



ELECTROBATT 2026

4-6 November, Rikli Balance Hotel, Bled, Slovenia

PROCEEDINGS

International Conference on
**Electrochemistry of Batteries and Energy
Storage Technologies - ElectroBatt 2026**



Organised by:



NATIONAL INSTITUTE
OF CHEMISTRY

Professional Congress Organiser (PCO)



 **cankarjev dom**

KONGRESNO
KOMERCIALNI
PROGRAM

CONGRESS
AND EVENT
MANAGEMENT



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Welcome Address

Dear colleagues, dear friends,

On behalf of the organizing committee, it is our great pleasure to welcome you to Bled and to the second edition of ELECTROBATT.

Two years ago, our first meeting in Romania set out to strengthen the European battery research community, with a particular focus on Central and Eastern Europe. Given more than 150 participants of second edition, we are delighted that this mission continues and grows stronger.

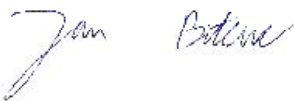
Over the next three days, we will cover the full breadth of electrochemical energy storage, ranging from next-generation battery chemistries and electrolyte design to electrode processing, recycling, modeling, and characterization. But the programme is only half of what makes a conference. The other, more important half is you: the conversations, the new partnerships, and the ideas that begin over a coffee break or a shared meal.

We especially want to welcome our young researchers. This is your community, and ELECTROBATT is meant to be a place where established experts and early-career scientists meet as equals and establish new collaborations. Please ask questions and challenge ideas.

We would like to thank our sponsors and exhibitors, whose support makes this meeting possible, as well as our invited speakers, the organizing committee, and all of you for your contributions.

We wish you an inspiring, productive, and enjoyable ELECTROBATT 2026.

Welcome to Slovenia!



Dr. Jan Bitenc
Conference Co-Chair



Alexandru Vlad
Conference Co-Chair

Committees

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Acknowledgements

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PROGRAMME



Programme

Wednesday, 4 November 2026 | Arnold Hall

10:45 - 11:00	WELCOME ADDRESS
11:00 - 13:00	Sustainability <i>Chairperson: Alexandru Vlad</i>
11:00 - 11:30	The Price of Circularity: Can Battery Electrochemistry Survive Recycling? Petr Novak <i>(Germany)</i> Invited Lecture
11:30 - 11:45	Towards Sustainable Prussian Blue Analogues: A Solvent-Free Mechanochemical Approach Paula Sanz Camacho , <i>Samuel Hernandez Robles, J.F. Marco, Lorenzo Stievano (Spain)</i>
11:45 - 12:00	Regenerated PBA as Active Material in Na-Ion Batteries José Antonio Coca Clemente , <i>Lydia Cuenca Martín, Mahdiah Hakimi, Mohhedine Wehbie, Mariela Gisela Ortiz, Juan Manuel Pérez, Paula Sanz Camacho (Spain)</i>
12:00 - 12:15	Relating Carbon Anode Porosity to Sodium Storage Performance Jonas Krug von Nidda , <i>Paul Appel, Alain Cerny, Glen Smales, Brian Pauw, Tim-Patrick Fellinger (Germany)</i>
12:15 - 12:30	Nanostructured Vanadium Oxides as High-Performance Cathodes for Sodium-Ion Batteries Andrea Zambotti , <i>Quynh Nguyen, Bruce Dunn, Keyue Liang, Yuzhang Li (United States)</i>

12:30 - 12:45	Graphene Quantum Dot-Based Nanostructured Electrodes for Advanced Sodium Ion Batteries Grainne Gilleece , <i>Dagou Zeze, Natasha Shirshova, Ensieh Hosseini (United Kingdom)</i>
12:45 - 13:00	Sustainable Aqueous Nanocellulose Biobinder for Lithium-Ion Battery Anode Processing Carlos Herreros-Lucas , <i>Miguel Varela Hoyos, Tamara Nóvoa González, Celia Urrutia Codesal, Pedram Ghorbanzade, Belén Veiga Seijo, Lidia Marquino Fernández, Vanesa López Puente, María del Mar Castro López, Rosalía Noguero Cal, (Spain)</i>
13:00–14:15	LUNCH BREAK
14:15 - 16:00	Electrochemical Characterization <i>Chairperson: Petr Novak</i>
14:15 - 14:45	A Novel Multi-Channel Online Electrochemical Mass Spectrometer for Battery Gas Analysis Applied to Electrolyte Additive Screening Michael Metzger <i>(Canada)</i> Invited Lecture
14:45 - 15:00	Ex Situ Degradation Diagnostics of NMC111, NMC622, and NMC811 Cathodes for Lithium-Ion Batteries Alicja Glaszczka-Ciftci , <i>Sai Rashmi Manippady, Magdalena Winkowska-Struzik, Michał Struzik, Andrzej Czerwinski, Dominika A. Buchberger (Poland)</i>
15:00 - 15:15	Probing, Preventing, and Healing Lithium-Ion Batteries: Third-Electrode Integration and Functional Separator Alexis Martin , <i>Bruna Canu, Rémi Dedryvere, Dominique Foix, Jean-Marc Krafft, Arnaud Perez, Christel Laberty-Robert (France)</i>

15:15 - 15:30	Impact of CC and CCCV Charging Methods on Degradation in Nickel-Rich Cathodes via In-Situ X-Ray Diffraction and Raman Spectroscopy <u>Paweł Stępnicki</u> , Dominika Buchberger, Alicja Głaszczka-Ciftci, Ioanna Pateli, Oxana Magdysyuk, Andrzej Czerwiński, John Irvine (Poland)
15:30 - 15:45	Standardization of Rate Performance Analysis Through Chronoamperometry <u>Sergio Pinilla</u> , David Muñoz-Torrero, Jesus Medina Santos, Tomas Garcia, Valeria Nicolosi (Spain)
15:45 - 16:00	The Influence of Potassium Metal Counter Electrodes on the Evaluation of Hazelnut-Derived Hard Carbon Anodes for Potassium-Ion Batteries <u>Noemi Martín Hernández</u> , Thomas Diemant, Dominic Bresser, Maider Zarrabeitia (Germany)
16:00–16:30	COFFEE BREAK
16:30 - 18:00	Post-Lithium Batteries <i>Chairperson: Miran Gaberšček</i>
16:30 - 16:45	Dynamic Electrochemical Impedance Spectroscopy Reveals Magnesium Anode Stabilization by Fluorinated Ether Additives in Mg Metal Batteries <u>Hafiz Ahmad Ishfaq</u> , Andrijana Marojević, Gregor Kapun, Jan Bitenc, Miran Gaberšček, Robert Dominko, Sara Drvarič Talian (Slovenia)
16:45 - 17:00	Decoupling Ion Transport From Interfacial Stability by Mixed Coordination Electrolytes for Magnesium Batteries <u>Toshihiko Mandai</u> (Japan)
17:00 - 17:15	Seeing the Chemical Components of SEI: Nanoscale TERS Imaging of Magnesium Anode Interfaces <u>Sirshendu Dinda</u> , Shivaraju G Chandrappa, Maximilian Fichtner (Germany)

17:15 - 17:30	Calcium Electrodeposition From Nitrile Solvents <u>Zoran Mandić</u> (Croatia)
17:30 - 17:45	Influence of Additive-Level Sodium Incorporation on the Electrochemical Performance and Morphology of Calcium Deposits in a Fluorinated Alkoxyborate Electrolyte <u>Tjaša Pavčnik</u> , Ngoc Thuan Vo, Jan Bitenc, Alexandre Ponrouch (Spain)
17:45 - 18:00	Pd NPs Modified Mg-Ni Alloys – Investigating Physicochemical Properties and Electrochemical Absorption of Hydrogen in Protic Ionic Liquid Małgorzata Pająk, Ewa Marcinowicz, <u>Katarzyna Hubkowska</u> , Agata Radziwonko (Poland)
18:00-20:00	WELCOME RECEPTION

Thursday, 5 November 2026 | **Arnold Hall**

08:30 - 10:30	Li-Ion Batteries <i>Chairperson: Jan Bitenc</i>
08:30 - 09:00	Tracking Electron and Ion Fluxes in Energy Storage Electrodes: Advanced Electrochemical Characterization Approaches Patrice Simon (France) Invited Lecture
09:00 - 09:15	Design and Integration of Core-Shell NMC Structures for High-Stability Lithium-Ion Batteries Dominika Buchberger , Magdalena Winkowska-Struzik, Natalia Firlej, Michał Grygiel, Alicja Glaszczka-Ciftci, Krzysztof Gadomski, Michał Struzik, Andrzej Czerwinski (Poland)
09:15 - 09:30	High-Performance Electrolyte Compositions for Lithium-Ion Batteries With Solvent-Free Cathodes Maciej Marczewski , Marek Marcinek, Maciej Smoliński, Natalia Izdebska, Hubert Noparlik (Poland)
09:30 - 09:45	Transmission Line Modeling of Li-Ion Insertion Porous Electrodes: The Role of Electrolyte Ambipolar Diffusion Jože Moškon , Sara Drvarič Talian, Lana Regent, Marko Firm, Robert Dominko, Miran Gaberšček (Slovenia)
09:45 - 10:00	Post-Mortem Analysis of Synthesized and Commercial NMC111 Cathodes After Long-Term Cycling in Li-Ion Cells Sai Rashmi Manippady , Alicja Głazszczka, Magdalena Winkowska-Struzik, Andrzej Czerwiński, Dominika Buchberger (Poland)
10:00 - 10:15	Operando Investigation of Degradation Mechanisms in Silicon Nanoparticle-Based Anodes <i>Petr Čech, Graciela Eguía Marquez, Manoj Muraleedharan Pillai, Milan Dopita, Otakar Frank, Zuzana Vlčková (Czech Republic)</i>

10:15 - 10:30 Oral	What Electrochemical Impedance Reveals and Hides in Graphite-Silicon Composite Particles Klemen Zelič , Jan Šuntajs, Tomaž Katrašnik (Slovenia)
10:30-11:00	COFFEE BREAK
11:00 - 13:00	Advanced Characterization <i>Chairperson: Patrice Simon</i>
11:00 - 11:30	Operando Studies of Intercalation Processes Clare P. Grey (United Kingdom) Invited Lecture
11:30 - 11:45	Unravel Battery Ageing Through Advanced Characterization and Modeling Yaolin Xu (Finland)
11:45 - 12:00	Insights Into Silicon Solid-State Battery Mechanical Degradations With Operando FIB-SEM and Digital Image Correlation Patrice Perrenot , Olga Stamati (France)
12:00 - 12:15	Tackling Complexity in Post-Li-Ion Battery Research: From Machine Learning-Assisted Scattering to Data-Driven Experimental Design Christian Prehal (Austria)
12:15 - 12:30	Chemical Transformations in Battery Materials by Operando X-Ray -Based Methods Alexey Koposov (Norway)
12:30 - 12:45	Compositionally Complex Spinel Oxides and Oxyhalides With Enhanced Electrochemical Properties Martin Fabián , Olena Porodko, Ladislav Kavan, Barbora Pitňa Lásková, Markéta Zukalová (Slovakia)

12:45 - 13:00	Beyond Superoxide & Peroxide: (Su)peroxocarbonates and Their Reactivity With Battery Electrolytes <u>Bhargavi Pant</u> , <i>Po-Hua Su, Stefan A. Freunberger (Austria)</i>
13:00–14:15	LUNCH BREAK
14:15 - 16:00	Post-Li-Ion Batteries <i>Chairperson: Clare Grey</i>
14:15 - 14:45	Scaling Vanadium Redox Flow Batteries: From Stack Development to Utility-Scale Energy Storage <u>Michal Bumbák</u> <i>(Slovakia)</i> Invited Lecture
14:45 - 15:00	Designing Li-S and Redox Flow Hybrid Storage Through Advanced Material Modelling and Development <u>Andrea Straková Fedorková</u> , <i>Veronika Ničšáková, Natália Podrojková, Renáta Oriňáková, Jakub Leščinský (Slovakia)</i>
15:00 - 15:15	A New Theoretical Framework to Investigate the Precipitation Kinetics of Discharge Products in Li-S Batteries <u>Albin Conde Reis</u> <i>(Belgium)</i>
15:15 - 15:30	From Lean to Viscous Electrolytes in Lithium Sulfur Batteries: A Combined Experimental and Modeling Investigation <u>Tommaso Filippo Lupatelli</u> , <i>Massimo Santarelli, Silvia Bodoardo (Italy)</i>
15:30 - 15:45	Data-Driven Benchmarking and Design Rules for Practical Lithium–Sulfur Batteries <u>Saeed Yari</u> , <i>Albin Conde Reis, Quanquan Pang, Momo Safari (Belgium)</i>
15:45 - 15:55	INDUSTRY TALK Modular Inert-Gas Mini-Environments for Lithium-Ion and All-Solid-State Battery Cell Production <u>Ferdinand Schmitt</u> - M. Braun

16:00–16:30	COFFEE BREAK
16:30-17:25	Aqueous Batteries <i>Chairperson: Michal Bumbák</i>
16:30-16:45	Challenging the Paradigm: CEI Formation on the Oxide Surface in a Conventional Aqueous Electrolyte <u>Milica Vujković</u> , <i>Borislav Vasić, Zorica Konstantinović, Benjamin Martinez, Natasa Tomić (Serbia)</i>
16:45-17:00	Designing Stable Aqueous Zinc-Ion Batteries via Electrolyte and Interface Regulation <u>Jiří Červenka</u> <i>(Czech Republic)</i>
17:00-17:15	Redox-Selective Control of Perylene Diimide for Ultrafast, Durable Aqueous Sodium-Ion Storage <i>Sebastian Liebl, Christoph Griesser, Daniel Werner, Toni Moser, Julia Kunze-Liebhäuser, Engelbert Portenkirchner (Austria)</i>
17:15-17:25	INDUSTRY TALK Powering Battery Innovation Through Flexible Automation <u>Arianna Tiozzo</u> - Comau
17:25-17:30	SHORT INFO
18:00 - 19:15	POSTER SESSION
19:45	GALA DINNER

Friday, 6 November 2026 | **Arnold Hall**

09:00 - 11:00	Solid-State Batteries <i>Chairperson: Michael Metzger</i>
09:00 - 09:30	Novel Electrolyte Components for Batteries and Supercapacitors <u>Guinevere Giffin</u> (<i>Germany</i>) Invited Lecture
09:30 - 09:45	Turning Waste Into Value: Biosourced and Recycled Polymers for Safe, Sustainable, High-Performing Li-Based Batteries <u>Hamideh Darjazi</u> , <i>Leonardo Balduccia, Alessandro Piovanoa, Giuseppina Meligranaa, Giuseppe A. Elia, Claudio Gerbaldia (Italy)</i>
09:45 - 10:00	Modeling Ion Transport in Solid-State Electrolytes: From the Perspective of Potential Energy Surfaces <u>Amber Mace</u> (<i>Sweden</i>)
10:00 - 10:15	Single- Ion Conducting Nanohybrid Electrolytes for Lithium Metal Batteries <u>Athira Mullakkal Ravikumar</u> , <i>Aurelie Gueguen, Laurent Castro, Anu Jacob, Maria Martinez-Ibanez, Michel Armand, Shanmukaraj Devaraj (Spain)</i>
10:15 - 10:30	Photocrosslinked PEO–PEC Electrolytes Enabling Long-Life Lithium and Sodium-Metal Solid-State Batteries <u>Rijul Bajaj</u> , <i>Hamideh Darjazi, Leonardo Balducci, Giuseppe A. Elia, Claudio Gerbaldi (Italy)</i>
10:30 - 10:45	Toward Scalable Dry Processing of Composite Single-Ion-Conducting Polymer Electrolytes for Lithium Metal Batteries <u>Meisam Hasanpoor</u> , <i>Kevin Vattappara, Federica Tidona, June Blanco Molina, Maria Carmen Morant Miñana, Sara Abada, Maxime Pelerin, Pierre-Louis Brient, Camille Chatard (Austria)</i>

10:45 - 11:00	Cathode Engineering in Sulfide Solid-State Batteries: From Insertion-Type NMC to Conversion-Type Li-Te Chemistries <u>Remith Pongilat</u> , <i>Ngoc-Tram Phung, Mathieu Pinault, Sylvain Franger (France)</i>
11:00–11:30	COFFEE BREAK
11:30 - 13:00	Solid-State Batteries and Material Processing <i>Chairperson: Guinevere Giffin</i>
11:30 - 11:45	High-Transference-Number Polymer-in-Solvent Single-Ion Electrolytes for Lithium Metal Batteries <u>Yassine Eddahani</u> , <i>Valerio Prisco, Damien Montarnal, Eric Drockenmuller, Renaud Bouchet (France)</i>
11:45 - 12:00	Interface Structural Stability and Li-Ion Transport in Anode-Side Li₉N₂Cl₃ Li₂ZrCl₆ Solid-Electrolyte Bilayer for All-Solid-State Batteries by Large-Scale Molecular Dynamics Simulations and Sparse Gaussian Process Regression Potential <u>Sudeshna Madhual</u> , <i>Kazunori Takada, Randy Jalem (Japan)</i>
12:00 - 12:15	Non-Crystalline Chlorides as New Electrolytes for Sodium-Ion Solid-State Batteries <u>Jean Rouveyrolles</u> , <i>Romain Berthelot, Long H.B. Nguyen (France)</i>
12:15 - 12:30	Optimization of Slurry Preparation and Coating Parameters in Ni-Rich NMC/LMFP Blended Cathodes and Their Electrochemical Performance <u>Kartal Arslan</u> , <i>Kamil Burak Dermenci, Maitane Berecibar (Belgium)</i>
12:30 - 12:45	Interface Engineering of Micro-Sized Silicon Particles by Atomic Layer Deposited ZnO for Advanced Silicon/Graphite Composite Anodes <u>Adarsh Sunilkumar</u> , <i>Helle-Mai Piirsoo, Boris Hudec, Ahmed Nada, Matej Mičušík, Peter Švec, Jr., Mansi Maruti Harkare, Magdaléna Precnerová, Zoltán Lenčేశ, Karol Fröhlich, (Slovakia)</i>

