-nano film from the precursor MOD ink offers a scalable pathway used to fabricate the 2D and 3D printed conductive structures directly onto flexible substrates.

PP-157

Simulation of Hydroxide Ion Transport for Optimizing Inter-electrode Distance in Electrochemical Bacterial Lysis

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Electrochemical Cell Lysis (ECL) is a rapid, reagent-free method for bacterial membrane disruption that utilizes the local generation of hydroxide ions at the cathode surface through water electrolysis reaction. In this work, a finite element model with COMSOL Multiphysics to simulate water electrolysis reaction using Pt-rGO modified screen-printed electrodes to optimize geometry and inter-electrode distance for optimal lysing of bacteria. Simulation results show the pH distribution across the inter-electrode distance varying from alkaline (pH >13) near the cathode to acidic pH.

PP-158

Electrochemical Sensing of pH in Aquaculture System using PANI-based Screen-printed Carbon Electrodes

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In aquaculture, pH plays an important role in the growth and reproduction of shrimps and fish, which plays a crucial role in supply chain economics. The alteration in pH levels affects factors such as ammonia production, fish metabolism and nutrient contents in aquaculture media which are majorly important for sustenance of the fishes [1]. In this study, a low-cost portable screen-printed carbon electrode (SPCE) was developed for real-time monitoring of pH. Conductive PANI enabled electrochemical pH detection via reversible protonation, while added graphene nanoparticles (GNP) improved conductivity, surface area, sensitivity, and overall sensor stability [2]. The modified SPCE was employed for pH sensing in the range of 6 to 11 with a sensitivity of 35 mV/pH. The sensor performance was further evaluated in terms of repeatability and reproducibility (n=5). Continuous monitoring capabilities of the PANI-modified electrode was recorded as a function of time for a period of 2 hours. The proposed sensor offers a simple, sensitive, cost-effective, and efficient approach for monitoring pH in aquaculture systems (Figure 1), highlighting its potential usage in environmental applications.

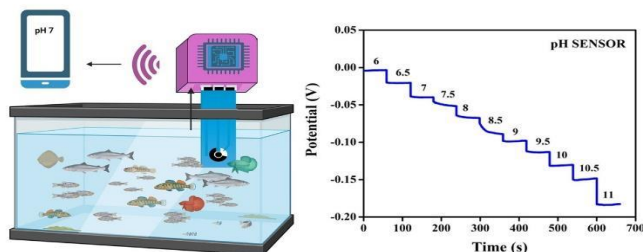


Figure 1. Schematic representation of pH sensing in aquaculture using PANI modified SPCE.

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PP-159

Development of a Disposable Label-free Electrochemical Immunosensor Using V_2O_5 -PANI-Chitosan Nanocomposite for Sensitive Detection of HER-2 Breast Cancer Biomarker

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Human epidermal growth biomarker (HER-2) is one of the major biomarkers for early detection of Breast cancer. The present work uses label free electrochemical immunosensor technique as an effective tool for sensitive detection of HER-2 biomarkers. A ternary nanocomposite of Vanadium pentoxide/polyaniline/chitosan (V_2O_5 /PANI/CS) was used for electrode modification on screen printed carbon electrodes (SPCE). In-situ formed PANI intercalated V_2O_5 (V_2O_5 /PANI) nanocomposite couples the good redox activity of V_2O_5 with the effective catalytic activity of PANI to provide a stable composite. Chitosan, a biopolymer, was mixed with the above composite owing to its amine functionality that helps in antibody immobilization. The sensor uses Electrochemical Impedance

Spectroscopy (EIS) to analyze the response of different concentrations of HER-2 on SPCE. With increasing concentration of analyte, the charge transfer resistance (RCT) increased gradually due to blocking of electron transfer by the protein molecule. The proposed sensor was found to detect a linear range of 0.001 to 100 ng/ml. It forms a sensitive, selective, stable and feasible tool for early detection of HER-2 and also has been extended for real sample analysis.

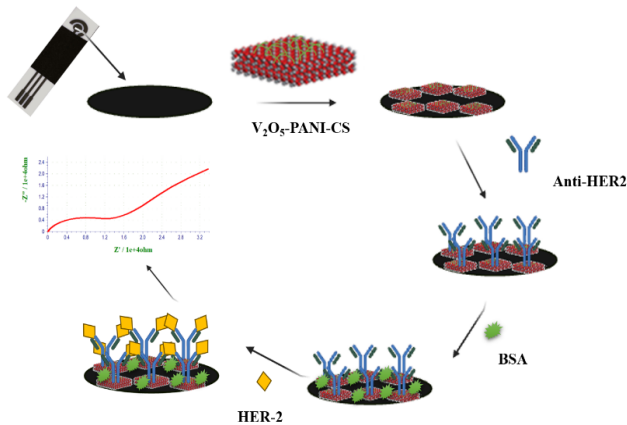


Figure 1. Steps involved in fabrication of immunosensor for HER-2 detection.

PP-160

Electrochemical Detection of Bilirubin Using Carbon dot Functionalised Screen-printed Electrode

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Development of a highly selective and sensitive biosensor for bilirubin has significant implications in clinical diagnosis as it is a vital biomarker for liver function. Hepatic diseases such as cholestasis, liver cancer, results in elevated level of bilirubin in blood, leading to a condition known as hyperbilirubinemia. The periodic monitoring of bilirubin levels in jaundice patients is extremely important and the development of an affordable point-of-care testing method has become the need of the hour. Here, we report a reliable and cost-effective disposable electrochemical sensor for the detection of bilirubin using copper doped carbon dots immobilized in an agarose dried film on screen-printed carbon electrodes. The interaction of bilirubin with the modified electrode has been

thoroughly studied using differential pulse voltammetry and amperometry. The copper doping of the carbon dot provides an active site for interaction with bilirubin due to the affinity of the centres toward the nitrogen present in bilirubin resulting in the formation of complexes. The electrode was fabricated by mixing Cu-carbon dot with hot agarose in 1:1 ratio and drop casting onto the electrode surface. Differential pulse voltammetry (DPV) recorded in 0.05 M Tris-buffer (pH 7.4) showed oxidation peak at 0.35 V. DPV results exhibits an increase in peak current with an increase in bilirubin concentration. Amperometry was conducted at a constant potential of 0.45 V and an increase in current response was observed on addition of bilirubin. Molecules such as uric acid, glucose, dopamine, KCl, NaCl, ascorbic acid, creatinine did not show any potential interference.

PP-161

Spiral Microfluidic Channel for Sequential Delivery of Fluids for Electrochemical Bacterial Detection

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Antimicrobial Resistance (AMR) is emerging as one of the major public health concerns of the 21st century. Accurate and efficient bacterial detection still remains as a greatest challenge in clinical diagnosis where the conventional methods involve intense labour workflows and are less sensitive. Electrochemical sensors are an efficient alternative as they offer rapid response, accurate results and high sensitivity. A Lab-on-chip platform was developed for the detection of bacteria which involves a selective electrochemical sensor integrated with microfluidic chip and microelectronics. This work explains the development of a spiral microfluidic platform for automated, sequential reagent delivery to the electrochemical sensing chamber for bacterial detection. The microchannel width was fixed as 200 μm , ensuring predictable fluid front propagation. The total channel length was defined based on calibrated inter inlet spacing to achieve spatially resolved reagent sequencing without premature mixing. The spiral geometry maximizes hydraulic path length within a compact footprint while minimizing dead volume. Three inlet ports were positioned at predefined intervals: the inlet nearest to the sensing chamber was assigned for sample introduction, the second for washing buffer delivery to remove unbound species, and the third for redox probe introduction for electrochemical interrogation. An air vent was integrated at the innermost terminal region to prevent bubble entrapment and ensure complete wetting of the electrode well. Fluid transport was achieved using a negative pressure outlet pump coupled with a downstream solenoid valve for temporal flow

regulation. Upon valve actuation, the imposed pressure gradient drives the selected reagent into the sensing chamber, and valve closure enables controlled incubation for immobilization or binding kinetics. Sequential valve reactivation permits reagent exchange with minimal cross contamination. Flow behavior follows Hagen Poiseuille dynamics, enabling reproducible, time-controlled multi-step electrochemical assay. The developed microchannel is integrated with the electrochemical sensor and is tested with bacterial sample for real-time validation (Figure 1).

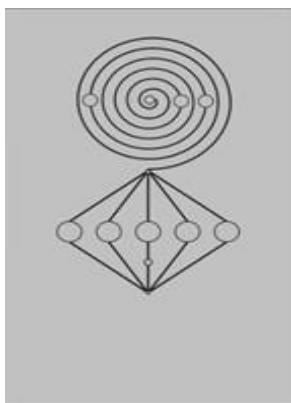


Figure 1. 3D of the microfluidic spiral channel.

Bioleaching of Waste Printed Circuit Boards Using *Bacillus megaterium* in a Stirred Tank Bioreactor

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There is a rising demand for eco-friendly techniques to recover valuable and rare metals due to the growing production of electronic materials. In this work, a stirred tank bioreactor was used to bioleach powdered waste printed circuit boards (WPCBs). In order to achieve steady and productive bioleaching, the bioreactor offered a controlled environment for efficient microbial activity, aeration, and mixing. Recognizing that *Bacillus megaterium* strains are effective in metal dissolving under mild working conditions, they were used as the leaching microorganisms. An alternative to the conventional chemical leaching techniques was assessed using *Bacillus megaterium* in conjunction with a stirred tank bioreactor. This bioreactor-based bioleaching process offers better environmental compatibility and operational simplicity as compared to conventional hydrometallurgical methods. The work delivers a foundation for future process development and scale-up and shows the possibility of employing *Bacillus megaterium* in a bioreactor system for the sustainable recovery of valuable metals from electronic waste.

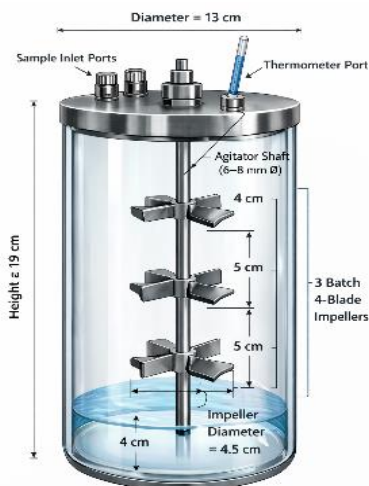


Figure 1. Schematic illustration of stirred tank bioreactor.

Electrochemical Oxidative Degradation of Acetaminophen using Nanostructured α -Fe₂O₃ on Nickel Foam: Optimization and Comparative Framework with g-C₃N₄ Composites

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Acetaminophen (paracetamol), a pervasive pharmaceutical pollutant in aquatic ecosystems due to improper disposal and wastewater discharge, poses significant risks to aquatic life and human health, necessitating advanced remediation technologies [1,3]. This study systematically investigates its electrochemical degradation using nanostructured α -Fe₂O₃ and α -Fe₂O₃/g-C₃N₄ nanocomposite electrocatalysts with varying g-C₃N₄ loadings (5 wt%, 10 wt%, 20 wt%) (Figure 1). Electrocatalysts were synthesized *via* a facile solvothermal method and subsequently immobilized on pretreated nickel foam *via* dip-coating to produce high surface area electrodes. Electrodes underwent comprehensive electrochemical characterization, including linear sweep voltammetry (LSV) and chronoamperometry (CA), in a three-electrode configuration featuring Ag/AgCl reference, platinum counter, and Nickel foam working electrodes. Acetaminophen concentrations were precisely quantified by ultraviolet-visible (UV-Vis) spectrophotometry at its characteristic absorption wavelength of 254 nm. Optimization experiments at an initial 100 mg/L acetaminophen feed independently varied pH (2.0–8.0), applied potential (100–300 mV vs. Ag/AgCl), and treatment duration (0–240 min), pinpointing optimal conditions of 300 mV and pH 3.0, where α -Fe₂O₃ achieved 99.5% removal efficiency in 2.5 minutes. Concentration-dependent performance across 10, 30, 50, and 100 mg/L feeds exhibited inverse relationships: degradation efficiency declined (e.g., 60–80% at 10 mg/L) while required treatment time proportionally increased. At the fixed optimal potential of 300 mV, nanocomposite electrocatalysts significantly outperformed α -Fe₂O₃ across all tested concentrations. Degradation efficiency comparisons across 10–100 mg/L feeds revealed that 10 wt% α -Fe₂O₃/g-C₃N₄ composites consistently achieved the highest performance (>95–100%), outperforming pristine α -Fe₂O₃ and 20 wt% variants, particularly at low concentrations where pristine efficiency dropped to ~75%. Triplicate experiments confirmed excellent reproducibility. The enhanced performance of composites is attributed to g-C₃N₄'s role in facilitating charge separation, expanding electroactive surface area, and promoting hydroxyl radical generation via accelerated oxygen evolution.

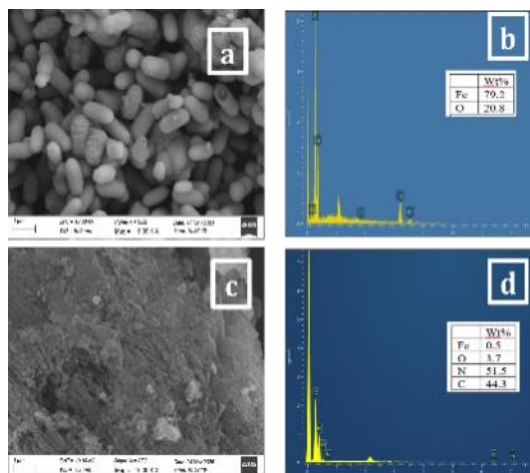


Figure 1. Structural characterization of α - Fe_2O_3 and α - $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$. (a) and (b) SEM and EDS of α - Fe_2O_3 ; (c) and (d) SEM and EDS of α - $\text{Fe}_2\text{O}_3/\text{g-C}_3\text{N}_4$.