12:45 - 13:00	Lithiophilic Sn@MXene Composite Electrodes as Hosts for Stable Lithium Metal Anodes <u>Nicholas Vallana</u> , Antonio Gentile, Stefano Marchionna, Lorenzo Stievano, Riccardo Ruffo (Italy)
13:00–14:15	LUNCH BREAK
14:15 - 15:30	Electrolytes and Post-Li-Ion Batteries <i>Chairperson: Robert Dominko</i>
14:15 - 14:30	Heat-Capacity-Mediated Driving Force Crossover for Solvation-Structure Evolution in Battery Electrolytes <u>Aiping Wang</u> , Miran Gaberšček, Robert Dominko (Slovenia)
14:30 - 14:45	Improving Reversible Deposition of Li for Anode-Free Technology by Tuning Electrolyte Composition <u>Emma Mourey Pineira</u> , Fannie Alloin, Lauréline Lecarme, Yanlong Zhou, Claire Villevieille (France)
14:45 - 15:00	Polyimide-Linked Hexaazatriphenylene-Based Porous Organic Polymer With Multiple Redox-Active Sites as a High-Capacity Organic Cathode for Lithium-Ion Batteries <u>Arindam Mal</u> , Jonathan Caroni, Manuel Souto (Spain)
15:00 - 15:15	Enhancing Energy Density in Non-Aqueous Redox Supercapacitors Through Interfacial Electron-Transfer Control <u>Suparna Das</u> , Beatriz Oraá-Poblete, Daniel Perez-Antolin, Rebeca Marcilla, Jesus Palma, Paula Paula Navalpotro (Spain)
15:15 - 15:30	Ionic Liquids for Next Generation Hydride Batteries. Unlocking the Potential of Mg-Ni-Based Alloys Katarzyna Hubkowska, <u>Małgorzata Pająk</u> , Dorota Monikowska, Agata Radziwonko, Ewa Marcinowicz, Andrzej Czerwiński (Poland)
15:30-15:45	CLOSING CEREMONY & CONCLUDING REMARKS

POSTERS



Posters

P-01	Phase-Selective Silicon Degradation and Its Impact on OCV-Based SOC Estimation in Commercial Li-Ion Batteries With SiG Composite Anodes <u>Martin Kemeny</u> , Ondrej Gallo, Miroslav Mikolasek (Slovakia)
P-02	Engineering Silicon-Graphite Anodes for High-Energy Lithium-Ion Batteries <u>Dominika Capkova</u> , Tomáš Kazda, Tomáš Zikmund, Jozef Kaiser (Czech Republic)
P-03	Developing High Energy Density Lithium-Ion Pouch Cell Through Electrolyte Selection <u>Iker Castrillo Maestro</u> , María Canal, Imanol Landa-Medrano, Rebeca Azpiri, Grace Bridgewater, Aitor Eguia (Spain)
P-04	Towards Chain Length Dependent CEI Engineering of Ni-Rich NMC Cathodes Using Nitrile Additives <u>Swathy Narayanan</u> , Balasubramanian Rajagopalan, Jakub Reiter, Markus Valtiner (Slovakia)
P-05	Tailoring an Inorganic-Rich Solid Electrolyte Interphase in Lithium-Ion Batteries With Cyclotriphosphazene Electrolyte Additives <u>Mahima Ann Paul</u> , Elmar Kataev, Balasubramanian Rajagopalan, Yan Lu, Jakub Reiter, Marcus Bär (Germany)
P-06	Effect of TMSB and TMSB/TMSP Additives in LP30-Based Electrolytes on the Electrochemical Performance of High-Voltage NMC811/Graphite Prismatic Cells <u>Cosmin Ungureanu</u> , Alexandru RizoIU, Adina Melinte, Alin Chitu, Adnana Spinu-Zaulet, Mihaela Buga (Romania)
P-07	Plasma-Functionalized Carbon Nanotubes as Conductive Additives for Water-Processed Li-Ion Battery Electrodes <u>Driëlle Müller</u> , Cédric Vandenabeele, Helene Tonnoir, Trung Pham Thanh, Nathalie Job, Stéphane Lucas (Belgium)

P-08	Tailoring Structural Defects in Li-Rich Layered Oxides Through Controlled Sol–Gel Synthesis <u>Rabail Badar Abbasi</u> , Marjan Bele, Giuliana Aquilanti, Jasper Plasier, Anton Meden, Elena Tchernychova, Robert Dominko (Slovenia)
P-09	Asynchronous Delithiation Driven by Surface Impurities in Ni-Rich Cathodes <u>Weidong Zhang</u> , Akshay Rao, Clare P. Grey (United Kingdom)
P-10	Beyond Al₂O₃: HfO₂ Atomic Layer Deposition Enables Stable Cathode-Electrolyte Interphases in Hybrid LiNi_{0.5}Mn_{1.5}O₄/Graphite Dual-Ion Batteries <u>Indranil Bhattacharya</u> , Oliver Lohrberg, Kristian Nikolowski, Boris Hudec, Karol Frohlich, Prangya Parimita Sahoo (Slovakia)
P-11	Exploring the Potential of High Entropy Oxides With Spinel Structure for Lithium-Ion Batteries <u>Olena Porodko</u> , Martin Fabián, Ladislav Kavan, Markéta Zukalová (Slovakia)
P-12	Shape-Controlled, Green-Synthesized Noble Metal Nanoparticles as Functional Modifiers of Lithium-Ion Battery Anode Materials <u>Oksana Velgosova</u> , Katarína Gáborová (Slovakia)
P-13	Green Silver Nanoparticles Modification of Biomass-Derived Carbon Anodes for Lithium-Ion Batteries <u>Katarína Gáborová</u> , Oksana Velgosová (Slovakia)
P-14	Synthesis Challenges and Electrochemical Characterization of Al-Containing Medium-Entropy Spinel Oxides for Lithium-Ion Batteries <u>Dávid Csík</u> , Lenka Oroszová, Gabriela Baranová, Beáta Ballóková, Zuzana Molčanová, Róbert Džunda, Mária Hagarová (Slovakia)
P-15	DRT-Assisted Impedance Analysis of Nano-Silicon Anodes <u>Petr Čech</u> , Graciela Eguía Marquez, Otakar Frank, Zuzana Vlčková Živcová (Czech Republic)
P-16	Low-Frequency Resistance Derived Using Analytical Impedance Theory as a Simplified Battery Model <u>Yadul Sethi</u> , Bharatkumar Suthar (India)

P-17	Direct Determination of Tortuosity of Ni-Rich NMC Electrodes via Full Insertion Transmission Line Modeling Lana Regent , Jože Moškon, Tommaso Battiston, Lucia Mancini, Miran Gaberšček, Robert Dominko (Slovenia)
P-18	Geometry-Induced Impedance Artifacts in Through-Plane Tortuosity Measurements of Porous Electrodes Manju Palanisamy , Abhishek Srivastava, Bharatkumar Suthar (India)
P-19	Advanced Diagnostics: Embedded Printed Sensors for Transition Metal Dissolution Detection in Lithium-Ion Batteries P-19 Amina Pašović , Tomáš Syrový, Sara Drvarič Talian, Robert Dominko (Slovenia)
P-20	Advanced AFM Characterisation Tools for Battery-Related Materials Matěj Hývl , Elena Tchernycheva, Robert Dominko, Martin Ledinský (Czech Republic)
P-21	Impact of Slurry Composition and Coating Thickness on the Electrochemical Performance of (CrMnFeCoNi)3O4 Anodes Gabriela Baranová , Dávid Csík, Alexander Kolšovský, Lenka Oroszová, Beáta Ballóková, Zuzana Molčanová, Róbert Džunda, Mária Hagarová (Slovakia)
P-22	PBM Techniques for Enhanced Particle Dynamics Modelling of Slurry Mixing: Viability and Outlooks Mitchell Rae , Mehakpreet Singh, Michela Ottaviani, Dominika Capkova, Tomáš Kazda, Petr Vyroubal (Czech Republic)
P-23	Engineering High Solid Loading Electrode Slurries for Sustainable Lithium-Ion Batteries Manufacturing Grgur Mihalinec (Croatia)
P-24	Impact of Cell Ageing on the Thermal Behaviour of Battery Energy Storage Systems Marek Sedlarik (Czech Republic)
P-25	Environmental and Morphological Evaluation of Controlled Thermochemical Processing for the Sustainable Pre-Treatment of Spent Battery Electrodes Anna Pražanová , Zbyněk Plachý, Jan Kočí, Jonáš Uříčář, Vaclav Knap, Daniel-Ioan Stroe (Denmark)

P-26	Membrane Configurations for Lithium-Cobalt Separation by Reverse Electrodialysis Maša Vračevič , Robert Dominko (Slovenia)
P-27	From Cathode Scrap to Battery-Grade Materials: A Low-Cost Approach for Reintegrating Lithium Iron Phosphate Scrap Into Cell Production Radu Andrei , Adina Melinte, Cosmin Ungureanu, Adnana Spinu-Zaulet, Daniela Berger, Cristian Matei, Mihaela Buga (Romania)
P-28	Electrochemical Viability of Harvested Electrode Materials in Direct Lithium-Ion Battery Recycling Frameworks Zbyněk Plachý , Anna Pražanová, Jan Kočí, Daniel-Ioan Stroe (Denmark)
P-29	Preparation of Prussian-Blue-Based Cathodes for Sodium Batteries: Impact of Non-Conventional Enabling Technologies Sofia Calderon Montero , Samuel Hernández Robles, Lydia Cuenca Martín, Pedro Cintas Moreno, Paula Sanz Camacho (Spain)
P-30	A Sulfonato-Catecholate Framework for High-Voltage Sodium-Ion Storage Nagaraju Nakka , Rambabu Darsi, Adnana Spinu-Zaulet, Anweshi Dewan, Mihaela Buga, Alexandru Vlad (Romania)
P-31	A NaFePO4 Comparative Study on Different Synthesis Precursors and His Battery Performances Claudia Paoletti , Roberto Nicoletti, Annalisa Aurora, Francesco Pietrobono, Pier Paolo Prosini, Isabella Chiarotto (Italy)
P-32	Sodium Storage and Co-Intercalation Phenomena in Vapor-Grown Carbon Fibres Dominika Działkowska , Szymon Ruczka, Paweł Gancarz, Sławomir Boncel, Yauhen Aniskevich (Poland)
P-33	Sustainable Engineering of Hard Carbon From Spent Coffee Grounds for Advanced Sodium-Ion Battery Anodes Archana Suresh , Miriam Koppel, Keri Aggenbach, Johan Hjelm, Poul Norby (Denmark)
P-34	SiOC/Sn Composite Anodes for Advanced Na-Ion Batteries Kumar Ashutosh , Giyos Khamdamov, Sushmita Dwivedi, Prangya Sahoo, Magdaléna Precnerová, Ahmed Nada, Zoltán Lenčేశ, Karol Fröhlich (Slovakia)

P-35	Direct Recycling and Scale-Up Regeneration of Prussian Blue Analogues for Circular Sodium-Ion Batteries <u>Lydia Cuenca Martín</u> , Jose A. Coca-Clemente, Mariela Ortiz, Mahdiah Hakimi, Moheddine Wehbie, Juan M. Pérez, Paula Sanz Camacho (Spain)
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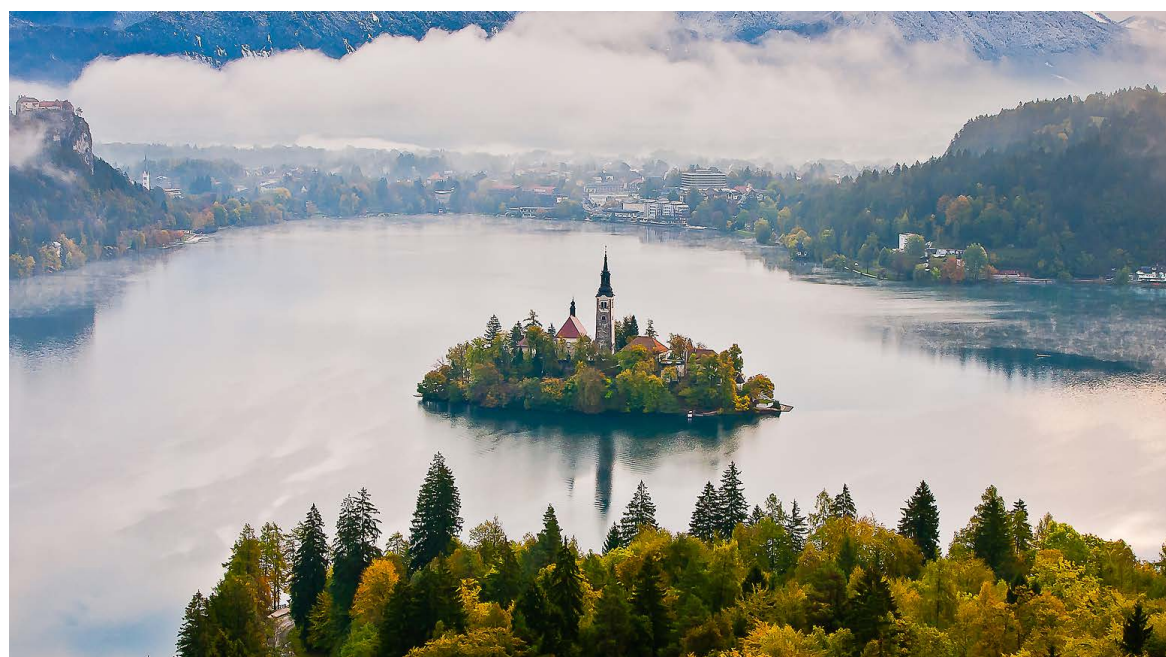
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Venue

Rikli Balance Hotel
Cankarjeva cesta 4
4260 Bled

Arnold Hall



Official Language

The official language of the conference is English. No simultaneous interpretation will be provided.

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Wireless internet connection is available at Rikli Balance Hotel via the network Rikli Balance Hotel. No login or password is needed.

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A Certificate of Attendance will be sent by e-mail to all registered participants after the conference.

Programme Disclaimer

The organisers reserve the right to make changes to the programme.

Social Programme

04
NOV

Welcome Reception

18:00-20:00

Wednesday, 4 November 2026

Venue: Rikli Balance Hotel

05
NOV

Conference Dinner

19:45

Thursday, 5 November 2026

Venue: Šobec Restaurant

Dress code: business casual

Buses to the dinner will depart from the Rikli Balance Hotel between 19:15 and 19:45. Return transfers will be provided after the dinner.

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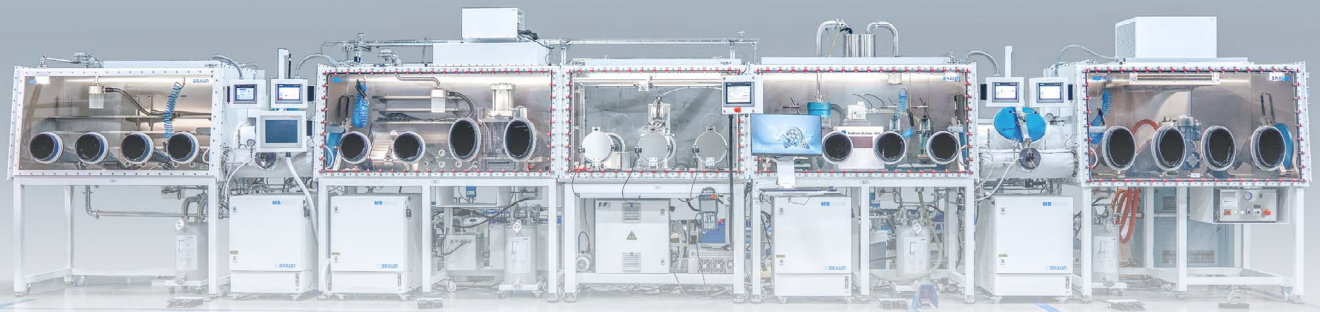
08:30-17:00*

Saturday, 7 November 2026

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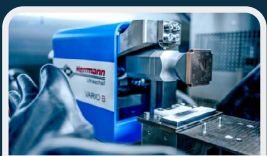
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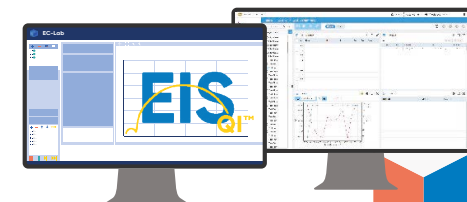
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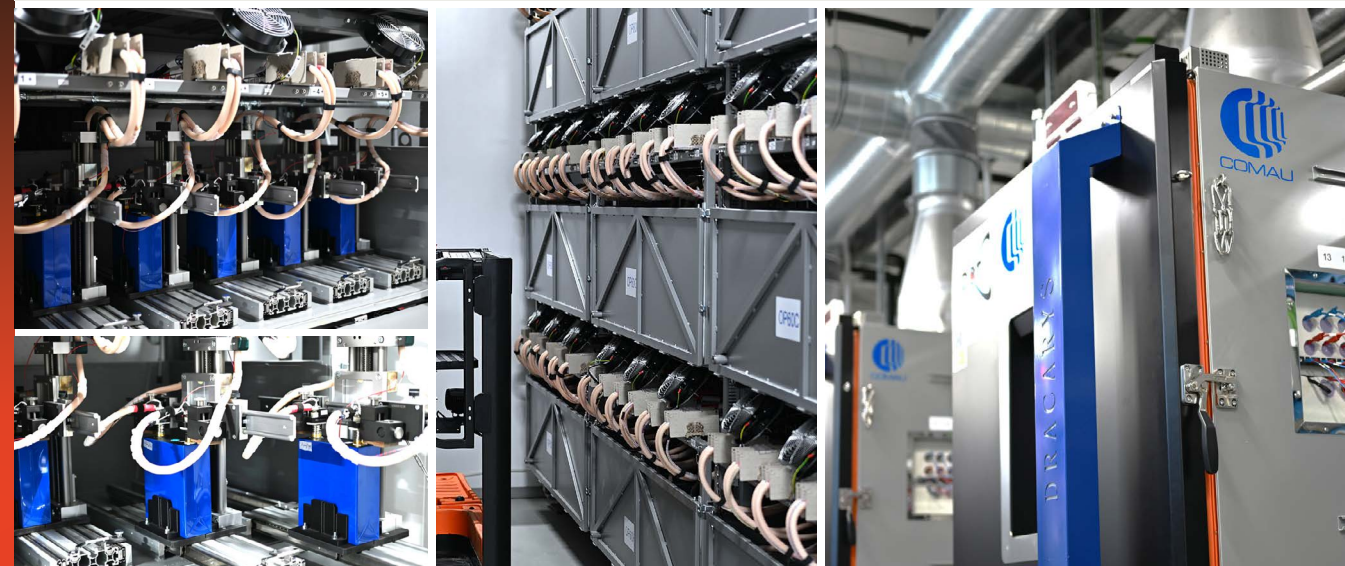
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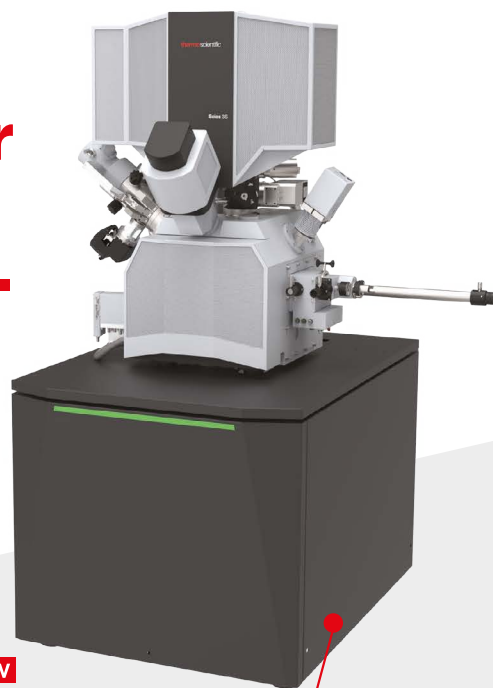
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Sustainability

The Price of Circularity: Can Battery Electrochemistry Survive Recycling?

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Introduction:

Results: The transition toward a circular battery economy is a must. Yet a fundamental question remains largely unanswered: what electrochemical compromises accompany material circularity? This keynote explores the often-overlooked interface between battery recycling and electrochemistry, asking whether truly circular lithium-ion batteries can be realized without sacrificing electrochemical performance. Drawing on recent investigations of cathode materials, graphite anodes, electrolytes, and recycled solvents, the presentation demonstrates how even trace levels of contaminants can profoundly influence cell behavior and ageing processes.

Transition-metal impurities can accelerate electrolyte decomposition, promote the formation of resistive interphases, increase cell polarization, and intensify capacity loss during cycling. Among these species, nickel-containing contaminants emerge as particularly critical. However, the challenge extends well beyond dissolved metal ions. Residual alcohols in recycled carbonate solvents, sodium contamination, oxalate-derived species originating from certain recycling processes, and complex impurity-additive interactions can significantly alter interphase chemistry, impedance evolution, and long-term degradation pathways.

At the same time, recycling does not inevitably degrade battery performance. Under appropriate purification and processing conditions, recovered graphite can even improve cycling stability under specific operating conditions. These findings highlight that the impact of recycling is highly system-dependent and cannot be assessed solely through conventional purity metrics.

The keynote argues that battery recycling is not merely a materials-recovery challenge but fundamentally an issue of electrochemical purity and impurity tolerance. The effects of contaminants depend not only on their concentration, but also on their chemical identity, solubility, interaction with electrolyte additives, and the ageing mechanisms they trigger. Future recycling strategies must therefore balance recovery efficiency, purification effort, economic viability, and electrochemical performance. Ultimately, the acceptable limits of impurity tolerance may become one of the defining factors determining the success of a truly circular battery economy.

Acknowledgements:

References:

Keywords:

Recycling, impurities, ageing, circular economy, lithium-ion

Towards Sustainable Prussian Blue Analogues: A Solvent-Free Mechanochemical Approach

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Introduction: Sodium-ion batteries (SIBs) have emerged as a cost-effective and sustainable alternative to the lithium-ion technology, particularly for large-scale energy storage applications. Amongst the cathodes materials studied for NIBs, Prussian blue analogues (PBA) represent a promising candidate thanks to its open framework with large channels that allows the reversible insertion of a large panel of cations (Na⁺, K⁺, Ca²⁺, Mg²⁺, Sr²⁺, Ba²⁺), their sustainability and low cost, their high specific energy and their good rate capabilities.¹

Results: In this work, the synthesis of Fe- and Mn-based Prussian Blue analogues (PBAs) is investigated using a range of methodologies, with particular emphasis on a novel solvent-free ball-milling approach. Mechanochemical synthesis offers a sustainable alternative to conventional methods, such as co-precipitation and hydrothermal synthesis, by significantly reducing both solvent usage and energy consumption.² As the synthesis route strongly influences the concentration of vacancies as well as the content of coordinated and zeolitic water, process optimization is essential because these structural features have a direct impact on electrochemical performance. The different synthesis methods will be systematically evaluated in terms of sustainability (by LCA), phase purity, structural evolution, and defect formation, and their influence on the electrochemical properties of the resulting materials will be established. Furthermore, operando FTIR spectroscopy will be employed to investigate the alkali-ion intercalation mechanism and the reversibility of the electrochemical processes in PBAs with different compositions. These insights will contribute to a deeper understanding of structure-property relationships and support the optimization of PBAs as cathode materials for next-generation SIBs

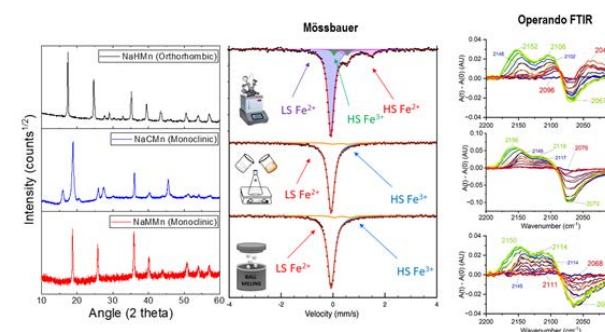
Acknowledgements:

This research was possible thanks to funding received through the European Union's Next Generation EU funds, articulated at the national level by the Recovery, Transformation and Resilience Plan.

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Figure:



Keywords:

Mechanochemistry, PBA, OperandoFTIR, SIBs

Regenerated PBA as Active Material in Na-Ion Batteries

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Introduction: Sodium-ion batteries (SIBs) have become an alternative to lithium-ion batteries (LIBs) due to the abundance and low-cost of their components. Among them, Prussian Blue Analogues (PBAs) have attracted attention due to their open framework structure, which enables fast sodium-ion diffusion and efficient charge-discharge processes [1].

Although PBAs use abundant, low-toxicity elements like sodium and iron, the presence of cyanide precursors requires careful handling and responsible waste management. The direct recycling of PBA materials is an interesting approach as can be low-cost, and environmentally friendly [2].

Results: In this work, a novel direct recycling method for PBA ($\text{Na}_2\text{Fe}_2(\text{CN})_6$) was developed, enabling recovery of precursor material ($\text{Na}_4\text{Fe}(\text{CN})_6$) through alkaline decomposition of the commercial sample, followed by the resynthesis of PBA using L-ascorbic acid.

Structural studies show that the precursor was successfully obtained. Regenerated PBA (Re-PBA) shows sharper bands in Raman, indicating improved local ordering compared to original PBA, consistent with the enhanced crystallographic ordering identified by XRD, suggesting a reduction in local structural heterogeneity within the regenerated framework. Such structural refinement may facilitate reversible Na-ion insertion during electrochemical cycling [3]. In fact, Re-PBA shows improved electrochemical performance, obtaining values near the theoretical specific capacity of 170 mAh/g as well as great stability for long cycling.

These findings establish a pathway toward circular SIB technologies based on the recovery and regeneration of active materials.

Acknowledgements: Funded by the European Union (RENOVATE, 101137745). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the CINEA. Neither the European Union nor the granting authority can be held responsible for them.

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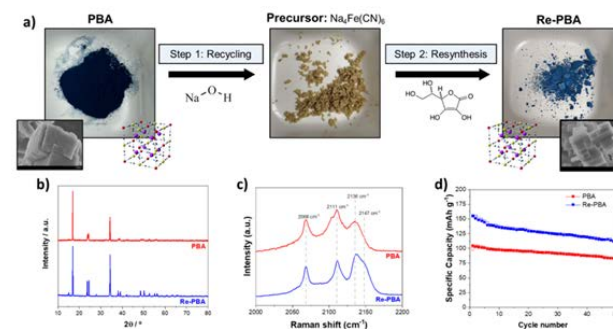


Figure 1. a) Schematics of recycling and resynthesis of PBA using L-ascorbic acid. Structural and electrochemical characterization for both PBA and Re-PBA: b) X-ray diffraction, c) Raman spectroscopy and d) cyclability.

Keywords:

Prussian Blue Analogues; direct recycling method

Relating Carbon Anode Porosity to Sodium Storage Performance

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Introduction: Hard carbons, typically derived from the pyrolysis of non-graphitizing precursors, are promising anodes for sodium-ion batteries but often exhibit low initial Coulomb efficiencies (ICEs) due to solid electrolyte interphase (SEI) formation.[1] Recent studies indicate that closed pores enable reversible Na-storage, particularly at low potentials, whereas open pores mainly contribute to irreversible losses.[2] Decoupling SEI-formation at the particle surface from Na-storage within the carbon matrix remains challenging because conventional high-temperature synthesis simultaneously modifies surface and bulk properties. To address this limitation, we recently introduced core-shell carbons comprising highly porous activated carbon (AC) cores coated with semi-permeable carbon shells via chemical vapor deposition (CVD), achieving reversible capacities of ~400 mAh g⁻¹ at ICE values approaching 80%.[3]

Results: Here, we extend this concept to different AC types and shell architectures to establish structure-performance relationships, focusing on the correlation between internal porosity and reversible Na-storage as well as between SSA and irreversible capacity losses.[4] N₂- and CO₂-physisorption, He-pycnometry, and particularly small-angle X-ray scattering (SAXS) are employed to characterize accessible and inaccessible pore networks. In addition, dynamic vapor sorption (DVS) using diethyl carbonate (DEC), a common electrolyte solvent, is introduced to provide a more realistic assessment of the liquid-solid interface than conventional gas probes. The CVD-shell strongly suppresses DEC-accessible surface area (e.g., from ~1900 to ~12 m² g⁻¹) while preserving the internal pore structure, resulting in substantially reduced first-cycle losses and improved ICE values (see Figure 1).

Overall, core-shell carbons represent both high-performance sodium-storage materials and a versatile model system for predicting electrochemical behavior from fundamental porosity descriptors.

Acknowledgements: We gratefully acknowledge all contributing partners.

References:

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- [2] Lu and Hu et al., DOI: 10.1002/aenm.201902852.
- [3] Appel and Feller et al., DOI: 10.1002/anie.202519457.
- [4] Appel and Feller et al., „Linking Porosity Features of Carbon Anodes to Sodium Storage Performance“, 2026, to be submitted.

Figure:

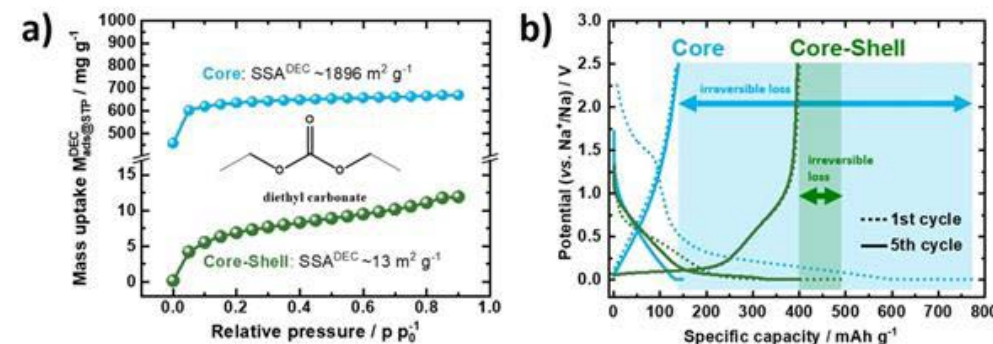


Figure 1: a) DEC vapor adsorption-desorption isotherms at 298 K of the core and the core-shell carbon. b) Electrochemical performance in half-cell vs. Na-metal of the core and core-shell carbon.

Keywords:

Sodium-Ion-Batteries, Hard Carbons, Sodium Storage, Core-Shell-Carbons

Nanostructured Vanadium Oxides as High-Performance Cathodes for Sodium-Ion Batteries

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Introduction: The development of high-performance cathodes is the main challenge limiting the commercialization of competitive sodium-ion batteries (SIBs). There is an indispensable need for SIBs to not only compete with lithium-ion technologies but to do so using earth-abundant chemistries. However, state-of-the-art cathodes such as sodium layered oxides and Prussian blue analogues remain constrained by insufficient cyclability and limited specific capacity. This talk explores vanadium oxide shear structures as promising alternatives to the current generation underperforming cathodes

Results: We find that Wadsley-Roth compounds such as V_6O_{13} possess unprecedented redox activity between 1.0 V and 4.0 V vs. Na^+/Na , delivering stable specific capacities above 300 mAh/g at 0.03 A/g and retaining more than 200 mAh/g at 3 A/g. This behaviour is the result of the inherent metallic conductivity of V_6O_{13} together with a novel hydrothermal synthesis strategy. In this synthesis, the active material precipitates in situ during the assembly of a permeable holey graphene oxide framework. This talk presents new insights and demonstrates the promise of using nanostructured tunnel oxides for a viable, sodium-based high-energy and high-power density energy storage technology incorporating earth-abundant electrode materials.

Acknowledgements: This material is based upon work supported by the U.S.

Department of Energy, Office of Science Energy Earthshot Initiative as part of the Center for STrain Optimization for Renewable Energy (STORE) under Award #DE-SC0024730. .

References:

Keywords:

Sodium-ion, V_6O_{13} , cathode, holey-graphene-framework, binder-less, Wadsley-Roth

Graphene Quantum Dot-Based Nanostructured Electrodes for Advanced Sodium Ion Batteries

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Introduction: Tungsten disulfide (WS_2) is a layered transition metal dichalcogenide (TMD) with rich redox chemistry and a high theoretical capacity. It is therefore a promising anode material for sodium-ion batteries (SIBs). However, WS_2 suffers from low conductivity, structural instability upon cycling and limited sodium ion diffusion kinetics. The addition of nitrogen-doped graphene quantum dots (N-GQDs) to WS_2 can mitigate these issues. N-GQDs provide further active sites, an increased surface area, and can act as a structure regulator. Furthermore, the nitrogen doping of the GQDs provides a greater number of ion diffusion channels and leads to a higher charge carrier density.

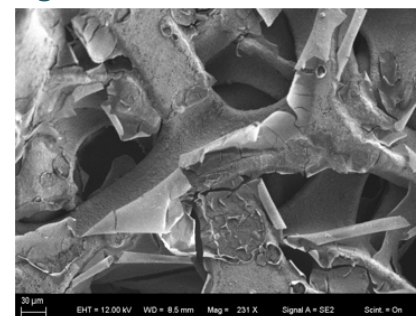
Results: N-GQDs with highly controllable bandgaps were first synthesised. The edge shapes and size of the nanoparticles were selected, alongside the battery electrolyte pH, to provide the most beneficial properties for SIBs. Self-assembled low crystallinity tungsten disulfide nanosheets with embedded N-GQDs were grown directly on the surface of nickel foam via electrodeposition, creating a binder-free anode. SEM images confirmed the presence of the nanosheets, while EDX, Raman and FTIR confirmed their composition. XRD and SAED data demonstrated that the interlayer spacing of the WS_2 was widened by 0.1 nm (from 0.62 to 0.72 nm) upon N-GQD addition.

The widened interlayer spacing facilitates sodium-ion intercalation and conversion reactions. Electrochemical characterisation confirms an increase in battery capacity, rising from 206 mAh/g for an electrode without N-GQDs embedding, to 311 mAh/g upon N-GQD addition. It has therefore been demonstrated that N-GQD addition in WS_2 greatly benefits its energy storage capabilities.

Acknowledgements: This work was supported by the Engineering and Physical Sciences Research Council [grant EP/W524426/1; DTP 2224 Durham University]. The authors thankfully acknowledge Leon Bowen and the G. J. Russell Electron Microscopy Facility.

References:

Figure:



SEM image of WS_2 with embedded N-GQDs deposited onto nickel foam

Keywords:

Graphene quantum dots, tungsten disulfide, batteries

Sustainable Aqueous Nanocellulose Biobinder for Lithium-Ion Battery Anode Processing

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Introduction: Lithium-ion batteries (LIBs) are central to modern energy storage thanks to their high energy density, long lifetime, and low self-discharge, enabling wide use in electronics and renewable-energy storage.[1] Although binders represent $\leq 10\%$ of electrode mass, they are essential: they bind active material and conductive additives, ensure adhesion to the current collector, and maintain mechanical stability while supporting effective electronic/ionic pathways for lithiation/delithiation and overall cycling performance.

PVDF remains the dominant binder in industry and academia due to its strong binding performance and ability to form high-quality electrodes.[2] However, the growing interest in replacing systems based on organic solvents with aqueous formulations, which are safer and more sustainable, together with the cost of PVDF, is accelerating the development of lower-impact and more affordable aqueous binders.

In this context, bio-based polymers, and particularly cellulose derivatives, are emerging as promising alternatives due to their abundance, processability, and stability, including functionalized nanocelluloses such as TEMPO-CNF and nanocrystals bearing carboxylic or phosphorylated groups.[3]

Results: In this work, we explore the use of nanocellulose as a binder for anode materials, analyzing how the nature of the biobinder and its interaction with the electroactive material influence the electrode structure and its electrochemical response. To this end, structural and electrochemical characterization techniques are combined to establish structure-property relationships that guide the design of sustainable, high-performance binders for the next generation of LIB electrode processing.

Acknowledgements: We gratefully acknowledge funding from the Spanish Center for the Development of Industrial Technology (CDTI) and the State Research Agency (AEI) for the Spanish project PLEC2023-010301, awarded within the framework of a coordinated action under the Transmissions initiative, with the support of the Ministry of Science, Innovation and Universities.

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Keywords:

Lithium-ion batteries, aqueous biobinder, nanocellulose, sustainability

Electrochemical Characterization

A Novel Multi-Channel Online Electrochemical Mass Spectrometer for Battery Gas Analysis Applied to Electrolyte Additive Screening

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Introduction: At Dalhousie University we built a novel multi-channel Online Electrochemical Mass Spectrometry (OEMS) system that can sample gases from up to six battery cells with a single quadrupole mass analyzer. We will explain how this system helps us to understand the reaction mechanisms of new additives.

Results: OEMS is an operando gas analysis method that continuously samples the evolved/consumed gases in battery cells.¹ In our efforts to develop high energy density Li-ion cells, we screen novel additives with this method to understand how they improve high-voltage operation. The type of gases and gas concentration in the cell headspace are used to draw conclusions about the reaction mechanisms.

Figure 1 shows the multi-channel Online Electrochemical Mass Spectrometer at Dalhousie University. It features two vacuum chambers connected with a central gas line to six battery cells in individually controlled temperature boxes. The right vacuum chamber contains the mass spectrometer for sampling gases from the battery cells, while the left vacuum chamber is empty and merely serves for purging the central gas line. The multi-OEMS system samples each cell once per hour using an automated switching sequence of computer-controlled valves optimized to remove residual gases from the central gas line connecting the six cells without affecting the vacuum chamber containing the quadrupole mass analyzer.