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PP-164

Electrodeposited Ni-based Alloy Coating as Effective Barrier for Hydrogen Permeation in Mild Steel

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Hydrogen embrittlement (HE) leads to a severe mechanical property degradation, which poses a significant challenge in structural materials. To address this challenge, an electrodeposited Ni-Zn alloy coating has been developed as an effective hydrogen permeation barrier on mild steel. The morphological and microstructural characterization of the coating reveals a uniform Ni and Zn distribution and the formation of the γ - $\text{Ni}_5\text{Zn}_{21}$ phase. Small punch test (SPT) reveals bare mild steel exhibited a significant reduction in strength and ductility after hydrogen charging, with an HE index of ~40.6%, whereas the Ni-Zn coated specimen showed a substantially lower HE index of ~6.9%,

indicating enhanced resistance towards hydrogen ingress. Electrochemical hydrogen permeation studies based on the Devanathan-Stachurski technique demonstrated a marked decrease in steady-state permeation current density from 0.718 to 0.114 $\mu\text{A}/\text{cm}^2$. The coating also exhibits a reduction in hydrogen concentration inside the specimen from 0.6384 to 0.0641 mol/m^3 achieving an effective hydrogen barrier efficiency of approximately 90%. Overall, the Ni-Zn coating acts as an efficient hydrogen diffusion barrier, significantly suppressing hydrogen ingress and improving structural integrity of metallic materials in hydrogen environments, making it a promising candidate for hydrogen energy infrastructure applications.

PP-165

Green Biocides and Inhibitors for Corrosion and Microbiologically Influenced Corrosion Mitigation using Plant Extracts

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The degradation of metallic materials in marine environments, oil and gas sectors, and fuel storage infrastructures occurs due to corrosion and microbiologically induced corrosion (MIC). The conventional control strategies in industries mostly utilizes synthetic oxidizing and non-oxidizing biocides as well as corrosion inhibitors. However, being synthetic in origin, these suffer from several drawbacks such as toxicity, secondary pollution, and microbial resistance. Recent advancements focused towards the development of eco-friendly, renewable and low-carbon footprint alternatives for corrosion and MIC inhibition. The present study investigates the dual-role of plant extract as green biocides and corrosion inhibitors. It is well documented that bioactive-phytochemicals such as alkaloids, tannins, flavonoids, terpenoids, and phenolic compounds provide strong antimicrobial activity and metal-chelating properties. These compounds may exhibit several mechanisms such as disruption of microbial cell membranes, inhibition of extracellular polymeric substance formation, and biofilm development. Simultaneously, adsorption of heteroatoms (such as N, O, S) - containing molecules onto metal surfaces forms a strong protective barrier film over metallic surfaces. The adsorption of phytochemicals on metal substrates may work as synergistic antimicrobial and corrosion inhibition.

PP-166

Advanced Engineered Boron Nitride for Corrosion Inhibitor Application: A View of Exploring Tailored Materials

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Hexagonal Boron Nitride (h-BN), a promising 2D material for multifarious applications because of its intrinsic properties. Till date, h-BN is incorporated in the coating matrix as an anti-corrosive additive. This work describes the synthesis of h-BN via molten salt synthesis (MSS) technique and further it works on the modification of h-BN with the hydride materials to enhance the performance of anti-corrosive coating for Cu substrate. The efficacious properties of the coating are achieved by the stratified property of h-BN. This performance can more greatly extend via tailoring the h-BN with the hybrid materials which hinders the ingress of corrosive species. The Electrochemical Impedance Spectroscopy (EIS) and Potentiodynamic polarization (PDP) studies reveals the incorporation of tailored h-BN in an aggressive chloride environment with optimal dosage leads to the drastic improvement in the anticorrosive properties of the system.

PP-167

Influence of Additive and Electrolyte Anions on Cobalt and Cobalt Hydroxide Electrodeposition

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Electrodeposition is a versatile and cost-effective technique for fabricating metal and metal hydroxide coatings with controlled structure and properties. Recent studies have shown that organic additives play a crucial role beyond surface brightening by significantly influencing interfacial electrochemical processes. This literature survey focuses on the role of a commonly used organic additive in the electrodeposition of cobalt from different electrolyte baths. Reported studies demonstrate that the organic additive promotes hydrogen evolution reactions, leading to local interfacial pH changes that

favour the formation of porous cobalt hydroxide instead of compact metallic cobalt deposits. Furthermore, the nature of the bath, including different anions such as sulfate, chloride, and nitrate, strongly affects phase formation, microstructure, and functional properties of the electrodeposits. The adsorption of the organic additive enhances hydrogen evolution due to water reduction that facilitates the formation of porous microstructures of cobalt hydroxide. Competition for adsorption sites between the organic additive and anions, and the dissolution of cobalt hydroxide by diffusing protons, result in a mixed metallic cobalt particle and a porous cobalt hydroxide microstructure.

PP-168

Reverse Electroplating: An Innovative Technique to Remove Diamond Particles and Recycle Stainless Steel Wire from Waste Diamond-coated Wire

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Diamond coated wire (DCW) has been widely used in various industries such as semiconductors, photovoltaics and ceramics for cutting and slicing. Notably, the increasing demand for these wires has led to a significant amount of waste generation. The disposal of used DCW raises significant environmental concerns, including waste accumulation through landfilling, potential toxicity, and resource depletion. Furthermore, the economic implications are substantial, resulting in the loss of valuable materials and increased production costs. In this study, we present a new method for recovering waste DCW by extracting diamond particles and stainless steel (SS) wire by removing the Ni coating using the reverse electroplating (REP) process. In this technique, process parameters such as acid concentration (mole), time (minutes), temperature ($^{\circ}\text{C}$), and current density (A dm^{-2}) are optimised to achieve better efficiency. The surface morphology of the DCW was investigated using X-ray diffraction (XRD), Raman spectroscopy, optical microscopy and scanning electron microscopy (SEM). The metal layers and their composition were investigated using energy dispersive X-ray spectroscopy (EDX) and X-ray photoelectron spectroscopy (XPS) analyses. After the REP, the particle size distribution of the retrieved diamond particles and the thickness of the SS wire core were measured. The removal efficiency for the nickel coating and diamond particles from the wire was calculated.

Tailored TiO₂@Ta₂CTx MXene Nanohybrid as Bifunctional Catalyst for Photochemical and Electrochemical Degradation of Congo Red

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In this work, we present a simple and eco-friendly method for preparing a bifunctional TiO₂@Ta₂CTx MXene nanocomposite for the efficient photocatalytic and electrochemical degradation of the Congo Red (CR) dye. After detailed structural and morphological characterization of the synthesized nanocomposite, a comprehensive study of its photo- and electrocatalytic properties was conducted for the degradation of CR. The TiO₂@Ta₂CTx MXene nanocomposite was employed as a photocatalyst in photocatalytic degradation tests and as an anode in electrochemical degradation experiments. Both photocatalytic and electrocatalytic investigations demonstrated maximum degradation efficiencies of 81.3% and 99.1%, respectively. The enhanced performance of the nanocomposite is attributed to the adaptable interaction between TiO₂ and Ta₂CTx MXene, which improves the electrical conductivity and surface area of the material. Furthermore, kinetic studies were carried out to determine the rate constant and activation energy of the degradation process. TiO₂@Ta₂CTx MXene nanocomposite exhibits the highest rate constant of 0.353 min⁻¹, indicating the most efficient electrocatalytic activity. In the electrochemical studies, the effects of various operational parameters, such as supporting electrolyte type, pH, current density, electrolyte concentration, and dye concentration, on the degradation efficiency were systematically investigated. Overall, the TiO₂@Ta₂CTx MXene nanocomposite exhibits excellent potential as a multifunctional material for both photocatalytic and electrochemical applications, making it a promising candidate for environmental remediation (Figure 1).