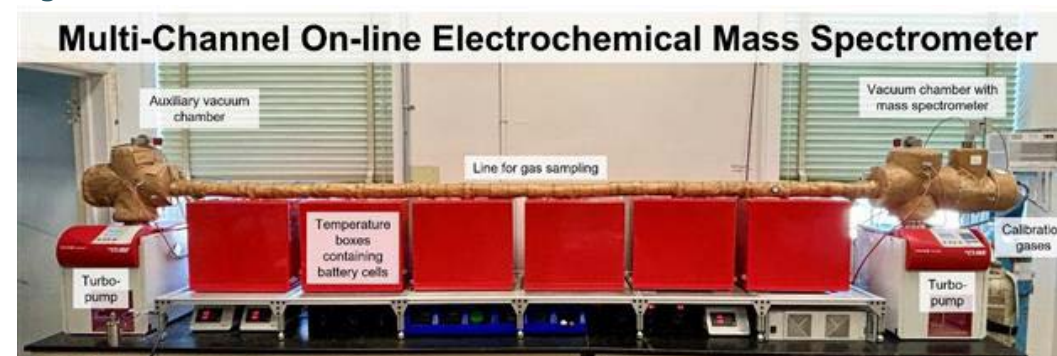
Using this new multi-OEMS system we will try to uncover how novel electrolyte additives improve the passivation of the negative electrode and how they affect gas generation at high voltage.

Acknowledgements: This work was primarily done by Michael MacDonald, Meredith Tulloch, Matthew Garayt, and Michel Johnson.

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- 1. M. Metzger and H. A. Gasteiger, *Energy and Environmental Materials*, 2022, 688–692.

Figure:



Keywords:

Li-ion cells, gas analysis, electrolyte additives

Ex Situ Degradation Diagnostics of NMC111, NMC622, and NMC811 Cathodes for Lithium-Ion Batteries

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Introduction: High-performance lithium-ion batteries increasingly rely on lithium nickel-manganese-cobalt layered oxides like NMC111, NMC622, and NMC811 to achieve elevated energy density [1]. However, structural degradation during repeated cycling causes severe capacity fade and safety risks [2]. This study investigates these complex electro-chemo-mechanical failure mechanisms across varying nickel contents. We combined X-ray diffraction (XRD), Raman spectroscopy mapping, and scanning and transmission electron microscopies (SEM, TEM) to capture degradation from the particle surface to the crystal lattice.

Results: Our findings reveal highly heterogeneous behavior across electrodes. Localized regions charge and discharge at different rates, generating uneven lithium distribution and internal stress. Over time, these gradients initiate critical failures: particle cracking, fragmentation, and a gradual loss of electrical contact. These mechanical failures expose fresh cathode surfaces to the electrolyte, accelerating parasitic reactions. TEM analysis uniquely revealed localized phase transitions, surface reconstruction layers, and nanoscale intra-granular micro-cracking at individual particle boundaries. These degradation phenomena scale dramatically with higher nickel content; NMC811 displays severe localized state-of-charge gradients and structural breakdown compared to the more stable NMC111. High operating voltages further induce phase transformations and mechanical strain, amplifying the damage. Connecting these analytical observations provides a foundation for designing targeted mitigation strategies, guiding the development of durable, efficient, and safer electrode materials.

Acknowledgements: This work was funded by the National Center for Science in Poland through the Sonata BIS 11 programme (No. UMO-2021/42/E/ST5/00390).

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Keywords:

Lithium-ion batteries, Degradation mechanisms, Phase transition

Probing, Preventing, and Healing Lithium-Ion Batteries: Third-Electrode Integration and Functional Separator

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Introduction: The performance and safety of lithium-ion batteries are limited by several degradation mechanisms:

thermal runaway triggered by separator failure¹, lithium inventory loss through SEI formation and aging², transition metal (TM) dissolution driven by HF promotion from LiPF₆ degradation², and the crosstalking phenomenon^{2, 3}, where dissolved TM ions migrate to the negative electrode and disrupt its protective SEI layer.

In this communication, we address these challenges through two complementary strategies: the functionalization of the separator membrane with a fire-retardant additive, and the integration of a user-controlled third electrode designed to mitigate and repair internal battery failures.

Results: A fire-retardant separator, TBBPA@PVDF-HFP, was synthesized by electrospinning and characterized by SEM, FTIR, and DSC, confirming TBBPA integration within the polymer fiber matrix. Flammability tests demonstrate self-extinction in less than 1 second.

In parallel, a Li-Al alloy reference electrode was integrated as a user-controllable third electrode. Applied as an electrocatalytic reductant at 2V vs. Li⁺/Li, it mitigates the accumulation of acidic decomposition products derived from LiPF₆ degradation, as confirmed by ¹⁹F, ¹H, and ³¹P NMR spectroscopy. Lithium inventory restoration was further demonstrated through the galvanostatic formation of a Li-Al alloy, enabling controlled Li⁺ release to compensate for lithium losses at positive electrode. In addition, the third electrode spontaneously scavenges dissolved transition metal cations (Ni, Mn, Co, Cu), preventing their deposition at the negative electrode, as confirmed by XPS and XRD.

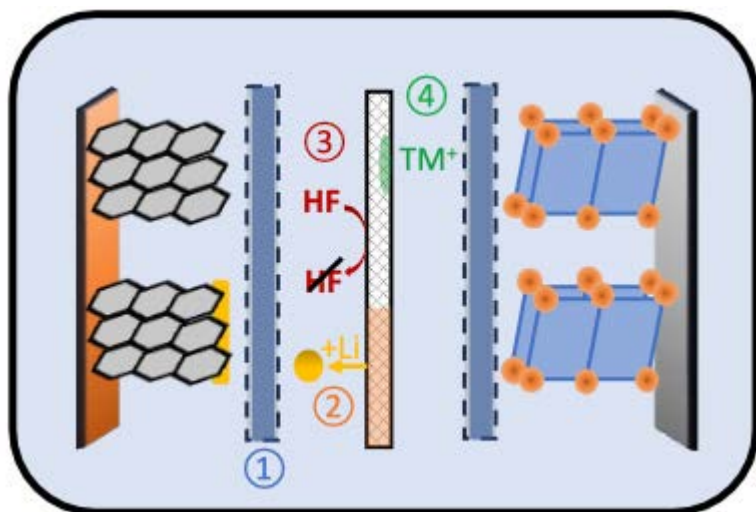
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this work was carried out within the framework of Heal B&B project (PEPR Batteries).

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Figure:

**Keywords:**

Lithium-ion, degradation mechanisms, self-healing, 3rd-electrode, smart-separator

Impact of CC and CCCV Charging Methods on Degradation in Nickel-Rich Cathodes via In-Situ X-Ray Diffraction and Raman Spectroscopy

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Introduction: To maximize the energy density of lithium-ion batteries, nickel-rich layered oxides are heavily researched. However, operating these materials at elevated cut-off potentials triggers localized structural degradation within the transition metal-oxygen network. To resolve these local dynamics, in-situ Raman spectroscopy is used to monitor bonding environments and oxidation states [1]. Furthermore, the progression of these degradation pathways depends significantly on the charging methodology, though the exact operational differences remain unresolved [2]. To capture these dynamic phenomena, in-situ X-ray diffraction (XRD) is essential for tracking global lattice parameters and phase fractions in real time [3]. This provides a macroscopic context to the severe phase transitions and irreversible shifts in transition-metal redox states encountered at high voltages [4].

Results: This work presents a comparative evaluation of NMC 622 and NMC 811 cycled under extended voltage windows using in-situ XRD and Raman spectroscopy techniques. By analyzing constant-current (CC) versus combined constant-current constant-voltage (CC-CV) procedures, we differentiate how distinct charging strategies alter structural and chemical instability pathways. XRD tracks bulk phase transitions and lattice dynamics, while Raman spectroscopy provides key insights into localized distortions within the Ni-O framework. Ultimately, these findings correlate specific electrochemical conditions with material degradation, offering a foundation for optimizing advanced battery cycling protocols.

Acknowledgements: This work was funded by the National Science Center, Poland under the Sonata BIS 11 program (Grant UMO-2021/42/E/ST5/00390).

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Keywords:

Lithium-ion batteries, NMC Cathodes, degradation mechanisms.

Standardization of Rate Performance Analysis Through Chronoamperometry

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Introduction: Battery rate performance, despite its increasing importance, lack of an standardized quantitative framework. This leads to a non-cohesive literature where is hard to establish fair comparisons and understand limitations. In recent years, significant efforts have been directed towards establishing this framework through models based on the master-curve concept.^{1,2}

These relates the experimental data with physical parameters, providing explainability to the rate behaviour. Concurrently, chronoamperometry (CA) has emerged as a faster alternative to traditional galvanostatic cycling for obtaining this rate performance data.³ It offers richer datasets with high temporal resolution and continuous data. However, the higher amount of information, the presence of contributions poorly understood and the lack of information on how experimental parameters affect the results, has led to its under-utilization by the community.

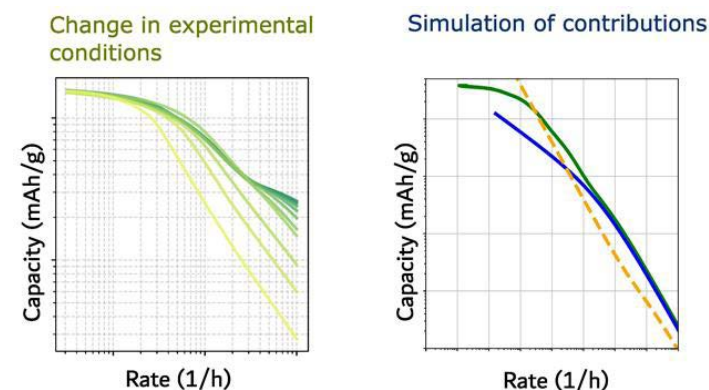
Results: In this study, we systematically evaluated chronoamperometry within the master-curve framework across four representative chemistries. We identified cell impedance as the dominant, previously unaccounted factor influencing the high-rate region of the master curve and demonstrated that it must be explicitly considered to extract meaningful kinetic parameters. Through simulations, we introduced a methodology to account for these impedance effects, significantly enhancing parameter reliability. We further demonstrate that the selection of the voltage window can alter key extracted parameters by up to an order of magnitude, provide a physical interpretation of this dependence, and propose practical guidelines for the standardized reporting of results. Collectively, these findings enhance the robustness, reproducibility, and comparability of CA-based rate analyses, with direct implications for material evaluation and cell optimization.

Acknowledgements: Financial support from Project PID2023-148703OA-I00 and from grant RYC2024-049910-I, funded by MICIU/AEI (10.13039/501100011033) and by the European Social Fund Plus (ESF+).

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Figure:



Keywords:

rate performance, chronoamperometry, battery, standardization

The Influence of Potassium Metal Counter Electrodes on the Evaluation of Hazelnut-Derived Hard Carbon Anodes for Potassium-Ion Batteries

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Introduction: Nowadays, lithium-ion batteries (LIBs) dominate the market due to their high energy density and technological maturity. Nevertheless, the limited abundance and uneven global distribution of critical raw materials used have driven the search for more sustainable alternatives, such as potassium-ion batteries (PIBs), owing to their low-cost (K abundance), high energy (low redox K⁺/K potential) and high power (high K⁺ diffusion in liquid) density. Among carbon-based materials, hard carbon has emerged as a promising anode material due to its defect-rich and porous structure. Its electrochemical performance is typically evaluated in a two-electrode cell configuration, using K metal as the counter electrode, whose high reactivity could influence the measurements, masking the intrinsic electrochemical behaviour of the active material [1].

Results: In this work, hazelnut-shell derived hard carbon was prepared through two different approaches: (i) one-step carbonization and (ii) two-step carbonization, including an acid-treatment step using 2 M HCl. The acid treatment removes inorganic impurities and improves electrochemical performance, increasing the specific capacity from 210 mAh/g to 240 mAh/g at 0.1C, with a capacity retention of ~98% after 180 cycles. These materials were evaluated in a two-electrode cell configuration, using 2 M KFSI in TEP as electrolyte, where a gradual increase in capacity was observed during the first ~20 cycles. This phenomenon is commonly attributed to material activation and improved electrolyte wettability. However, this work demonstrates that the observed capacity increase originates from the reactivity of the K metal. The results highlight the importance of using a three-electrode cell configuration, especially when evaluating materials for PIBs.

Acknowledgements: This work was supported by the SPIRIT (03XP0186A) project from M.Era. Net and the Bundesministerium für Bildung und Forschung (BMBF).

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Keywords:

Potassium-ion batteries, hard-carbon, bio-waste, K reactivity

Post-Lithium Batteries

Mg Metal Interface Characterization in Chloride Based Electrolytes

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Introduction: Magnesium metal anodes offer a promising pathway for high-energy-density post-lithium batteries, but their practical application is hindered by a poorly understood electrode-electrolyte interphase. While lithium metal anodes operate via an ionically conductive and electronically resistive SEI, it remains unclear if magnesium operates under similar principles.

Results: We demonstrate that the surface film formed on magnesium in chloride-based glyme electrolytes is fundamentally distinct from a traditional SEI. By combining electrochemical impedance spectroscopy with focused ion beam scanning electron microscopy (FIB-SEM), transmission electron microscopy (TEM), and X-ray photoelectron spectroscopy (XPS), we identify a dual-layer interphase consisting of a thick, porous outer layer and a thin (~10 nm), compact inner layer. Crucially, we present electrochemical and morphological evidence—including identical-location microscopy of deposits and polysulfide probe measurements—proving that this compact layer is ionically insulating but electronically conductive. Consequently, magnesium plating occurs on top of the passivation layer via electron tunneling, whereas stripping requires the mechanical rupture of the film. This inherent asymmetry and the "anti-SEI" nature of the magnesium interphase challenge current interface engineering strategies and suggest that future improvements must address the electronic leakage and mechanical instability of the surface film.

Acknowledgements: The authors acknowledge the funding from the Slovenian Research Agency ARIS (core program funding P2-0423). SDT acknowledges financial support by the Slovene Research Agency ARIS with research project Z2-4465 funding. The research was cofunded under the HyBREED project, supported by the European Union - NextGenerationEU.

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Data for this article are available at Zenodo repository at <https://doi.org/10.5281/zenodo.18746519>, published in Faraday Discussions, 2026, DOI: 10.1039/D6FD00029K

Keywords:

Magnesium anode, interface, impedance spectroscopy, SEI

Decoupling Ion Transport From Interfacial Stability by Mixed Coordination Electrolytes for Magnesium Batteries

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Introduction: Rechargeable magnesium metal batteries (RMMBs) are promising options for large-scale energy storage applications, yet achieving high-energy density and stable operation at high-voltage remains difficult.[1] The weakly-coordinated anion-based electrolytes would offer excellent magnesium plating/stripping performance and sufficient oxidative stability on the inert current collectors; however, the recent study identified the chemical crossover-driven failure mechanism of RMMBs, especially operated with high-voltage oxide-based positive electrodes at elevated temperature.[2] To overcome the above interface and interphase issues, we herein propose new concept in designing functional electrolyte formulations, namely mixed coordination electrolytes, to promote anion-derived interphases and enhance cycling stability in high-voltage RMMBs.

Results: The proposed electrolyte formulation integrates dissociative and associative conductive salts to optimize both Mg ion transport and interphase formation, while the molecular additive facilitates the development of uniform, robust interphases. Upon decoupling Mg ion transport from interfacial stability by genuinely designed electrolyte formulations, the long-term cycling of a [Mg || FeV3O9] full cell was achieved for 200 cycles at relatively high current density.[3]

Acknowledgements: This work is financially supported by GteX program (grant number: JPMJGX23S1) of Japan Science and Technology Agency.

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Keywords:

Magnesium battery, coordination, interphases, ion transport

Seeing the Chemical Components of SEI: Nanoscale TERS Imaging of Magnesium Anode Interfaces

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Introduction: The solid electrolyte interphase (SEI) critically governs the performance and durability of electrochemical systems, forming through electrolyte decomposition during cycling. Controlling SEI formation on Mg metal is therefore essential for advancing high-performance rechargeable magnesium batteries. In this work, tip-enhanced Raman spectroscopy (TERS) is employed as a nanoscale chemical probe to identify SEI components formed under practical Mg secondary battery conditions and to correlate interphase chemistry with electrochemical behaviour. Using a Cl-free Mg[B(hfip)₄]₂/DME electrolyte with tris(trimethylsilyl)borate (TMSB) as an additive, we demonstrate how TERS provides direct molecular-level insight into additive-mediated SEI regulation on Mg metal anodes in symmetric electrode cells.

Results: TERS reveals that in the absence of TMSB, electrochemical cycling produces thick SEI layers enriched in magnesium oxalate and acetate, arising from ongoing solvent decomposition. Pronounced B–O vibrational features indicate the formation of inorganic magnesium borate-type species. These observations support the dissociation of the Mg[B(hfip)₄]₂/DME electrolyte into HFIP[−] and its proposed catalytic role in driving multistep degradation pathways.

With TMSB present, the interphase chemistry shifts toward siloxane- and silanol-rich components, characterized by Si–O–Si and related vibrational modes. This change is attributed to Me₃Si⁺ fragments generated from the additive, which scavenge HFIP[−], thereby suppressing solvent decomposition and promoting the formation of a thinner, more uniform, and more stable SEI. TERS imaging of SEI fragments further highlights nanoscale chemical heterogeneity, revealing a mosaic-like structure on the magnesium anode. [1]

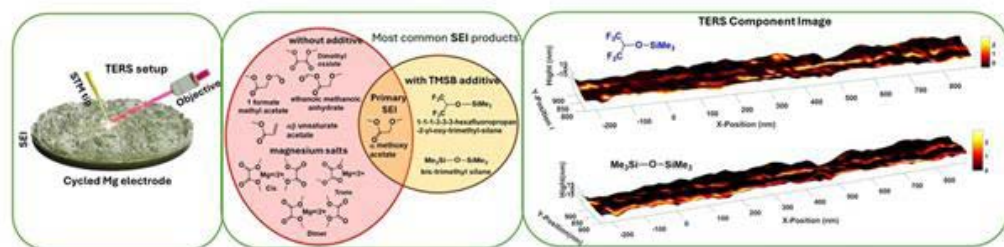
These nanoscale chemical insights via TERS imaging directly correlate with improved electrochemical performance and establish TERS as a powerful diagnostic tool for application-driven SEI engineering.

Acknowledgements: CELEST (Center for Electrochemical Energy Storage Ulm-Karlsruhe) and was funded by the German Research Foundation (DFG) under Project ID 390874152 (POLiS Cluster of Excellence, EXC 2154).