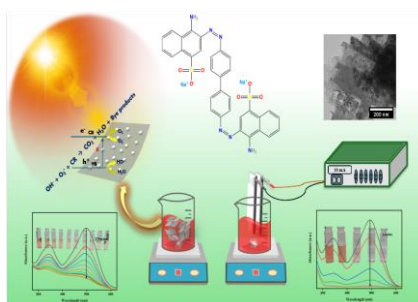


Figure 1. Graphical abstract.

PP-170

Harnessing Microbial System for Corrosion Inhibition: Advances in Bio Inhibition Mechanism and Future Research Strategies

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Microbiologically influenced corrosion (MIC) is a critical concern for industrial infrastructure. Bio-based corrosion inhibitors have been explored as green alternatives to existing corrosion inhibitors due to their green chemistry nature. These corrosion inhibitors inhibit corrosion through mechanisms such as biofilm formation, extracellular polymeric substance production, biomineralization, competitive surface colonization, and electrochemical reaction modification. These mechanisms inhibit corrosion by forming biofilms that produce extracellular polymeric substances. In addition, biomineralization techniques, such as microbially induced calcium carbonate precipitation, are employed to inhibit corrosion. The microbial metabolic activities, including oxygen consumption and extracellular electron transfer, influence anodic and cathodic reactions, which assist in corrosion inhibition. However, the application of microbial corrosion inhibitors is limited by environmental conditions such as pH, temperature, and salinity. Microorganisms are dual-functioning like inhibit corrosion, while others, such as sulphate-reducing bacteria, accelerate corrosion. The focus of this research lies in highlighting knowledge gaps in understanding microbes' interaction with metals in the context of electron transfer, metabolic regulation, and biofilm formation with multiple microbial species. The absence of standardized evaluation methods and insufficient integration of omics and modelling approaches are other challenges.

PP-171

Electrophoretic Deposition of Piezoelectric-bioactive Hydroxyapatite–Barium Titanate Coatings for Implant Applications

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Electrophoretic deposition (EPD) is an effective technique for fabricating hydroxyapatite-based biomedical coatings. Piezoelectricity is believed to play a vital role in stimulating the formation of bone or osseous cells. In this study, nanostructured hydroxyapatite (n-HAp) and HAp/BaTiO₃ (HBT) nanocomposite coatings with weight ratios of 70:30, 50:50, and 30:70 was successfully deposited on titanium substrates at 15 V for 5 min for implant applications. Structural analyses using Raman spectroscopy, FT-IR, and XRD confirmed the characteristic phases of n-HAp and the successful incorporation of BaTiO₃ within the composites. FESEM, EDAX, AFM, XPS, and HR-TEM revealed uniform nanoscale morphology and compositional homogeneity. Nanoindentation showed enhanced hardness and elastic modulus for the composite coatings, indicating improved mechanical stability. Electrochemical studies in simulated body fluid demonstrated superior corrosion resistance of HBT coatings compared to pure n-HAp. The HBT coatings exhibited measurable piezoelectric d_{33} values, suggesting potential osteogenic stimulation under physiological loading. Contact angle analysis confirmed hydrophilic behaviour. In vitro studies, including live/dead staining, MTT assay, protein adsorption, and blood clotting tests, verified excellent biocompatibility and hemocompatibility. Overall, the results demonstrate that EPD-derived HBT-55 nanocomposite coating exhibits promising mechanical, electroactive, corrosion-resistant, and biological performance, making it a strong candidate for next-generation bioactive and piezo-responsive implant coatings.

PP-172

Cobalt Porphyrin Mediated Reduction of Bicarbonate at Liquid-liquid Electrified Interface

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Electrochemical conversion of bicarbonate into value-added products at solid-liquid interfaces have been widely explored. However, the conventional solid-liquid interfacial reaction suffers from several critical limitations, including dominant hydrogen evolution, catalyst surface poisoning, and poor stability. Interfaces between two immiscible electrolytic solutions (ITIES) represent a unique and emerging electrochemical reaction platform that offers numerous advantages, including high selectivity, tunable reaction environments, mechanistic transparency, and exceptional design flexibility. Herein, we developed a novel ITIES platform based on H₂O||DCB containing cobalt porphyrin (Co-Pphy) and decamethylferrocene (DMFc) for effective chemical reduction of bicarbonate to produce value added products which was shown in Figure 1. Co-Pphy plays an essential

role in mediating electron transfer process and DMFc acts as a lipophilic electron donor catalyst. In this system, Co-Pphy and DMFc cooperatively transfer 6 e⁻ for the selective reduction of bicarbonate to methanol, while protons are supplied from the aqueous phase (HCl). The reaction duration and concentrations of HCl, DMFc, and Co-Pphy were systematically optimized and the methanol yield was quantified by NMR spectroscopy. Under the optimized reaction conditions, the chemical reduction of bicarbonate resulted in a methanol with a yield of 8 μM. These results demonstrate that the proposed liquid–liquid interfacial platform provides a promising strategy for the selective chemical conversion of bicarbonate into methanol.

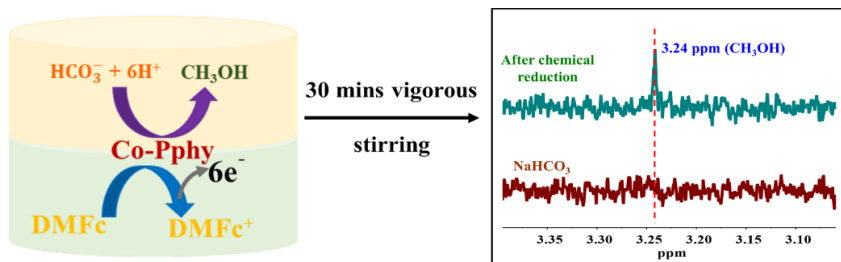


Figure 1. Schematic representation of chemical reduction of bicarbonate to methanol at liquid-liquid interface.

PP-173

Electrochemical Entry to Alkynylphosphonates *via* Copper Redox Catalysis Enabled C_{sp}-P Coupling

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In this letter, we report the C_{sp}-P coupling between terminal acetylenes and dialkylphosphites under electro-redox copper catalysis to prepare alkynylphosphonates. The reaction works via electrochemical generation of cuprous-acetylide, a requisite intermediate for oxidative addition/reductive elimination steps to deliver the product. Few intrinsic features of this chemistry are good synthetic yields, applicability to electron-rich/poor alkynes together with the use of base additive in controlling the product selectivity. Deuterium replacement experiments suggest that the yield variation is pronounced in phosphites rather than alkynes. Assessing the reactivity of electronically distinct alkynes via competitive reactions revealed that the product ratio is somewhat more favored in electron-rich alkynes.

Development of Multi-component TiMN (M = Al, C, Cu) Coatings on Ti6Al4V Alloy for Enhanced Corrosion Resistance

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The development of advanced hard coatings on Ti6Al4V alloy is critical for enhancing their surface durability and corrosion resistance in aerospace applications. In this study, TiN, TiCN and TiAlN coatings were deposited onto 3D-printed Ti6Al4V substrates using magnetron co-sputtering in a reactive gas environment. Nitrogen (N₂) and acetylene (C₂H₂) gases were introduced to promote the formation of nitride and carbonitride phases. The phase structure and surface morphology of the coatings were systematically characterized using X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), and energy-dispersive X-ray analysis (EDAX). In addition, X-ray photoelectron spectroscopy (XPS) was employed to analyze the chemical states and confirm the formation of the desired compounds. The results verified the successful synthesis of dense and uniform coatings with well-defined nitride and carbonitride phases. The corrosion performance of the coated and bare Ti6Al4V substrates was evaluated in 3.5 wt.% NaCl solution to simulate aggressive service environments. Electrochemical impedance spectroscopy (EIS) and Tafel polarization measurements were conducted to assess the corrosion resistance. All coated samples exhibited significantly improved corrosion resistance compared to the bare substrate, indicating effective surface protection. This study demonstrates that reactive magnetron co-sputtering is an effective approach for developing multi-component hard coatings on 3D-printed Ti6Al4V substrates. The improved corrosion resistance and structural stability of these coatings make them promising candidates for aerospace components exposed to harsh operating conditions.

Pitting and Microbial Corrosion Prevention in SS316L Pipeline Section Using a Green Inhibitor-based Surface Modification Method

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An underground pipeline, designed with a 10-inch diameter and constructed from SS316L stainless steel, was engineered to transport a specific chemical compound from a production facility to the port area, spanning a distance of 8.5 kilometers. However, during hydrostatic testing, the pipeline failed to sustain the required pressure, which necessitated a subsequent excavation. Upon investigation, multiple leaks were identified along a significant 70-meter stretch of the pipeline, with individual holes measuring up to 10 millimeters in diameter. In addition to these primary leak sites, several other random locations along the pipeline also exhibited similar leakages. The environmental conditions surrounding the pipeline's installation could have played a critical role in its deterioration. Its proximity to the seashore, along with localized storage of sodium chloride (NaCl) and the potential ingress of saline water, created an environment conducive to chloride-induced pitting corrosion on the inner surface of the SS316L material. A thorough biological assessment revealed a concerning ecosystem of microorganisms, including iron-oxidizing bacteria (IOB), manganese-oxidizing bacteria (MOB), traces of sulfur-reducing bacteria (SRB), and methanogens, all of which might have contributed to the corrosion process. Further inspections focused particularly on areas close to the circumferential weld zone, heat-affected zone (HAZ) surrounding the welds, as well as the as-received SS316L pipe material. These assessments revealed a sensitized microstructure characterized by an abundance of grain boundary carbides, indicating a significant alteration in the material properties due to improper pipeline manufacturing processes. In response to the alarming corrosion issues, a detailed laboratory assessment was initiated, leading to the innovative development of a green corrosion inhibitor and biocide formulation based on aloe vera. This eco-friendly mixture effectively mitigated the corrosion problems affecting the pipeline and provided a sustainable solution to the maintenance challenges posed by the aggressive environmental conditions.

Electrochemical Oxidation of Furans into 2,5-dimethoxy-2,5-dihydrofurans

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Electrochemical oxidation of five-membered oxygen- and nitrogen-containing heterocyclic compounds such as furan, pyrrole, and their derivatives has been extensively studied due to their importance in organic synthesis, materials science, agrochemicals, and pharmaceutical chemistry. These heterocycles exhibit distinct anodic oxidation behaviour governed by aromaticity, heteroatom effects, and substituent patterns, which significantly influence oxidation potentials and reaction pathways. Furan and its substituted analogues undergo anodic oxidation to generate reactive intermediates that participate in nucleophilic addition or ring transformation reactions, yielding functionalized dihydrofuran derivatives. The use of electrochemical methods eliminates the need for stoichiometric chemical oxidants, offering enhanced control over reaction selectivity and sustainability. This study highlights recent advances in the electrochemical oxidation of furan- and pyrrole-based systems (Figure 1), emphasizing mechanistic understanding, structure–reactivity relationships, and potential applications in green synthesis, electroactive materials, and fine chemical production.

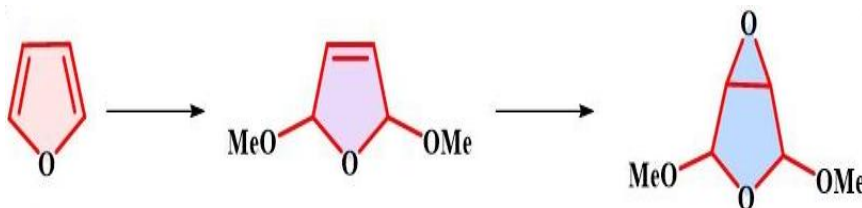


Figure 1. Electrochemical synthesis of 2,5-dimethoxy 2,5-dihydrofuran.

Experimental and Theoretical Study of *Bougainvillea glabra* Leaf Extract as Green Corrosion Inhibitor

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Corrosion of stainless-steel equipment and infrastructures exposed to saline environments is a major challenge in marine, and off-shore regions owing to the continuous exposure to corrosive ions like Cl^- etc. The utilization of inorganic and synthetic corrosion inhibitors is effective, but pose several environmental hazards and toxicity concerns. Therefore, the utilization of renewable and bio-mass derived biodegradable phytochemicals has attained significant attention as green corrosion inhibitors. In the present study, *Bougainvillea glabra* leaf extract as a plant leaf-based green corrosion inhibitor have been investigated to mitigate corrosion of Stainless Steel 304 in 3.5 wt % NaCl medium. The corrosion inhibition efficiency has been elucidated using weight loss measurements, and electrochemical measurements. The surface morphology analysis has been performed using optical microscopy. Electrochemical analysis results indicated a significant reduction in corrosion rate and increased corrosion inhibition efficiency with increasing inhibitor concentration. It has been attributed to the effective adsorption of phytochemicals present in the leaf extract that formed a thin protective layer. Additionally, density functional theory studies of phytochemicals revealed the presence of reactive and electron rich sites suitable for adsorption. A correlation between inhibition efficiency obtained from experimental techniques and theoretical analysis have been established. The findings demonstrated that bio-based green inhibitors provide a cost-effective, eco-friendly, and renewable strategy for corrosion inhibition of Stainless Steel 304 in marine environments (Figure 1).