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Figure:

**Keywords:**

TERS, Nanoscale-Imaging, SEI, Mg-Battery

Calcium Electrodeposition From Nitrile Solvents

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Introduction: The development of calcium-anode batteries as a technology aiming to replace conventional lithium-ion chemistry is hindered by the sluggish electron-transfer kinetics of Ca^{2+} ions and the formation of passive layers, which, in contrast to the SEI formed on lithium, are poorly permeable to calcium ions. As the electrolytes play a crucial role in the formation of such interfaces, their rational design has become a key strategy for enabling reversible and efficient calcium electrodes. In our previous research, we demonstrated that a synergistic effect between $\text{Ca}(\text{BF}_4)_2$ and acetonitrile exists, which enhanced the electrodeposition of calcium with a high yield of pure calcium. Expanding on our previous observations, the present work investigated the influence of different nitrile solvents on calcium electrodeposition. To establish the structure-property relationship governing electrolyte performance, six structurally diverse nitrile solvents were selected: succinonitrile, acetonitrile, propionitrile, malononitrile, valeronitrile, and methoxyacetonitrile.

Results: Electrochemical measurements were conducted using cyclic voltammetry and electrochemical quartz crystal microbalance (EQCM) in a three-electrode configuration, using stainless steel as the working electrode for calcium deposition, while platinum wires served as the counter and reference electrodes. Formed deposits on the stainless steel electrode were further analyzed using grazing incidence X-ray diffraction (GIXRD) and scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (EDS).

The results reveal that the introduction of additional nitrile groups generally leads to increased calcium deposition, while extending the alkyl chain favors the formation of undesired decomposition products and reduces deposition efficiency. These findings provide novel insights into the relationship between nitrile solvent and electrodeposition, highlighting the critical role of electrolyte design in battery performance.

Acknowledgements: This work was funded by European Union within the project „Development of advanced coating technologies“ PK1.1.12.0319

References:**Keywords:**

calcium, electrodeposition, electrolyte desing, nitrile solvents

Influence of Additive-Level Sodium Incorporation on the Electrochemical Performance and Morphology of Calcium Deposits in a Fluorinated Alkoxyborate Electrolyte

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Introduction: Rechargeable calcium (Ca) metal batteries are considered promising candidates for sustainable high-energy-density energy storage, although reversible Ca plating/stripping under practical conditions remains challenging.¹ Dual-cation electrolytes have recently emerged as an effective approach to improve Ca electrochemistry. In this work, additive-level alkali-metal incorporation in the fluorinated alkoxyborate electrolyte is investigated. Specifically, Na[B(hfip)₄]₂ (hfip = hexafluoroisopropoxy) was introduced as an additive into Ca[B(hfip)₄]₂/DME electrolyte to investigate its effect on Ca deposition, electrochemical performance, and deposit morphology.

Results: Additive-level Na incorporation significantly improved Ca plating/stripping by reducing polarization, increasing Coulombic efficiency, and enhancing cycling stability compared with the pristine Ca[B(hfip)₄]₂ electrolyte. The electrolyte with the molar ratio of Ca[B(hfip)₄]₂:Na[B(hfip)₄] = 95:5 exhibited the best performance, with a Coulombic efficiency of up to 83%. Galvanostatic measurements further demonstrated that deposited capacity and current density strongly influence both electrochemical performance and deposit morphology. Lower deposited capacities and higher current densities promoted the formation of smaller, uniformly distributed deposits and improved cycling stability, whereas increasing deposited capacity resulted in deposit agglomeration, lower stripping efficiency, and accelerated cell failure. SEM-EDX analysis confirmed that the deposits remained predominantly Ca-based despite Na addition, while the relative Na contribution decreased with increasing deposited capacity. Compared with the pristine electrolyte, Na incorporation promoted more uniform deposits and suppressed the formation of heterogeneous fluorine-rich deposit structures. The results demonstrate that additive-level Na incorporation improves Ca deposition while highlighting the critical role of deposition conditions in governing metal growth, morphology, and reversibility.

Acknowledgements: The authors acknowledge funding from the European Research Council (grant agreement 101089281), the Spanish Agencia Estatal de Investigación Severo Ochoa Programme for Centres of Excellence in R&D (CEX2023-001263-S), the M-ERA.NET call 2023 project COBRA (958174), and the Slovenian Ministry of Education, Science and Youth (C3360-25-452015).

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Keywords:

Calcium; Electrodeposition; Alkoxyborate; Dual-cation; Metal anode

Pd NPs Modified Mg-Ni Alloys – Investigating Physicochemical Properties and Electrochemical Absorption of Hydrogen in Protic Ionic Liquid

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Introduction: Mg₂Ni alloys are promising anode candidates for nickel-metal hydride (Ni-MH) batteries owing to their high hydrogen storage capacity and the low cost of magnesium. However, their practical use is limited by the high thermodynamic stability of the hydride phase, sluggish hydrogen sorption kinetics, and severe corrosion in conventional aqueous alkaline electrolytes, which leads to rapid capacity degradation. This study aims to overcome these limitations by nano structuring Mg₂Ni through ball milling, enhancing its hydrogen absorption kinetics with palladium nanoparticles, and replacing the conventional aqueous electrolyte with a non-aqueous, protic ionic liquid to suppress corrosion.

Results: Mg₂Ni powders were synthesized by high-energy ball milling from the precursor of MgH₂ and Ni powder. Palladium nanoparticles were deposited onto the alloy surface using a microwave-assisted polyol method. The resulting composite was characterized structurally (XRD) and morphologically (SEM and TEM) using standard techniques, and its electrochemical behavior was evaluated through charge-discharge cycling, and cyclic voltammetry, primarily in a non-aqueous ionic liquid electrolyte, with conventional concentrated KOH electrolyte used for comparison. Ball milling followed by hydrogenation and hydride decomposition produced fine, homogeneous Mg₂Ni alloys, while Pd decoration improved hydrogen dissociation and sorption kinetics. The non-aqueous ionic liquid electrolyte (diethylmethylammonium trifluoromethanesulfonate) markedly reduced corrosion-related capacity loss compared to the aqueous KOH system, while maintaining acceptable ionic conductivity and electrochemical activity throughout cycling. The combination of nanostructured, Pd-modified Mg₂Ni with a non-aqueous ionic liquid electrolyte (DEMA TFO) offers an effective strategy for improving the cycling stability and corrosion resistance of magnesium-based anodes, supporting their potential for practical application in Ni-MH battery systems.

Acknowledgements: We thank the National Science Centre, Poland funding agency for the grant under Sonata 19 Reg. No: 2023/51/D/ST5/01990

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Keywords:

Mg₂Ni, Corrosion, Ionic liquids, Hydrogen, Electrosorption

Li-Ion Batteries

Tracking Electron and Ion Fluxes in Energy Storage Electrodes: Advanced Electrochemical Characterization Approaches

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A detailed understanding of ion dynamics at the electrode/electrolyte interface, together with ion organization within the bulk of active materials, is essential for enhancing charge storage in electrochemical energy storage devices such as batteries and supercapacitors. Yet, unraveling solvent-ion and ion-electrode interactions during adsorption, intercalation, extraction, and transport processes remains particularly challenging, as these phenomena take place at the nanoscale and under strong confinement.

In this presentation, we show how the use of advanced electrochemical methods can probe coupled ionic and electronic transport down to the nanometer scale in electrode materials. We highlight how electrolyte confinement in sub-nanometer environment modifies ion solvation and governs charge storage mechanisms. Such insights open pathways toward the rational design of high-power, fast-response electrochemical energy storage systems.

Design and Integration of Core-Shell NMC Structures for High-Stability Lithium-Ion Batteries

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Introduction: Nickel-rich layered lithium transition-metal oxides, particularly lithium nickel manganese cobalt oxides (NMC), are among the most considered cathode materials for high-energy lithium-ion batteries because of their high specific capacity. However, increasing Ni content accelerates degradation through structural instability, cation mixing, and enhanced surface reactivity, limiting long-term electrochemical performance. In this work, we address a key challenge in electrochemical energy storage through the design of core-shell NMC particles that combine high-capacity Ni-rich cores with compositionally optimized outer shells.

Results: To identify suitable core and shell compositions, we conducted a systematic performance evaluation of several Ni-rich and Co-rich NMC stoichiometries. The NMC precursors in this study were synthesized via co-precipitation in a Couette-Taylor flow reactor, providing the necessary mixing conditions to achieve high compositional uniformity, spherical precursor morphology, and defined shell deposition. In parallel, in situ and ex situ X-ray diffraction (XRD) measurements were performed to monitor phase evolution during calcination and evaluate the thermal-structural compatibility required for successful core-shell integration [1]. A structural and compositional evaluation of core-shell and gradient structures was conducted using a scanning electron microscope (SEM) with EDS detector. The results show that both composition selection and calcination conditions are critical for obtaining structurally robust core-shell cathodes. Pairing Ni-rich core materials with low-Ni, Co-rich shell compositions can lead to improved structural stability and degradation resistance [2,3]. Our new findings demonstrate how integrated materials design, detailed structural characterization, and electrochemical performance evaluation can guide the development of cathodes for durable electrochemical energy-storage systems.

Acknowledgements: This work was funded by the National Science Center in Poland through the Sonata 17 programme (No. UMO-2021/43/D/ST5/03094).

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Keywords:

NMC, core-shell structure, calcination, Li-ion batteries

High-Performance Electrolyte Compositions for Lithium-Ion Batteries With Solvent-Free Cathodes

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Introduction: The growing global demand for energy, driven by technological progress and the proliferation of portable electronic devices since the late 20th century, has highlighted the critical need for advanced battery technologies. In recent years, research on next-generation lithium-ion batteries has intensified, with a particular focus on improving sustainability and reducing environmental impact. Conventional lithium-ion battery production relies heavily on organic solvents that are hazardous to human health and the environment. These solvents are essential for electrode fabrication but require energy-intensive drying and solvent recovery processes. To address these challenges, our research explores two key areas of improvement.

Results: First, we propose a solvent-free electrode preparation method, enabling the dry processing of cathodes. This approach eliminates the need for toxic solvents such as N-methyl-2-pyrrolidone (NMP), thereby reducing energy consumption, simplifying manufacturing, and minimizing environmental and safety risks.

Second, we are developing novel electrolyte systems featuring new lithium salts as potential alternatives to the commonly used LiPF₆. The replacement salts aim to reduce or eliminate fluorine content, mitigating issues related to toxicity, cost, and the generation of corrosive HF species. Additionally, tailored electrolyte additives are being designed to enhance electrochemical performance and stability.

Together, these innovations contribute to more sustainable, cost-effective, and energy-efficient lithium-ion cell production, aligning with the objectives of the European Green Deal.

Acknowledgements: This research is supported by the National Science Centre Poland under the M-ERA.NET 3 Call 2023.

References:

Keywords:

lithium-ion batteries, solvent-free cathode, fluorine-free electrolyte

Transmission Line Modeling of Li-Ion Insertion Porous Electrodes: The Role of Electrolyte Ambipolar Diffusion

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Introduction: Transmission line models (TLMs) are powerful tools for impedance modeling of porous Li-ion insertion electrodes because they naturally capture distributed properties. De Levie's original works demonstrated this by representing the porous electrode as an effective single pore, enabling distributed double-layer capacitance [1] and coupling with electrode reaction resistance [2]. This conventional de Levie topology is still widely applied today for representing distributed electrode-scale properties of insertion systems, as reviewed by Huang et al. [3]. However, the need to include diffusion in the electrolyte phase within the electrode pores was later demonstrated by White et al. [4].

Results: We present a full physics-based insertion TLM circuit that includes all key components needed to properly model porous ion insertion electrodes combined with an adjacent separator [5]. The key upgrade compared to conventional de Levie approaches is the inclusion of ambipolar diffusion in the liquid electrolyte phase within both the electrode pores and the separator. We show fundamental differences in simulations that include this ambipolar diffusion versus those that do not. Most importantly, we find that the conventional de Levie approach, although useful for explaining the interfacial impedance response, is not adequate to properly simulate dynamics in these systems over the full frequency range down to low frequencies [6]. For NMC cathodes, we demonstrate that neglecting electrolyte ambipolar diffusion can easily lead to an overestimate of the solid-state diffusion resistance in the active material by a factor of 10 or more [7, 8]. This highlights the necessity of incorporating electrolyte-phase diffusion for accurate low-frequency impedance modeling [9].

Acknowledgements: Jože Moškon thanks the Slovenian Research and Innovation Agency for financial support in the framework of project J2-4463. Robert Dominko thanks the Slovenian Research and Innovation Agency for financial support in the framework of national program no. P2-0423. Miran Gaberšček thanks the Slovenian Research and Innovation Agency for financial support in the framework of national program no. P2-0393. The support of the M-Era.net project "Inert Coatings for Prevention of Ageing of NMC Cathode for Lithium-Ion Batteries" (InCoatBat), Project Reference Number 10341 is also acknowledged.

Keywords:

transmission line model (TLM), porous electrodes, electrochemical impedance spectroscopy (EIS), ambipolar diffusion

Post-Mortem Analysis of Synthesized and Commercial NMC111 Cathodes After Long-Term Cycling in Li-Ion Cells

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Introduction: Lithium nickel manganese cobalt oxide (NMC111) remains one of the most widely used cathode materials for lithium-ion batteries (LIBs) due to its balanced energy density, cycling stability, and safety characteristics [1]. However, prolonged electrochemical cycling can induce structural and morphological degradation, resulting in capacity fading and performance deterioration. Understanding the degradation behavior of NMC111 materials from different sources is therefore essential for the development of durable LIBs.

Results: In this work, a comparative study of synthesized and commercially available NMC111 cathodes subjected to long-term cycling is presented. Electrochemical tests were performed using both constant current (CC) and constant current-constant voltage (CCCV) charging protocols to reproduce practical battery operating conditions [2]. Long-term cycling experiments were conducted for up to 1000 cycles at a 2C rate.

Ex-situ XRD provides insights into crystal structure retention and possible bulk phase transformations induced by prolonged cycling. Raman mapping were utilized to assess structural disorder, local compositional variations, and the formation of secondary phases during repeated cycling. After 1000 cycles, the electrode did not fully return to its discharged state following the CCCV protocol, remaining partially charged, consistent with Raman results. SEM investigations revealed particle cracking, surface degradation associated with electrochemical aging.

By correlating electrochemical performance with structural and morphological observations, this study identifies the key degradation pathways governing long-term cycling behavior in both synthesized and commercial NMC111 cathodes. The results provide valuable insights into the relationship between material origin, structural stability, and electrochemical durability, contributing to the design and optimization of next-generation NMC-based cathodes.

Acknowledgements: This work was funded by the National Science Centre, Poland, through the Sonata BIS 11 project (No. UMO-2021/42/E/ST5/00390).

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Keywords:

NMC111, degradation, long cycling, ex-situ study

Operando Investigation of Degradation Mechanisms in Silicon Nanoparticle-Based Anodes

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¹Heyrovský Institute, Czech Academy of Sciences, Prague, Czech Republic, ²Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Introduction: Silicon is a promising anode material for next-generation lithium-ion batteries owing to its exceptionally high theoretical capacity. However, its practical application is limited by severe volume changes during lithiation/delithiation, leading to mechanical degradation, unstable solid electrolyte interphase (SEI) formation, and rapid capacity fading. Understanding these dynamic processes requires advanced operando techniques capable of monitoring structural, chemical, and morphological changes under realistic battery operating conditions. The objective of this work is to investigate the early degradation mechanisms of silicon nanoparticle anodes by combining operando Raman spectroelectrochemistry [1] and operando small-angle X-ray scattering (SAXS) [2].

Results: Silicon-based anodes prepared from Si nanoparticles (6–90 nm) with different binder systems were investigated by electrochemical methods together with operando Raman spectroscopy and operando SAXS. In addition, the influence of protective surface modifications (ALD and polymeric coatings) applied to both silicon nanoparticles and complete electrodes was evaluated. Particular attention was paid to the initial formation cycles, where SEI formation and structural changes induced by silicon volume expansion determine the long-term electrode stability. Operando Raman spectroscopy enables real-time monitoring of stress evolution, progressive amorphization of crystalline silicon, and electrolyte decomposition associated with SEI formation through changes in the first-order Si Raman band and characteristic electrolyte vibrations. Complementary operando SAXS measurements reveal consistent trends during the early formation cycles, confirming the structural evolution of silicon nanoparticles and providing additional insight into nanoscale morphological changes during lithiation and delithiation. The combined operando approach provides a comprehensive understanding of the degradation mechanisms of silicon anodes and supports the development of more durable, high-capacity lithium-ion batteries.

Acknowledgements: Supported by TA ČR project TS01030029 (SILION) and SUNFLOWERS project 09102-03-V01-00022 (EU NextGenerationEU Recovery and Resilience Plan of Slovakia).

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Keywords:

silicon anodes; lithium-ion batteries; operando techniques

What Electrochemical Impedance Reveals and Hides in Graphite-Silicon Composite Particles

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Introduction: Graphite-silicon composites offer a practical route to higher-capacity lithium-ion battery anodes while retaining the stability provided by graphite. Their electrochemical response, however, is difficult to interpret because graphite and silicon differ strongly in thermodynamics, lithium transport, and interfacial kinetics. Electrochemical impedance spectroscopy (EIS) is widely used to identify limiting processes, but conventional interpretations often assume homogeneous particles or independent contributions from each material. In a heterogeneous composite particle, these assumptions may conceal which phase is actually controlling the measured response.

This work investigates how the constituent materials and their spatial arrangement shape the impedance of graphite-silicon composite particles across frequency and state of charge. We use a spatially resolved, physics-based model that computes the small-signal response directly in the frequency domain. The analysis progresses from simple two-phase configurations to multidomain microstructures, separating the influence of material properties from that of particle architecture and surface accessibility.

Results: Simulation results indicate that a phase can remain electrochemically active while becoming almost invisible in the overall impedance spectrum. At low frequencies, the relative contribution of graphite and silicon is strongly influenced by their local open-circuit-potential slopes. At intermediate frequencies, their different transport time scales create distinct spatial responses and frequency-dependent shifts in phase participation. The arrangement of the materials further changes which processes are expressed most clearly, particularly when one material is enclosed within the particle rather than exposed to the electrolyte.

The impedance of a composite particle therefore cannot be understood as a simple sum of two single-material spectra. By connecting spectral features with internal phase activity and microstructure, this study provides a basis for more reliable EIS interpretation and for designing graphite-silicon architectures with better balanced transport and reaction behaviour.

Acknowledgements: The authors acknowledge support from the European Unions Horizon 2020 research and innovation programme under Grant Agreement No. 101069910 (NEXTCELL).

References:

Keywords:

Impedance, electrode, composite, silicon, graphite, modeling

Advanced Characterization

Operando Studies of Intercalation Processes

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This talk will discuss the development and application of operando methods to study how ions are inserted into lithium- and sodium-ion electrode materials. Together with Prof. Akshay Rao, we have shown that optical methods that probe changes in light scattering can be used with sufficient time and spatial resolution to follow (de)intercalation processes in single, micron-sized particles. A variety of different mechanisms have been observed, which depend (i) on the ion diffusivities in the solids, and how they change as a function of e.g., Li⁺ and Na⁺ content, (ii) the rate of ion insertion, (iii) particle size and (iv) in layered materials, coupling between the layers. In LiCoO₂, delithiation follows a shrinking core model, ions being removed from all surfaces of the particle, while the poor Li transport in the fully lithiated material results in an “intercalation wave” mechanism, involving a single nucleation site, the new phase propagating across the particle. A new mechanism is identified for intercalation in the dilute stages of graphite that is reminiscent of an “avalanche” phase transition, where layers within sub-domains of the particle are intercalated individually. In the dense stage, where there is stronger coupling between the layers, a more conventional intercalation wave mechanism is seen. Facet dependent processes can be followed, along with communication between particles. These mechanisms can then be correlated with degradation mechanisms such as particle cracking. Finally new methods to study formation of lithium ion batteries and the role of protons in battery degradation processes will be discussed.

Keywords:

Operando methods, phase transitions

Unravel Battery Ageing Through Advanced Characterization and Modeling

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Introduction: Li-ion batteries (LIBs) dominate the current battery market but face challenges in future use. Understanding detailed ageing mechanisms of LIBs under various working protocols and conditions will not only enable more efficient utilization but facilitate R&D advancement of batteries, which is crucial to the development of battery technologies.

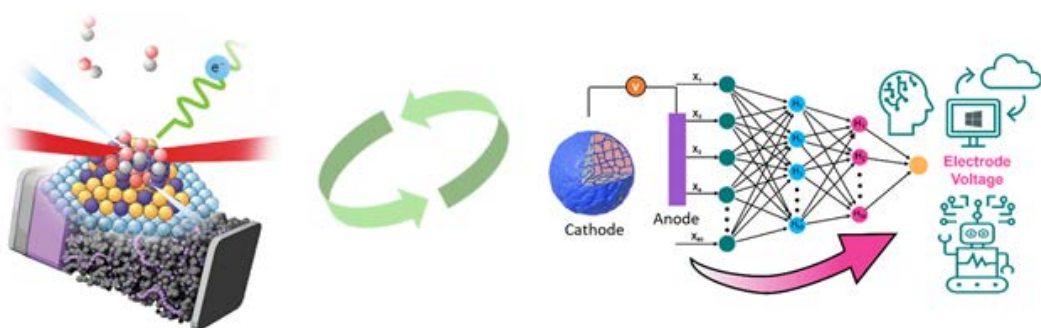
Results: We have unraveled the ageing mechanisms of commercial NMC/graphite LIBs under different working protocols, e.g., pulse current charging [1] and real-life EV battery discharge [2], through multi-modal characterization (XRD & XAS and Raman spectroscopy, etc.) of aged batteries to unveil the chemical, morphological and structural changes of electrode materials and interphases. To obtain more comprehensive mechanistic understanding of battery ageing mechanisms, we have been developing advanced physics-based and data-driven battery models [3,4] to complement experimental results. The findings will help to advance battery management systems and battery design in future energy systems.

Acknowledgements: N.A.

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- [3] J. Mater. Chem. A 2026, DOI: 10.1039/d6ta03434a
- [4] Appl. Energy 2026, 422, 128306.

Figure:



Keywords:

Li-ion batteries, ageing mechanisms, characterization, modeling

Insights Into Silicon Solid-State Battery Mechanical Degradations With Operando FIB-SEM and Digital Image Correlation

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Introduction: The development of solid-state batteries (SSBs) stands on understanding and mitigating mechanical degradation mechanisms, particularly in negative electrodes. Silicon's (Si) exceptional specific energy (3579 mAh·g⁻¹) is outweighed by its 300% volume change during full lithiation, which induces severe mechanical stress and structural degradations [1].

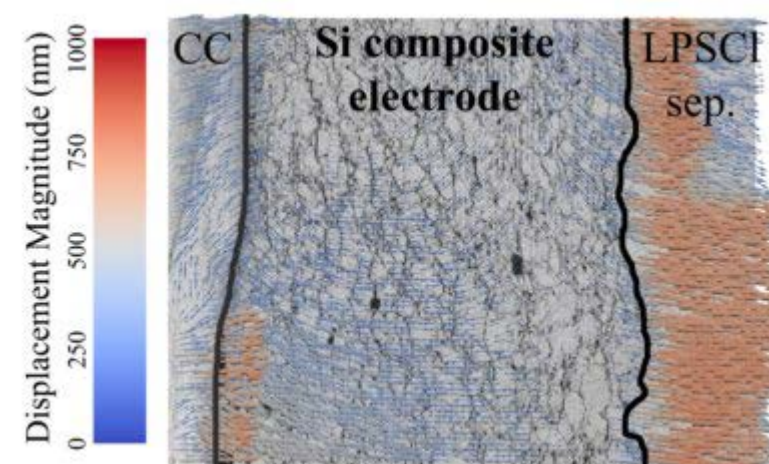
Results: Using operando Focused Ion Beam Scanning Electron Microscopy (FIB-SEM) combined with Digital Image Correlation (DIC), we investigated the mechanical degradation of a composite negative electrode composed of Si, Li6PS5Cl solid electrolyte, and carbon additives at the nm scale [2], [3]. By monitoring the morphology evolution of the composite electrode during cycling, the results reveal that lithiation at the negative electrode/separator interface (physical interface) induces the nucleation and propagation of cracks, which not only degrade the electrode/separator interface integrity but also propagate into the separator, leading to significant mechanical failure and reduced battery performance (Figure 1). This work provides unprecedented insights into the failure mechanisms at the heart of SSB degradation, emphasizing the critical role of interface stability in designing durable solid-state battery architectures.

Acknowledgements: This work was funded by the OPENSTORM (ANR-24-PEBA-0001) Project within the PEPR Batteries.

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Figure:



Keywords:

morphology imaging, operando FIB-SEM, DIC

Tackling Complexity in Post-Li-Ion Battery Research: From Machine Learning-Assisted Scattering to Data-Driven Experimental Design

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Introduction: Post-lithium-ion batteries such as lithium-sulfur and sodium-ion promise higher energy density and more sustainable raw materials. However, their key processes, from conversion reactions and nanoscale phase transformations to complex, multi-parameter synthesis routes, remain fundamentally hard to understand. In this talk, I discuss how machine learning tackles this complexity by (i) interpreting information-rich, structurally complex operando data of Li-S batteries, and (ii) navigating high-dimensional experimental parameter spaces using active learning for optimizing Na-ion battery anodes.

Results: In the first part, I show how operando SAXS/WAXS and SANS, combined with machine learning-accelerated stochastic modelling, quantify nanoscale conversion mechanisms across solid-liquid-solid and quasi-solid-state pathways in Li-S batteries [1-3]. Combined with cryo-TEM, the data reveal a biphasic deposit of nanocrystalline Li₂S and amorphous short-chain polysulfide. Resolving this detail across the full state-of-charge range only became practical using fast neural-network-based data fitting.

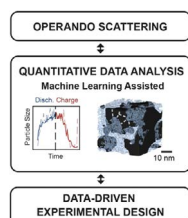
In the second part, I turn to active learning for navigating large parameter spaces in battery materials synthesis and testing [4]. Bayesian optimization with Gaussian process surrogate models automatically selects the next most informative experiment, reducing the measurements needed to identify optimal conditions. I present work applying this approach to scattering-based quality control of hard carbon anode synthesis for Na-ion batteries, where active learning links structural descriptors (from SAXS) to sodium storage performance, pointing toward closed-loop, data-driven materials optimization.

Acknowledgements: Supported by the ERC Starting Grant SOLIDCON (101078271). The author thanks J.-M. von Mentlen, V. Wood (both ETH Zürich), P. Dutta, K. Neumayr, S. Dunkel, and S. Stock for their contributions.

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Figure:



Keywords:

Li-S, Na-ion, operando scattering, machine learning

Chemical Transformations in Battery Materials by Operando X-Ray -Based Methods

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Introduction: The rapid growth of battery industry and production across the globe revealed new challenges related to fundamental understanding of battery chemistry. The lack of this knowledge impedes further development of existing and emerging battery technologies. The design and optimization of new materials, their efficient implementation in a battery, possible recycling pathways strongly depends on their operating mechanism, i.e. what kind of chemical transformations a material undergoes in a battery cell. The use of operando X-ray based methods allows to directly pinpoint the structural transformation of active materials.

Results: In the present talk, the application of operando X-ray based methods for characterization of battery materials will be discussed, illustrating the potential benefits and challenges associated with the use of those techniques (beam damage and cell architecture). In addition, the use of multimodal operando techniques will be demonstrated for the discovery of new materials and characterization of complex mechanisms in emerging cathode materials with antiperovskite structure. In addition, it will be demonstrated that operando methods can be used not only for the analysis of active materials, but also for analysis of other chemical and mechanical processes in batteries, such as relaxation and mechanical deformation of active components.

Acknowledgements: This work was performed with the support of FME Battery, a Norwegian Centre for Environment-friendly Energy Research, funded by the Research Council of Norway (project number 350373), and BaSSET (project number 325316), Joint Transnational Call 2023 M-ERA.NET3 (FUNCY-SSB, Research Council of Norway grant No. 353798), SALAMANDER project funded by the European Union's Horizon Europe research and innovation programme under grant agreement No. 101104028 and 101104022 (BATTERY 2030+ CSA3).

References:

Advanced Energy Materials 16, no. 19 (2026): e06777.

Keywords:

Operando characterization, X-ray diffraction, operating mechanism

Compositionally Complex Spinel Oxides and Oxyhalides With Enhanced Electrochemical Properties

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Introduction: Compositionally complex spinel oxides with high configurational entropy have attracted considerable attention as promising electrode materials due to their enhanced structural stability and tunable electrochemical properties [1]. In this work, a high-entropy spinel oxide (Zn_{0.25}Mg_{0.25}Co_{0.25}Cu_{0.25})Fe₂O₄ (HEOFe) together with its lithiated oxyfluoride Li_{0.5}(Zn_{0.25}Mg_{0.25}Co_{0.25}Cu_{0.25})_{0.5}Fe₂O_{3.5}F_{0.5} (LiHEOFeF) and oxychloride Li_{0.5}(Zn_{0.25}Mg_{0.25}Co_{0.25}Cu_{0.25})_{0.5}Fe₂O_{3.5}Cl_{0.5} (LiHEOFeCl) were synthesized by mechanochemical processing followed by heat treatment. Their structural and electrochemical properties were systematically investigated.

Results: X-ray diffraction confirmed the formation of single-phase cubic spinel structures, while electron microscopy revealed homogeneous nanoparticles with sizes ranging from 50 to 200 nm and elemental compositions close to the nominal values. ⁵⁷Fe Mössbauer spectroscopy showed that Li incorporation together with F or Cl substitution and oxygen vacancy formation does not affect the preferential occupation of octahedral sites by Fe³⁺ cations. Electrochemical measurements in Li half-cells demonstrated high initial charge capacities of 450, 593, and 694 mA h g⁻¹ for HEOFe, LiHEOFeF, and LiHEOFeCl, respectively. The superior performance of LiHEOFeCl is attributed to its smaller particle size and the lowest initial charge-transfer resistance. Although all materials exhibited gradual capacity fading during 100 galvanostatic cycles at a 1C rate, Raman spectroelectrochemical analysis confirmed the reversibility of the electrochemical reaction during the initial cycles. Electrochemical impedance spectroscopy further revealed a gradual decrease in charge-transfer resistance for both lithiated oxyhalides during cycling, whereas HEOFe exhibited a slight increase, indicating a different electrochemical reduction mechanism. These results demonstrate that lithium incorporation and halogen substitution effectively improve the electrochemical response of high-entropy spinel oxides, highlighting lithiated oxyhalides as promising conversion-type electrode materials for advanced electrochemical energy storage.

Acknowledgements: Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project SUNFLOWERS No. 09I02-03-V01-00022.

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Keywords:

High-entropy spinel oxides; lithiated oxyhalides; mechanosynthesis

Beyond Superoxide & Peroxide: (Su)peroxocarbonates and Their Reactivity With Battery Electrolytes

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Introduction: Li-rich layered oxides (LRLO), achieve high energy density by combining transition metal redox with additional oxygen redox activity. While oxygen participation enables extra capacity, it also induces parasitic processes such as oxygen release, voltage hysteresis, surface reconstruction, and electrolyte decomposition, often linked to highly reactive oxygen species (ROS) [1-2]. These species can also be formed during the oxidation of lithium carbonate[3], which is commonly used as a precursor in LRLO. However, despite some studies[4-5], the reactivity of specific ROS toward electrolyte solvents, and the mechanisms that govern these interactions remain insufficiently understood.

Results: Here, lithium and potassium superoxo and peroxo-carbonates are synthesized, characterized and treated as chemical analogues of ROS that form during cell cycling, enabling to decipher their reactivity, which is beyond the conventionally studied superoxide and peroxide species. Their interactions with both cyclic and linear carbonate electrolytes were systematically investigated. Gas evolution, monitored by mass spectrometry, provides insight into the oxidative tendencies of these species through the detection of CO₂ and O₂, key products commonly observed during battery operation. Complementary Nuclear Magnetic Resonance analysis indicates solution phase decomposition. Also, the relative tendencies of different ROS to generate singlet oxygen (¹O₂) and the factors governing the ¹O₂ formation are examined by means of the ¹O₂-specific near infrared emission. We show reactivities of ROS relevant to oxygen redox in LRLO and how can they strongly influence electrolyte stability and interfacial chemistry, particularly at high states of charge.

Acknowledgements:

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Keywords:

Oxygen Redox, Reactive species, Interfaces, Batteries

Post-Li-Ion Batteries

Scaling Vanadium Redox Flow Batteries: From Stack Development to Utility-Scale Energy Storage

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Introduction:

Long-duration energy storage is becoming an essential component of future power systems with increasing penetration of renewable energy sources. Among the available technologies, vanadium redox flow batteries (VRFBs) offer unique advantages including independent energy and power scaling, long service life, high operational safety, and full electrolyte recyclability. However, successful commercialization depends not only on electrochemical performance but also on effective engineering of the complete battery system at competitive price level.

Results:

This presentation discusses the engineering approach adopted at InoHub Energy for the development of next-generation VRFB stacks and integrated energy storage systems. The talk highlights the relationship between electrochemical design and system-level performance, covering key aspects such as electrolyte distribution, membrane and electrode integration, pressure losses, thermal management and Plant optimization.

Special attention will be given to the challenges encountered during the transition from laboratory-scale development to manufacturable stack architectures and modular energy storage systems. Practical engineering trade-offs affecting efficiency, reliability, maintainability, and lifetime will be discussed together with strategies for reducing system complexity and improving levelized cost of storage (LCOS).

The presentation will conclude with an outlook on future development directions including higher power density stacks, advanced monitoring and diagnostics, digital engineering tools, and the role of VRFB technology in Europe's emerging long-duration energy storage market.

The presented work aims to demonstrate how close integration of electrochemistry, mechanical engineering, and system design is essential for accelerating the industrial deployment of Vanadium Redox Flow Batteries.

Acknowledgements:

References:

Keywords:

Vanadium Redox Flow Battery Scale-up

Designing Li-S and Redox Flow Hybrid Storage Through Advanced Material Modelling and Development

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Introduction: As the global energy grid transitions toward decarbonization, relying on a single battery technology is no longer sufficient. While traditional lithium-ion batteries have set the benchmark, meeting diverse grid demands requires a shift toward hybrid storage systems. This study explores the powerful synergy of combining lithium-sulfur (Li-S) batteries [1] known for their exceptional energy density, with redox flow batteries (RFBs), which excel in long-duration discharge, scalability, and operational lifespan. By pairing these technologies, we can address both rapid, high-power peaks and long-term bulk energy storage in a single, coordinated system. This research bridges the gap between molecular-level material design and system-level scaling to optimize this hybrid architecture.

Results: Through a combination of high-throughput computational screening and machine learning, we successfully identified promising, ethically sourced redox-active species for the RFB component and optimized electrode chemistries to mitigate the polysulfide shuttle effect in the Li-S component. Our models effectively decoupled and addressed internal efficiency bottlenecks, specifically minimizing ohmic resistance within the RFB's ion-exchange membrane to maintain high voltage efficiency during high-current operations. Furthermore, physical transport modeling accurately predicted electrolyte behavior and ion dynamics under dynamic charging cycles, facilitating efficient physical scaling.

Ultimately, our findings demonstrate that hybridizing Li-S and RFB technologies creates a highly resilient and complementary storage architecture. By overcoming critical material-level barriers, we unlocked a synergistic cooperation where the RFB component successfully manages steady, long-term grid stabilization, while the Li-S component seamlessly delivers the rapid, high-power response required during peak demand. This integrated hybrid system, prioritized with sustainable chemistries and high end-of-life recyclability, offers a technically robust and environmentally responsible pathway for next-generation power grids.

Acknowledgements: This work was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project SUNFLOWERS No. 09I02-03-V01-00022.

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Figure:

**Keywords:**

Hybrid energy storage, Li-S, Redox-flow, Modelling,

A New Theoretical Framework to Investigate the Precipitation Kinetics of Discharge Products in Li-S Batteries

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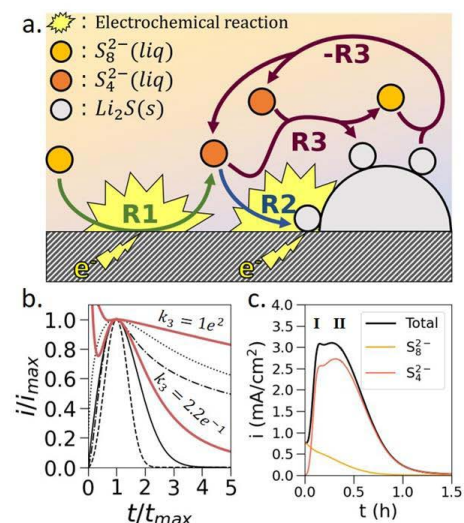
Introduction: Polysulfides interactions are one of the most impacting and characteristic factors in lithium-sulfur batteries, a leading candidate for next generation batteries. They open electrochemical pathways, influence kinetics and create unique challenges such as the shuttle effect. Due to their complexity, those interactions, a series of disproportionation reactions with equilibrium states, sparked numerous investigations, resulting in many proposed interpretations. It is indeed very challenging to establish analytical tools for quantitative investigations of Li-S batteries. The need for such analytical tools is particularly crucial when applied to precipitation dynamics, which is a key limiting step to the sulfur utilization and rate performance of the Li-S battery. There is no clear agreed consensus on the exact mechanistic of the deposition, yet numerous studies use standard electro-deposition models to characterize the process. Moreover, some ideas, like the gradual cathode passivation during discharge remain widespread despite piling evidence against it and alternative explanations being regularly proposed.