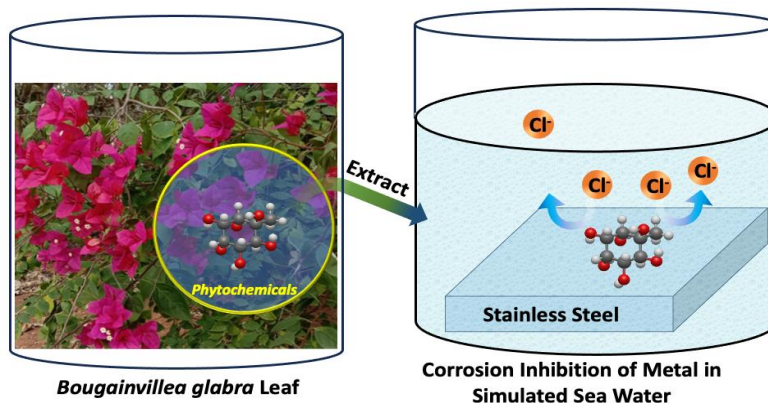


Figure 1. Graphical abstract.

Sustainable Recovery of Copper from Waste Printed Circuit Boards *via* Bioleaching Using *Bacillus megaterium*

Smriti Menon¹, Deepak K Pattanayak², Poonam Singh¹, Rakesh Chandra Barik^{1*}

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Waste printed circuit boards (WPCBs) are a major source of valuable metals, particularly copper. However, traditional recovery methods involve high energy consumption and are detrimental to the environment. The present study investigates an eco-friendly bioleaching strategy employing *Bacillus megaterium* for copper recovery from WPCBs. Powdered PCBs were subjected to bioleaching in a shaking conical flask under conditions at a pulp density of 0.5g/150mL for a period of 15 days (Figure 1). Metal solubilization was mediated by the bacterial strain primarily through the production of organic acids. Bioleachate was constantly analysed using ICP-OES, and revealed a steady increase in copper concentration throughout the incubation period. A maximum copper recovery of 64% was achieved after 15 days of bioleaching. The gradual solubilization trend indicates sustained microbial activity and efficient metal mobilization under optimized laboratory conditions. The findings demonstrate the potential of *Bacillus megaterium* as a sustainable and environment friendly alternative for copper recovery from electronic waste. Further optimization of operational parameters could enhance recovery efficiency and support scale-up for industrial applications.

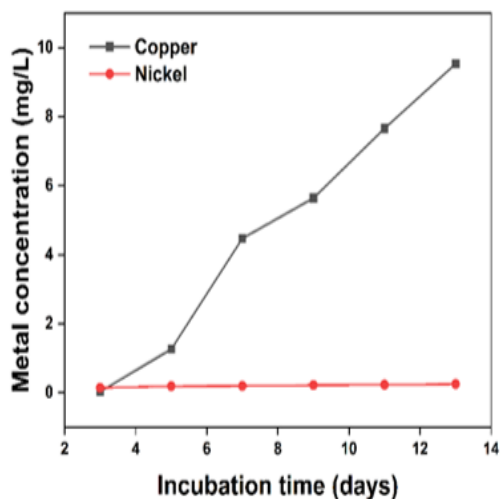


Figure 1. Variation in copper and nickel concentrations (mg/L) in the leachate as a function of incubation time, as measured by ICP-OES analysis.

Sustainable Bimetallic Ag/Zn-Ta₂C MXene Catalyst for Dual Electrocatalysis of Hydrogen Evolution and Acetonitrile Reduction Reactions

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Electrocatalytic water splitting is a sustainable and ecologically friendly process to produce hydrogen (H₂). However, the cathodic hydrogen evolution reaction (HER) typically requires a high overpotential due to its slow kinetics. On the other hand, electrocatalytic reduction of acetonitrile (ARR) offers a more energy-efficient technique with the added benefit of producing secondary and tertiary amines with added value. A bimetallic Ag/Zn-Ta₂C MXene composite was developed in this work as a durable and efficient electrocatalyst for both the HER and ARR in mild conditions. In two distinct environments, the composite showed outstanding catalytic performance: alkaline (1 M KOH) for the ARR and acidic (0.5 M H₂SO₄) for the HER. A current density of 10 mA/cm² was attained by the modified MXene electrode for HER at an overpotential of only 0.083 V vs. RHE and for ARR at -0.23 V vs. RHE. Notably, the hybrid catalyst remained robust under both reaction conditions and maintained high activity for 24 h of continuous operation. The improved exposure of active sites and the mitigation of issues such as mixed valence states and particle aggregation are the reasons for the bimetallic MXene's superior performance over its monometallic counterparts (Figure 1). These results demonstrate the potential of Ag/Zn-Ta₂C MXene as a bifunctional catalyst, providing an economical and environmentally friendly substitute for materials based on noble metals for energy-efficient electrocatalysis.

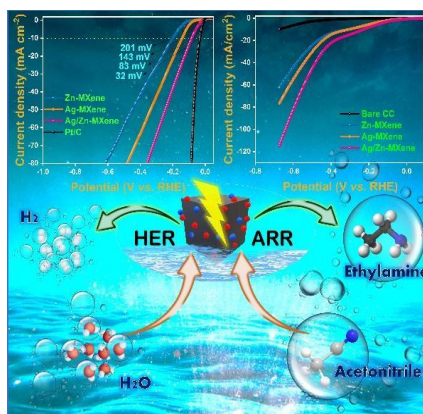


Figure 1. Graphical abstract.

Rare Earth Zirconate-based Novel Coating Systems for Antifouling Applications

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The individual systems of Samarium (Sm), Neodymium (Nd), and Ytterbium (Yb) zirconates were synthesized using a hydrothermal route in an autoclave reactor. The synthesized particles exhibited considerable uniformity in their size and morphology. The characteristics of the synthesized particles were evaluated by Fourier Emission Scanning Electron Microscope (FTIR), X-Ray Diffraction (XRD), and Field Emission Scanning Electron Microscopy (FESEM), Energy Dispersive Spectroscopy (EDS), and High-Resolution Transmission Electron Microscopy (HR-TEM) methods. Each rare earth zirconate powder material was carefully mixed with an appropriate resin and a solvent to produce a colloidal solution of the synthesized zirconate powder materials. Coating was applied over a mild steel substrate after preparing its surface as per the requirements outlined in the coating standard. The rare earth zirconate-coated substrates were exposed in a 3.5% NaCl solution for 30 days. After the removal from the NaCl solution, the substrates were thoroughly examined by various instrumental analyses for any fouling activities by the microorganisms. Further, the work has also been planned for long-term exposure of the coated samples in natural seawater, say a year or two, to evaluate their antifouling characteristics.

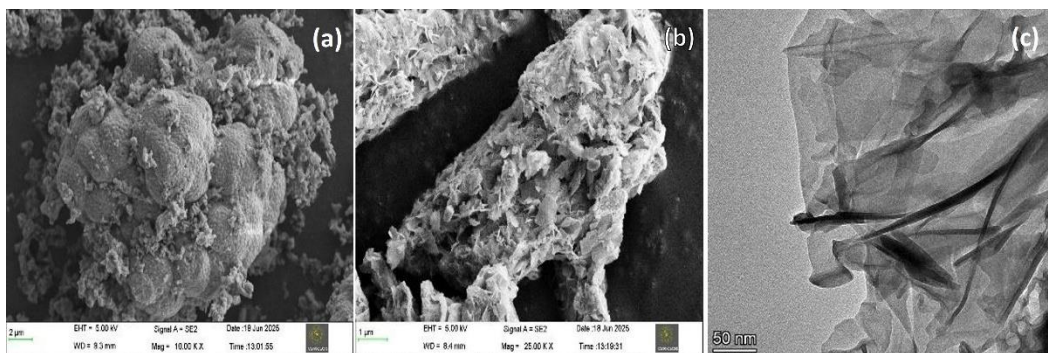


Figure 1 (a-b) SEM images and (c) HR-TEM image of rare earth zirconate nanoparticles.

PP-181

Electrochemical Dating: A Non-destructive and Inexpensive Analysis on Metal and Alloy Based Indian Artifacts

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Dating is an important target in archaeometric studies. Several dating procedures have been proposed based on the analysis of the extent of aging processes on archaeological artefacts. It is not easy in the case of metallic artefacts where the ¹⁴C radiocarbon method can occasionally only be performed when traces of organic matter appear. A general challenge, however, is the achievement of archaeometric information through non-destructive techniques. In our work, we are applying the voltammetry of microparticles (VMPs), and Parafilm Impregnated Electrodes (PIGEs), solid-state and non-destructive electrochemical methods. The research work is based on determining the tenorite/cuprite ratio by exploiting the production of well-differentiated voltammetric responses by such compounds. Known copper and copper alloy coins from different centuries were collected and calibration plots were plotted by CuO/Cu₂O current ratio value vs age of the artifacts. From the calibration plot the age of coins whose age was unknown was calculated. The elemental composition and surface oxidation state of the samples are also analysed by spectroscopic methods.

PP-182

High-Performance Ru₅₀/Pt₅₀-MoS₂/rGO Bifunctional Electrocatalyst for Sustainable Overall Water Splitting and Seawater Electrolysis

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Electrodes play a crucial role in bifunctional applications for alkaline environments, where they catalyze both hydrogen and oxygen evolution reactions. Advanced electrode materials like molybdenum disulfide (MoS₂) embedded in reduced graphene oxide (rGO) layers are pivotal for enhancing catalytic activity in these settings. Their design and material composition directly influence the efficiency and stability of energy conversion processes, making them key to addressing the supply-

demand imbalance in renewable energy. In this work, we have synthesized MoS₂ nanoparticles embedded in rGO layers, enhancing their catalytic activity for both the hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) in alkaline environments. The development of such bifunctional electrodes is crucial for efficient water electrolysis, a key process in the sustainable production and utilization of renewable energy. The nanocomposite materials were characterized using various spectroscopic and microscopic techniques. A Tafel slope of approximately 40 mV/decade suggests that the Volmer-Heyrovsky mechanism predominates in the HER process with the MoS₂/GO composite acting as the catalyst, pinpointing electrochemical desorption of hydrogen as the rate-limiting step. The composite demonstrated superior catalytic behavior compared to the MoS₂/rGO composite, with lower activation energy values indicating faster HER kinetics. Importantly, the robust performance of these alkaline-based electrodes makes them particularly suitable for seawater electrolysis, where they can effectively handle the challenging conditions posed by high salinity and pH levels. This advancement is crucial for the OER as well, ensuring efficient and stable operation under such conditions. This work underlines the importance of developing stable, efficient electrodes for alkaline seawater electrolysis, contributing significantly to the field of energy conversion and storage in renewable energy systems.

PP-183

High-performing Nickel Sulfide Nanoparticles Decorated 2D MXene Electrocatalysts for the Valorization of Furfural

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Furfural, an emerging biomass-derived bio-oil compound, plays a crucial role in achieving carbon neutrality through biomass valorization. This valorization can be achieved *via* electrochemical hydrogenation (ECH), which enables efficient conversion of furfural into value-added chemicals compared to traditional methods. However, optimizing electrode materials and understanding reaction mechanisms for producing value-added products remain challenging in the ECH of furfural. In this work, we investigate the morphology dependence on the precursor concentration of nickel sulfide (NiS) nanoparticles synthesized using ethylenediamine-tetraacetic acid (EDTA) and decorated on 2D MXene. The influence of precursor concentration was analyzed using SEM and HRTEM, revealing sphere-like nanoparticles composed of interconnected nanosheets uniformly deposited on 2D MXene nanosheets. This unique morphology significantly enhances the electrocatalytic activity toward furfural conversion. Furthermore, this study examines the effects of key operational parameters, including electrolyte concentration and applied potential, on conversion efficiency, product yield, and selectivity. The results demonstrate that the NiS/MXene nanocatalyst enables

enhanced furfural conversion into value-added biofuels with high selectivity and yield under mild operating conditions. Overall, this study highlights the critical roles of catalyst morphology and electrolyte concentration in achieving efficient electrochemical hydrogenation of furfural.

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2. R. Karthikeyan, M. Navaneethan, J. Archana, D. Thangaraju, M. Arivanandhan, Y. Hayakawa, Dalton Transactions **46** (2014) 17445-17452.

PP-184

Electro-potential Tuned Dual-functional 2D-on-2D MXene@RGO Symmetric CDI for Scalable Desalination and Lithium-ion Recovery from Spent Batteries

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The escalating demand for clean water and recovery of lithium necessitates sustainable technologies capable of addressing both challenges simultaneously. With global freshwater scarcity influencing over two billion people and lithium demand projected to triple by 2035, sustainable desalination and selective lithium extraction have become pivotal to water energy resource security. However, 2D materials like MXene and RGO experience fundamental constraints, including restacking, reduced ion-accessible sites and limited long-term stability. In particular, proficient removal of saline ions and selective recovery of lithium from spent lithium-ion battery (LIB) leachates are indispensable for supporting water security and circular-economy strategies. In this work, a 2D-on-2D MXene@RGO-based symmetric capacitive deionization (S-CDI) platform was engineered for dual-function applications in desalination of saline water and selective lithium-ion extraction from multicomponent leachates of spent LIB. The hierarchical MXene@RGO heterostructure exhibited tuneable surface functionalities, high conductivity, and abundant redox-active sites, enabling efficient charge transport and ion accessibility. During desalination, the S-CDI system delivered a salt adsorption capacity (SAC) of 86 mg g⁻¹ in 600 mg L⁻¹ NaCl, maintaining rapid electro sorption–desorption kinetics and excellent cycling stability. When applied to simulated LIB leachates containing Li⁺, Co²⁺, Cu²⁺, and Al³⁺ ions, the system achieved a maximum Li⁺ removal efficiency of 53 % at 1.4V while suppressing multivalent-ion co-adsorption to below 10% owing to favourable Li⁺ interactions at the MXene/RGO interface. The superior Li⁺ selectivity arose from its smaller hydrated radius, higher ionic mobility, and favourable

binding interactions at MXene–RGO interfaces, assisted by a cation-exchange membrane (CEM) that minimized co-ion interference. This cost effective, low-voltage, solvent-free, and reusable system establishes a scalable pathway toward integrated water desalination and critical-metal recovery, advancing circular-economy strategies for sustainable water–energy–waste management. The dual-mode capability validated here enhances the broader significance of 2D heterostructure electrodes in enabling multifunctional electrochemical separation technologies.