Results: In this work, we conducted controlled experimentation to record the precipitation signatures for micro-electrodes and conventional porous electrodes for Li-S chemistry. This enabled the foundation of a new analytical framework which fills the gap of existing theory and provide some avenue for quantitative characterization of the precipitation mechanism in Li-S batteries. More specifically, it reconciled electro-deposition models with the core mechanism of Li-S batteries: the disproportionation reactions. Using this tool, we explored different deposition scenarios and successfully explain experimental data, both from our controlled set or from existing publications, including previously unaccounted behaviors. Most notable among those is a double deposition peak produced during chronoamperometry tests in certain conditions. The new analytical framework allows a deeper understanding of the most crucial step in the lithium-sulfur reactions chain, laying ground for guided optimization of practical Li-S batteries.

Acknowledgements: The authors are grateful for financial support from FWO-Vlaanderen.

References:

Figure:



a) Schematic of the simplified deposition mechanism at the basis of the new formalism introduced in this work. The species involved consist of the dissolved polysulfides ("liq") and solid ("s") lithium sulfide. The three reactions consist of two irreversible electrochemical reactions R1 and R2 occurring at the substrate/electrolyte interface and a reversible disproportionation reaction R3 occurring at the precipitate/electrolyte interface. The Li ions present in the electrolyte are not depicted for clarity purposes. **b)** Sensitivity of the normalized chronoamperometric profiles to the rate constant of the disproportionation reaction (k_3). **c)** a simulated current transient that features a double peak.

Keywords:

Battery, lithium-sulfur, lithium-sulfide, deposition, model, mechanistic

From Lean to Viscous Electrolytes in Lithium Sulfur Batteries: A Combined Experimental and Modeling Investigation

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Introduction: The constantly growing global energy demand and the urgent need to replace fossil fuels with more sustainable alternatives have driven significant interest in advanced energy storage systems. Among these, batteries play a key role; however, further improvements in performance, particularly in terms of energy density, are still required. In this context, lithium-sulfur (Li-S) batteries emerge as one of the most promising technologies, offering theoretical specific capacities up to ten times higher than those of conventional systems, along with potentially lower costs.

Despite these advantages, Li-S batteries are hindered by their complex electrochemistry, which involves soluble active species. This leads to several challenges associated with mass transport phenomena, including both reversible and irreversible capacity losses, as well as electrolyte polarization due to increased viscosity.

Results: This work presents a comprehensive study combining experimental investigation and modeling to characterize electrolytes for Li-S systems. In particular, the effect of LiTFSI concentration is systematically explored, spanning from lean to highly concentrated (viscous) regimes, with the aim of identifying an optimal compromise that ensures high sulfur utilization, stable solid electrolyte interphase (SEI), and improved capacity retention. In parallel, cathodes with different loadings are investigated by tuning the thickness of the active material, in order to better understand how transport properties, analyzed through impedance spectroscopy and titration techniques, affect the performance of high-sulfur-loading cathodes.

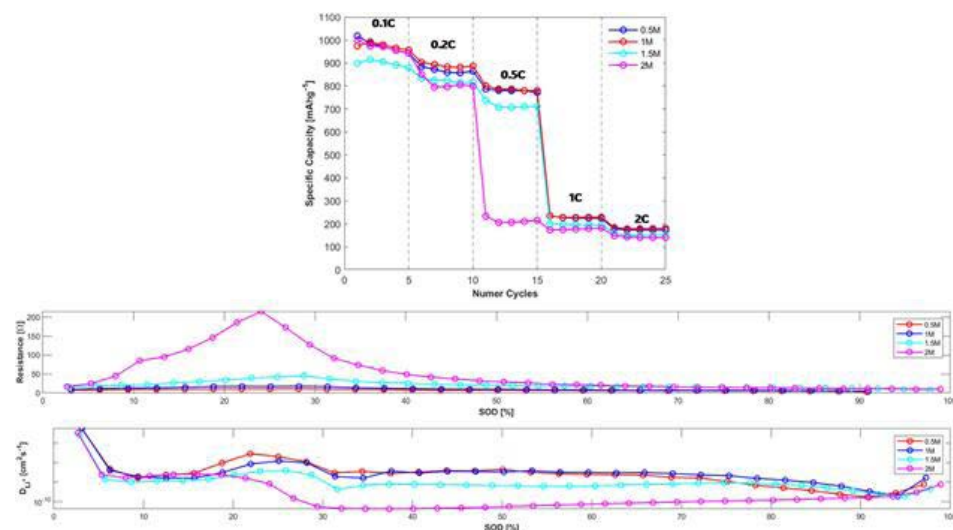
On the modeling side, a dedicated framework is developed to simulate both single-cycle behavior and long-term cycling, providing deeper insight into the role of the electrolyte in governing electrode morphology evolution.

Acknowledgements: T.F. Lupatelli acknowledges Stellantis - CRF (Centro Ricerche Fiat) for co-funding the Ph.D. scholarship.

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Figure:



Keywords:

Li-S battery; Electrolyte; Multiscale-modeling; Optimization;

Data-Driven Benchmarking and Design Rules for Practical Lithium–Sulfur Batteries

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Introduction: Lithium–sulfur batteries (LSBs) are promising next-generation energy storage systems with a theoretical specific energy of 2600 Wh kg⁻¹. However, despite extensive research, the field lacks a unified quantitative framework to compare results across studies and to leverage the growing volume of experimental data for large-scale performance analysis and practical evaluation. This work addresses this gap by developing a standardized, data-driven benchmarking framework based on 866 digitized datasets collected from 184 publications. The methodology integrates cathode host properties and full-cell design parameters, applying standardized assumptions to generate comparable cell-level specific energy and power metrics.

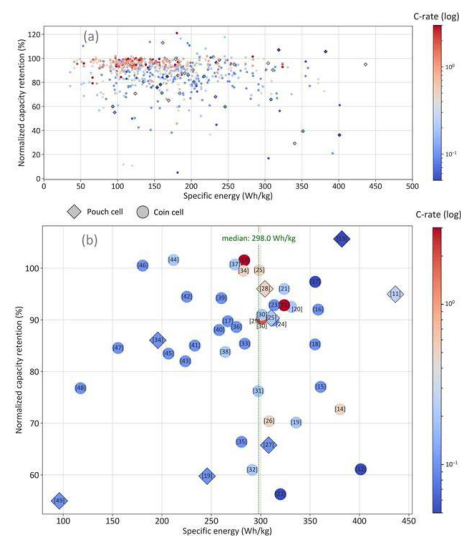
Results: The benchmarking analysis shows that LSB systems achieve a maximum specific energy of 441 Wh kg⁻¹, with a median of 298 Wh kg⁻¹ for practically relevant configurations. Correlation analysis identifies the electrolyte-to-sulfur ratio (E/S) as the dominant factor controlling energy density, exhibiting a stronger negative effect than the positive contribution of sulfur loading. This indicates that reducing electrolyte content is more important than increasing sulfur loading to achieve high energy density. Sulfur loading above ~6 mg cm⁻² provides diminishing gains in areal capacity due to increased ionic and electronic transport limitations. A strong synergistic effect was also observed: lean-electrolyte cells performed better when conductive carbon black content was minimized. In material design, 2D hosts with surface areas of ~200–400 m² g⁻¹ consistently showed superior performance. Benchmarking rate performance shows that LSBs achieve a median discharge capacity of 1145 mAh/g at 1 C, 945 mAh/g at 3 C, and 871 mAh/g at 5 C, indicating substantial improvements in material innovation. Reducing conductive additives to ~10 wt.% (from ~20 wt.%) further improved electrode tortuosity, enhancing high-rate performance.

Acknowledgements: Supported by SIM and VLAIO through the SBO “FuGels” project (HBC.2021.0016) within the SIMBA program.

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Zhou, G., et al.. Formulating energy density for designing practical lithium–sulfur batteries. Nat. Energy 7, 312–319 (2022)

Figure:

**Keywords:**

Li-S, Benchmarking, Specific energy, Data analysis

Aqueous Batteries

Design of Aqueous Electrolyte for High-Performance Iron-Air Battery

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Introduction: With the rapid advancement of battery technologies, their applications have expanded into emerging fields such as distributed energy storage, embodied intelligence, and deep space exploration. This expansion imposes requirements on battery safety and cost-effectiveness. Consequently, the development of intrinsically safe, green, and low-cost battery systems has become a focal point—and a significant challenge—in current research. Iron-air batteries, utilizing abundant metallic iron as the anode and oxygen from the ambient air as the cathode within an aqueous electrolyte, combine high specific energy with environmental safety. They are thus considered a promising candidate for next-generation energy storage. However, this system still faces critical challenges regarding calendar life and cycle life due to electrolyte side reactions. Addressing these challenges, this work focuses on the regulation of discharge products by CO₂ and electrolyte design.

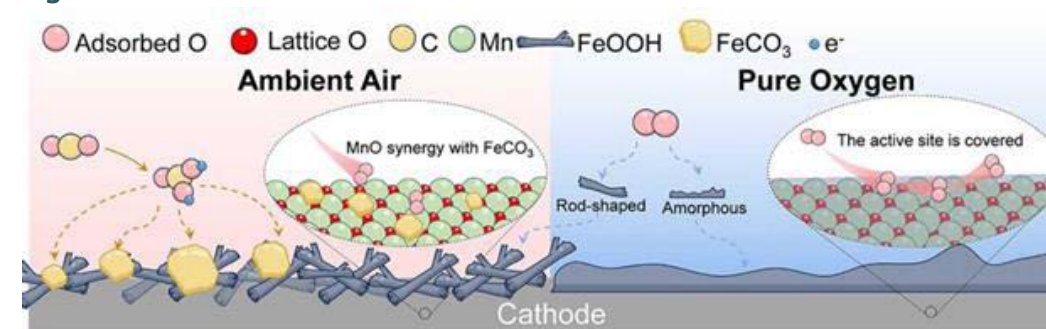
Results: First, we developed an Fe³⁺-based iron-air battery using 1 M Fe(OTf)₃ electrolyte. In real-air conditions, the battery achieved a high areal capacity of 8.43 mAh cm⁻² and stable cycling for over 320 hours, outperforming pure oxygen environments. In situ Raman spectroscopy and DFT calculations revealed that trace CO₂ promotes a beneficial FeCO₃ intermediate, inducing dispersed rod-like FeOOH growth. This prevents the formation of dense passivation layers, ensuring full active site exposure.

Second, to mitigate anode corrosion, we introduced a low-water-activity electrolyte with 60% DMF. DMF molecules preferentially adsorb on the iron surface to block water contact, while simultaneously disrupting the hydrogen-bonding network to suppress water activity. This dual mechanism—combining interfacial adsorption with bulk solvation modulation. Consequently, the cycle life of the iron-air battery successfully exceeds 700 hours, demonstrating a robust strategy for high-performance aqueous batteries.

Acknowledgements: Authors acknowledge the financial support of NSFC of China (22179095).

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Figure:**Keywords:**

Iron-air battery, aqueous electrolyte, DMF

Challenging the Paradigm: CEI Formation on the Oxide Surface in a Conventional Aqueous Electrolyte

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Introduction: Although the Cathode-Electrolyte-Interface (CEI) formation has long been considered exclusive to organic electrolytes, recent findings suggest that it may also occur in conventional aqueous electrolytes [1,2].

Results: Herein, we demonstrate the formation of a cathode-electrolyte interface (CEI layer) on the V₂O₅ surface during initial cycling in an aqueous Li⁺ electrolyte, using a thin, flat film prepared by pulsed laser deposition (PLD). By combining Cyclic Voltammetry with X-ray diffraction (XRD) analysis, micro-Raman spectroscopy and Atomic Force Microscopy (AFM) at different stages of cycling, the formed passivating layer is found to play a dual protective role by simultaneously preventing vanadium oxide dissolution in the aqueous electrolyte and suppressing low-potential irreversible Li⁺-involving reactions. The mechanism underlying CEI formation and evolution, together with its influence on the specific capacity during cycling, is discussed in detail.

Acknowledgements: This material is based upon work supported by the Air Force Office of Scientific Research under award number FA8655-25-1-7015. This publication is based upon work from COST Action OPERA - European network for Innovative and Advanced Epitaxy - CA20116, supported by COST (European Cooperation in Science and Technology, www.cost.eu).

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Keywords:

vanadium pentoxide, PLD, aqueous electrolyte, CEI

Designing Stable Aqueous Zinc-Ion Batteries via Electrolyte and Interface Regulation

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Introduction: Rechargeable aqueous zinc-ion batteries (AZIBs) are attractive candidates for safe and low-cost energy storage, but their practical application is hindered by electrolyte-induced instabilities, including dendrite growth, parasitic reactions, and limited cycling stability. This work presents an integrated strategy combining electrolyte engineering, interphase regulation, and electrode design to improve AZIB performance.

Results: Systematic regulation of electrolyte composition revealed that anion chemistry, salt concentration, and functional additives collectively govern Zn²⁺ solvation, interphase formation, and electrochemical stability [1,2]. Water-in-salt electrolytes expanded the stability window to 3.7 V, while multifunctional additives, including vinylene carbonate, amino acids, polymers, nanoparticles, and salt-particle suspensions, formed stable, ion-conductive interphases that suppressed dendrite growth, reduced parasitic reactions, and enabled highly reversible Zn plating/stripping for over 6000 h [3,4]. In parallel, interfacial engineering of manganese- and vanadium-based oxides, graphite, and chalcogen cathodes improved Zn²⁺ transport, mitigated structural degradation, and enhanced redox reversibility. The combined electrolyte and electrode design delivered Zn || graphite, Zn || MnO₂, and Zn || V₆O₁₃ full cells with high capacity retention and stable cycling beyond 1000 cycles, demonstrating a scalable strategy for durable aqueous zinc-ion batteries [5].

Acknowledgements: We acknowledge financial support from the Czech Science Foundation (GAČR, Grant No. 24-10535K) and from the OP JAK (Project AMULET, Reg. No. CZ.02.01.01/00/22_008/0004558) financed by the Czech Ministry of Education, Youth, and Sports, and the European Union.

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Keywords:

zinc-ion batteries, electrolytes, solvation, interphases, cathodes

Redox-Selective Control of Perylene Diimide for Ultrafast, Durable Aqueous Sodium-Ion Storage

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Introduction: Organic electrodes offer sustainable, tunable alternatives for metal-ion batteries but often suffer from dissolution, parasitic reactions, and unstable redox states in conventional electrolytes [1,2]. Perylenetetracarboxylic diimide (PTCDI) has shown promise for sodium-ion storage, including in aqueous systems, yet mechanistic origins of instability at deep reduction remain unresolved [3,4]. We hypothesize that confining PTCDI operation to the neutral/radical-anion couple can unlock fast, durable storage in water.

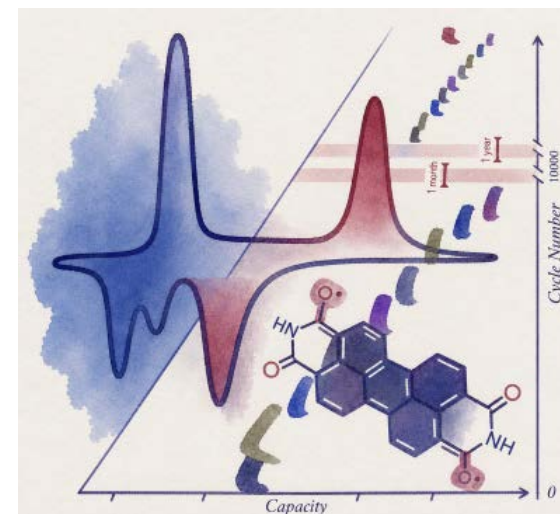
Results: Using a 5 m sodium acetate electrolyte and a fully organic composite (PTCDI/carbon black with a biodegradable chitosan binder), we demonstrate that restricting PTCDI to its first one-electron redox step enables exceptional rate capability and longevity. Differential electrochemical mass spectrometry (DEMS) identifies hydrogen evolution as a continuous corrosion pathway and rapid oxygen-driven reoxidation as a second self-discharge route of the dianion, motivating exclusion of the radical-anion/dianion couple. Ex situ X-ray photoelectron spectroscopy (XPS) and energy-dispersive X-ray spectroscopy (EDX) confirm Na-ion coordination to reduced carbonyls as the dominant charge-compensation mechanism. A symmetric PTCDI|PTCDI coin cell retains 81% of the theoretical one-electron capacity at ~1 min charge (52C), recovers full capacity at 1C, and sustains nearly 100% coulombic efficiency over 19,000 cycles. The potential gap between the two redox steps yields a radical-anion formation constant $K_{\text{radical}} \approx 4.4 \times 10^{13}$, underscoring intrinsic radical stability in water [5]. These results establish redox-selective control as a general route to combine high power with long life in aqueous organic sodium ion batteries.

Acknowledgements: Supported by the Austrian Science Fund grants DOI 10.55776/P34233 and DOI 10.55776/P35510.

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Figure:



Keywords:

Aqueous, sodium-ion, Radical-anion, selectivity, High-rate, stability

Solid-State Batteries

New Solutes, PFAS-Free, for Polymer Electrolytes

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Introduction: The need for improved electrolytes to be used in batteries with liquid and polymer solvents is appearing more clearly with the drawbacks of LiPF₆ and the increasing awareness of the danger of PFASs in the environment. LiTFSI is an example of a PFAS salt that must be replaced. In this presentation, we usher some new salts and polysalts that contain only inorganic fluorine or are fluorine-free.

Results: in a first development, we have focussed on the dicyano-imidazole chemistry as a base for fluorine-free anions. dicyano-imidazole, a Hückel anion, derives from the diaminomaleonitrile (DAMN) chemistry, a widely used tetramer of hydrocyanic acid. Affixing a chlorine atom in the 2 position of imidazole resulted in a thermally stable lithium or sodium salt (400°C) and the Cl atom is sufficiently electron-withdrawing to give conductivities in liquid (EC-DMC) or polymer electrolytes (PEO) that are on a par with that given by TFSI. The voltage stability widow on the anodic side exceeds +4.2V and reversible Li plating is visible on the cathodic side. Neither in PEO nor in liquid (PC) electrolytes any aluminium current collector corrosion is observable. Li|PEO-LiDCCI|LiFePO₄ cells cycle steadily with minimal drift.