PP-185

Synergistic Catalytic Effect of Pt-Ni₂P/rGO Composite for Efficient Ammonia Oxidation toward Greener Hydrogen Production

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Hydrogen gas (H₂) is difficult to store and transport because of its very low volumetric density, which forces the use of high-pressure cylinders or cryogenic systems. In contrast, ammonia (NH₃) contains 17.8 wt% hydrogen higher than most hydrides and alcohol-based hydrogen carriers and can be liquefied under relatively mild conditions (-33 °C or 8-10 bar), allowing safe, economical storage and long-distance transport. Therefore, storing hydrogen as ammonia is a better and cheaper way to handle it than managing it directly. Furthermore, when required, the hydrogen can be extracted from the ammonia easily. Herein, a ternary Pt-Ni₂P/rGO composite was successfully produced and tested as a high-efficiency electrocatalyst for the hydrogen evolution reaction (HER), the oxygen evolution reaction (OER), and the electrochemical ammonia oxidation reaction (AOR). Electrochemical studies show that the Pt-Ni₂P/rGO catalyst is substantially more active for HER, OER, and AOR activity than pure Pt, Ni₂P, and binary Pt-Ni₂P catalysts. It has a low overpotential, high peak current density, high stability, low cell voltage, and a higher turnover frequency in alkaline medium. These studies indicate that the Pt-Ni₂P/rGO composite is an excellent electrocatalyst for efficient hydrogen production *via* ammonia oxidation and also give significant insights for the strategic development of multifunctional catalysts for future energy applications.



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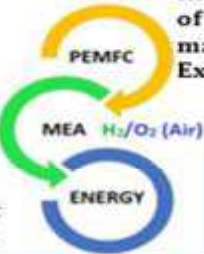
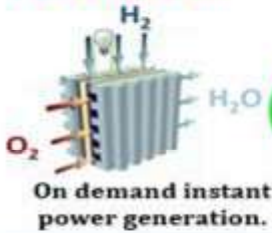
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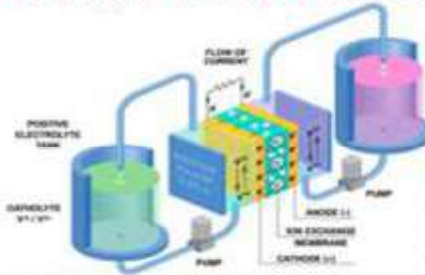
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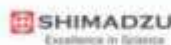




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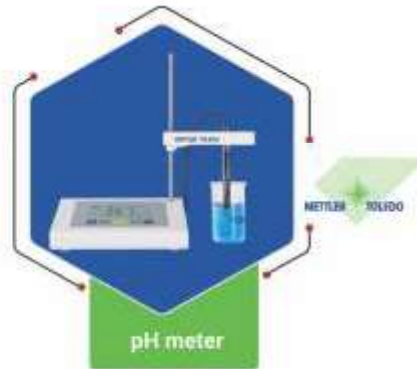
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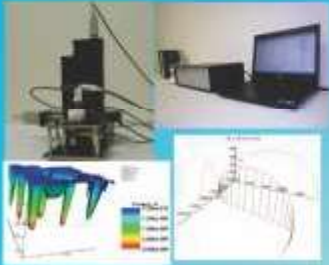


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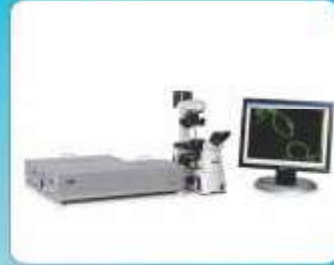
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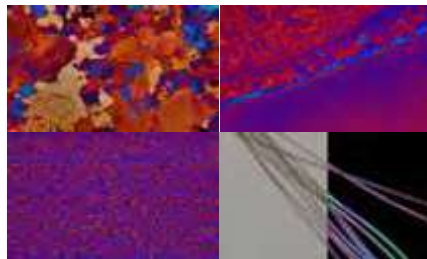
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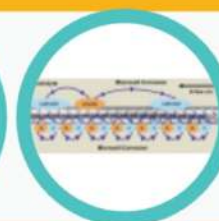
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Twenty Fourth **National Convention of Electrochemists**

Date :
April 27 & 28, 2026

Venue :
Amrita Vishwa Vidyapeetham, Coimbatore

NCE-24



Organized by :

**Society for Advancement of
Electrochemical Science and Technology,
Karaikudi**

in Association with

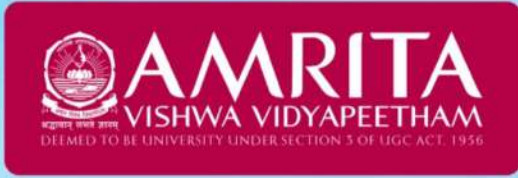


**CSIR-Central Electrochemical
Research Institute, Karaikudi**



**Amrita Vishwa Vidyapeetham,
Coimbatore**





Come. Become.



10

CAMPUSES



20

CONSTITUENT
SCHOOLS



300+

PROGRAMS



30,000+

STUDENTS



2000+

FACULTY
MEMBERS



800+

PH.D. FACULTY



**NAAC A++
ACCREDITED**



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UGC, GOVT. OF INDIA**

**No.1
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AMARAVATI | AMRITAPURI | BENGALURU | CHENNAI
COIMBATORE | FARIDABAD | HARIDWAR | KOCHI | MYSURU | NAGERCOIL



FUEL CELL TEST STATION

- ✓ 5mL/min to 100LPM
- ✓ 5ltr capacity with auto filtering
- ✓ Load 1kW to 6kW
- ✓ HFR @ 1KHz
- ✓ rsi software

AEM/PEM ELECTROLYSER TEST BENCH

- ✓ Accurate flow
- ✓ Control power supply mA to A
- ✓ Hydrogen flow monitor
- ✓ Voltage 0 to 100V
- ✓ rsi suite



- ✓ Electrochemical Workstation
- ✓ Multichannel Upgradation
- ✓ EIS 5MHz @ 7.5V AC
- ✓ ± 1 A, ± 5 A, ± 10 A & ± 20 A @ ± 15 V
(Ideal For Battery Pack Testing)

ROTATING DISK ELECTRODE

- ✓ Up to 10,000 RPM
- ✓ Easy To Use
- ✓ Compatible with any Potentiostat



- ✓ AEM, AEL, PEM, RFB and Fuel cell complete software control (RSI Suite Software) And accessories