Moreover, dicyanoimidazole salts have been grafted to a polymer, resulting in a polysalt here again with high thermal stability. The anodic voltage limit now reaches 4.5V in NMP and the polysalt alloyed with PEO results in tough membranes whose T₊ = 1 conductivity is comparable to that given by PEO-LiPSTFSI, a PFAS single ion conductor taken as state-of-the-art.

The non-PFAS moieties —SO₂F that impart the excellent properties of FSI anion have been arranged in a different manner to give anions, as discrete or polymeric species that surpass FSI, and in the case of the polysalt with PEO, give T₊ = 1 conductivity up-to-now unreported

Acknowledgements:

References:

Keywords:

PFAS-free anions, single-ion conductors, Hückel anions

Novel Electrolyte Components for Batteries and Supercapacitors

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Significant advancements have been made in electrochemical energy storage technologies since the first commercialization of the lithium-ion battery in 1991. Many of these advancements are associated with the development of new materials which enable improved performance and safety, reduced cost and extended lifetimes (although often not concurrently). These material developments have been more focused on active materials, while electrolytes have traditionally taken a back seat. In many ways, the electrolytes used in today's lithium-ion batteries, as an example, are much the same as they were in 1991. In recent years, additives have received much focus, as a secret sauce to improved properties, as they can have a significant impact on performance, but don't have a huge impact on the cost or production processes. Beyond additives, there is still a large electrolyte playing field that is open to be examined. This contribution will address novel electrolyte component development based on boron and phosphorus chemistries for lithium- and sodium-ion batteries and supercapacitors ongoing at the University of Würzburg.

The authors acknowledge funding from following sources: the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101147457 (INERRANT) with the involvement in No. 101104022 (Battery 2030 CSA3) and under grant agreement N° 101091997 (EMPHASIS); the German Federal Ministry of Research, Technology and Space under the funding number 03XP0560A (NaKlaR); and the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – SFB1762. This output reflects only the authors' view and the funders cannot be held responsible for any use that may be made of the information contained therein.

Turning Waste Into Value: Biosourced and Recycled Polymers for Safe, Sustainable, High-Performing Li-Based Batteries

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Introduction: Commercial alkali metal (Li, Na)-ion secondary batteries currently rely on liquid electrolytes containing toxic and volatile organic carbonate solvents. These systems are prone to side reactions, oxidative decomposition, gas production, and combustion, particularly at elevated temperatures. A promising alternative is the development of all-solid-state batteries based on polymer materials, films, ceramics, low-volatility additives, and sustainable components [1]. To reduce both cost and environmental impact, efforts should focus on the use of low-cost and bio-sourced materials, the development of eco-friendly manufacturing processes, and the reuse and revalorisation of recycled materials and components.

Results: In this context, this work presents an overview of recent developments in our laboratories on innovative recycled and bio-based polymer electrolytes for sustainable and high-performance Li/Na-based batteries. In particular, recycled polyvinyl butyral (PVB) from post-consumer laminated glass waste (automotive and construction), which cannot be recycled for its original application due to degraded optical properties [2,3], and bio-manufactured vitrimeric polyhydroxyalkanoates (PHA) were investigated. These materials were incorporated into polyethylene oxide (PEO)-based solid polymer electrolytes in order to address both performance and sustainability challenges.

This approach enabled the design of a series of polymer electrolytes with improved mechanical strength, thermal stability, and electrochemical performance, while promoting the use of recycled and bio-based materials to reduce environmental impact. To assess manufacturability and practical relevance, both lab-scale and industrial-format full cells were assembled and tested, showing stable long-term cycling at room temperature. These results highlight a concrete pathway toward safer, lower-cost, and more sustainable Li/Na-based energy storage technologies.

Acknowledgements: The SUNRISE (GA 958243), BIOMAPS project (GA 101177344), and HIPERZAB project (GA 101115421) have received funding from the European Union's EIC research and innovation programme.

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Modeling Ion Transport in Solid-State Electrolytes: From the Perspective of Potential Energy Surfaces

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Ion transport in solid state electrolytes limits the performance of safe, high energy density solid state batteries. Improving these materials requires reliable predictions of ionic conductivity and mechanistic insight into how chemistry, structure, and disorder control lithium diffusion, which in turn demands efficient modeling approaches that overcome the time and length scale limitations of molecular dynamics.

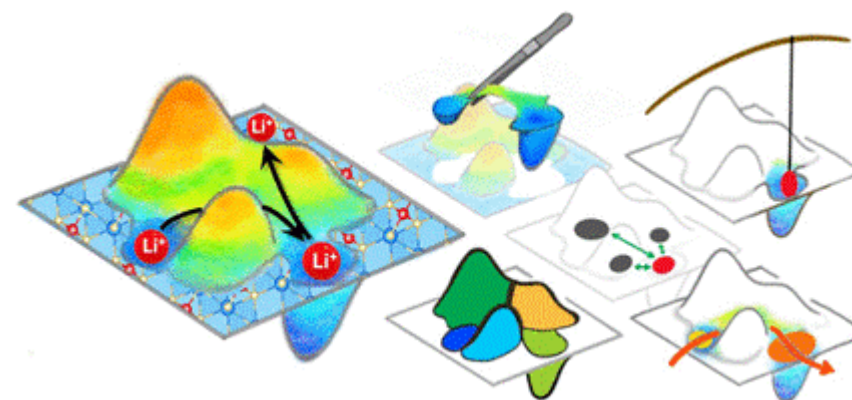
In this talk, I will present our work on cost efficient multiscale tools for modeling ion diffusion in solid state electrolytes. The approach applies topological and geometric analysis of the potential energy landscape to identify ion sites, diffusion pathways, and transport bottlenecks, and couples this with efficient statistical models to predict ionic diffusivities in electrolyte materials with ab initio molecular dynamics accuracy at a fraction of the computational cost. The framework also generates physically interpretable energy landscape descriptors – such as migration barrier distributions and network connectivity – that directly connect structure to ionic transport and performance, and enable physics based machine learning models for accelerated materials discovery.

I will further discuss insights from our calculations, including the effects of ion substitution and configurational entropy on the effective free energy landscape for lithium transport, and outline ongoing efforts to extend this methodology to non crystalline electrolytes such as polymer based systems and multiphase composites.

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Figure:



Single- Ion Conducting Nanohybrid Electrolytes for Lithium Metal Batteries

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Introduction: The rise in electrification has accelerated research into new battery materials and chemistries. Over the past few years, all-solid-state batteries have emerged as promising next-generation batteries due to their enhanced safety and high energy density. In this context, incorporating nanoparticles into polymer electrolytes has been shown to improve ionic conductivity and mechanical stability. However, incomplete dendrite suppression has driven the development of single-ion conducting polysalts, enabling homogeneous lithium deposition and fast charging. Anion immobilisation[1] within the polymer matrix enables Li⁺-only conduction, reducing concentration gradients and suppressing dendrite growth.

Results: Herein, we present a nanohybrid solid polymer electrolyte that integrates anion-immobilised nanofillers with a polymer matrix to achieve single-ion lithium conductivity and enhanced mechanical stability. Flexible amine-terminated tethers anchor the anions, extending Li⁺ delocalisation while reducing polymer relaxation time. A systematic investigation of the synthesis of a sulfonamide salt tethered to an amine-terminated silane coupling agent and the functionalisation of nanoparticles with this salt, which also serves as the electrolyte salt, is conducted. Incorporation of these salt-functionalised nanofillers into a plasticised poly(ethylene oxide) matrix results in Li⁺-only conduction, with a lithium transference number of 0.7 and an ionic conductivity of 10⁻⁴ S cm⁻¹ at 70 °C at the optimum filler loading. The functionalised nanofillers provide a three-in-one effect by enhancing electrochemical stability, single-ion conduction, and the mechanical properties of the polymer electrolyte. The synthesis, functionalisation strategy, and comprehensive physicochemical and electrochemical characterisation of the resulting nanohybrid polymer electrolyte, together with its electrochemical performance in lithium batteries, will be presented.

Acknowledgements: The authors acknowledge the Toyota Motors Europe for funding this project.

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Keywords:

Lithium metal batteries, nanohybrid electrolytes, polymers

Photocrosslinked PEO–PEC Electrolytes Enabling Long-Life Lithium and Sodium-Metal Solid-State Batteries

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Introduction: The development of safe, high-energy-density alkali-metal batteries requires solid-state electrolytes that simultaneously combine high ionic conductivity, mechanical robustness, wide electrochemical stability, and stable electrode/electrolyte interfaces. However, conventional poly(ethylene oxide) (PEO)-based electrolytes remain constrained by crystallization-induced limitations in ion transport. Here, a solvent-free strategy is employed to fabricate UV-crosslinked poly(ethylene oxide)-poly(ethylene carbonate) (PEO–PEC) salt-in-polymer electrolytes via extrusion, hot pressing, and in situ photopolymerization.[1-3] The resulting crosslinked architecture is designed to regulate polymer segmental motion, suppress crystallinity, and enhance structural and electrochemical stability.

Results: The UV-crosslinked PEO–PEC framework forms a mechanically resilient and stable electrolyte matrix with improved amorphous character and wide electrochemical stability. Incorporation of cyclic carbonate additives further tailors ion-solvation environments and polymer dynamics. Among the investigated systems, 1,2-butylene carbonate provides the most significant enhancement, lowering the glass-transition temperature, promoting ion-dissociation, and facilitating rapid Li⁺ transport. Consequently, the electrolyte sustains stable lithium plating/stripping for more than 2300h and enables near-theoretical capacity utilization in LiFePO₄ cells at room temperature, together with excellent rate capability and cycling reversibility.[4] Extending this platform to sodium metal batteries, optimized NaFSI/NaDFOB dual-salt formulations combined with tetraglyme and Pyr14FSI ionic liquid promote favorable Na⁺ transport kinetics and robust interphase formation.[5] The resulting sodium systems exhibit enhanced ionic conductivity, stable Na-metal cycling exceeding 450h, excellent rate performance, and near-theoretical capacities in Na₄Fe₃(PO₄)₂P₂O₇ half cells at 40°C. The developed polymer electrolyte platform successfully bridges fast ion transport and stable metal–electrolyte interfaces in alkali metal batteries.

Acknowledgements: Support by the European Union's Horizon Europe research and innovation program under the MSCA (RIDERS Doctoral Network, GA N. 101120432, <https://www.riders-dn.eu>).

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Keywords:

Solid Polymer Electrolytes, UV-Crosslinking, PEO, PEC

Toward Scalable Dry Processing of Composite Single-Ion-Conducting Polymer Electrolytes for Lithium Metal Batteries

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Introduction: Solid polymer electrolytes (SPEs) based on polyethylene oxide (PEO) are promising for lithium metal batteries due to their improved safety, mechanical robustness, and ability to suppress lithium dendrite growth compared with conventional liquid electrolytes [1,2]. However, SPEs are commonly produced by solvent casting, which requires energy-intensive drying and may leave residual solvent impurities that affect electrochemical performance. Dry-processing methods offer a sustainable alternative by eliminating solvents, reducing environmental impact and manufacturing costs, and enabling scalable production. In this work, we investigate the transition from wet processing to dry processing of scalable composite single-ion-conducting polymer electrolytes and evaluate the influence of processing on their structural, thermal, mechanical, chemical, and electrochemical properties.

Results: Composite single-ion-conducting polymer electrolytes were successfully fabricated by melt extrusion, yielding self-standing membranes suitable for electrochemical cell assembly. Structural characterization using synchrotron X-ray tomography and complementary microscopy revealed clear differences between dry- and wet-processed membranes, including variations in phase distribution, homogeneity, and microstructural integrity that may affect membrane stability and performance. Thermal and mechanical properties were investigated using thermogravimetric and calorimetric analyses, demonstrating the influence of processing route on material behavior.

Chemical and electrochemical stability were evaluated in Li|SPE|Li symmetric cells and high-voltage lithium-metal full cells. The results demonstrate that extrusion-based processing can produce high-quality composite single-ion-conducting polymer electrolytes while eliminating solvent-related manufacturing challenges. The study also identifies critical processing-induced effects that must be considered when transitioning to solvent-free manufacturing without changing electrolyte composition. These findings support scalable and sustainable production of polymer-based solid-state batteries.

Acknowledgements: The authors acknowledge funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101147688 (HyLiST project).

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Keywords:

Solid polymer electrolyte; Dry processing

Cathode Engineering in Sulfide Solid-State Batteries: From Insertion-Type NMC to Conversion-Type Li-Te Chemistries

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Introduction: All-solid-state batteries (ASSBs) are emerging as leading candidates for next-generation energy storage, offering higher energy density, faster charging, enhanced safety, and improved cyclability over conventional lithium-ion systems.[1] However, their performance is strongly governed by electrode fabrication and cathode-electrolyte interfacial stability, both of which remain key barriers to upscaling. Pellet-based cells often suffer from limited solid-electrolyte infiltration into the cathode, causing side reactions, contact loss, and capacity fade. [2] Here, we address these interfacial challenges across two distinct cathode mechanisms- insertion-type NMC and conversion-type tellurium- to probe how fabrication method and reaction chemistry each govern ASSB performance.

Results: For NMC, we systematically varied the ratio of electronic/ionic conductive additives and compared composite cathodes prepared via a solution process against conventional pellet-based electrodes. The solvent-processed NMC cathode outperformed the pellet-based cell, owing to improved contact between the active material and the Li6PS5Cl solid electrolyte, confirming fabrication method as a primary performance lever for insertion-type cathodes.

For tellurium, a conversion-type cathode, we instead focused on the reaction mechanism and interfacial stability. A hand-mixed Te composite electrode delivered a discharge capacity of 240 mAh g⁻¹ at a loading of 5 mg cm⁻² in an ASSB. Post-mortem XRD, EIS, and GITT analyses confirmed reversible formation of Li2Te with no detectable side reactions with the sulfide electrolyte, demonstrating excellent chemical compatibility. EIS revealed the evolution of interfacial resistance over cycling, while GITT measurements provided insight into Li⁺ diffusion kinetics during the conversion reaction. This work demonstrates a fundamental understanding of two distinct cathode systems, providing critical insights into processing, fabrication, and interfacial behavior that will guide their respective development toward high-energy-density, sulfide-based all-solid-state batteries.

Acknowledgements: NA

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Keywords:

Solid-State Batteries; Argyrodite; Li-Te Batteries; Interface

Solid-State Batteries and Material Processing

High-Transference-Number Polymer-in-Solvent Single-Ion Electrolytes for Lithium Metal Batteries

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Introduction: Lithium metal batteries (LMBs) are next-generation batteries owing to lithium metal's lowest redox potential and high theoretical capacity. However, practical implementation remains hindered by non-uniform lithium plating/stripping and dendrite growth during cycling in liquid electrolytes.

Single-ion-conducting polyelectrolytes (SIPs), in which the anions are covalently immobilized on the polymer backbone, offer an attractive alternative by promoting predominantly Li^+ transport ($t_{\text{Li}^+} \approx 1$), thereby reducing concentration polarization, mitigating dendrite formation and improving interfacial stability [1].

Results: In this work, PMTFSI-based SIPs were synthesized via radical polymerization in two different solvents (water and DMF), yielding homopolymers with identical chemical structures but significantly different molecular weights (5.2×10^6 and $3.9 \times 10^5 \text{ g}\cdot\text{mol}^{-1}$, respectively), roughly a factor 10. While most literature studies improve ionic conductivity by swelling polymers with solvent to form gels, we adopted the opposite approach by dissolving the SIPs in propylene carbonate to form polymer-in-solvent electrolytes with polymer contents ranging from 1 to 20 wt%. The influence of molecular weight on ion transport, rheological properties, and electrochemical performance was systematically investigated.

The results show that increasing molecular weight raises viscosity by up to a factor of 54, consistent with enhanced chain overlap and entanglement [2]. Nevertheless, ionic conductivity remains nearly unchanged, reaching $0.6 \text{ mS}\cdot\text{cm}^{-1}$ at 20°C despite the large viscosity differences, demonstrating a strong viscosity-conductivity decoupling. PFG-NMR and electrochemical measurements confirm that lithium ions are the dominant charge carriers, with a transference number close to unity ($t_{\text{Li}^+}=0.97$). Finally, Li/Li symmetric pouch cells exhibited a stable lithium plating/stripping for more than 1200 h, while Li/LFP pouch cells employing a thin ($40\mu\text{m}$) lithium delivered highly reversible cycling with remarkable Coulombic efficiencies close to 100% after 190 cycles, highlighting the potential of these polymer-in-solvent SIPs for lithium metal batteries.

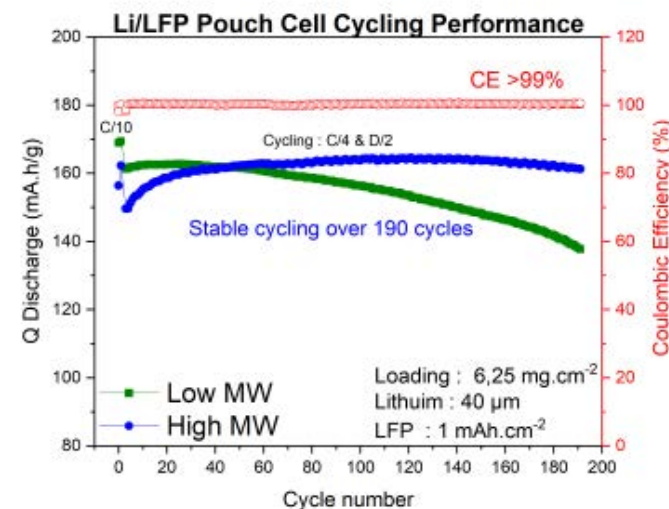
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Figure:



Keywords: Lithium metal batteries, Polyelectrolytes, Single-ion polymer

Interface Structural Stability and Li-Ion Transport in Anode-Side $\text{Li}_9\text{N}_2\text{Cl}_3$ | Li_2ZrCl_6 Solid-Electrolyte Bilayer for All-Solid-State Batteries by Large-Scale Molecular Dynamics Simulations and Sparse Gaussian Process Regression Potential

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Introduction: Recently, halide-type solid electrolytes (SEs) with high Li ion conductivities ($> 10^{-4} \text{ S cm}^{-1}$) have been reported as promising materials for all-solid-state batteries (ASSBs). However, they tend to decompose when in direct contact with Li metal anode, resulting to an anode-SE interface with poor contact and non-uniform current density distribution, Li dendrite formation and eventual short-circuiting. To address this, interphase layers are employed to improve interface chemical compatibility and contact. In this work, using large-scale molecular dynamics (MD) simulations with an optimised machine-learning potential based on sparse gaussian process regression (SGPR) formalism, the $\text{Li}_9\text{N}_2\text{Cl}_3$ | Li_2ZrCl_6 bilayer interface is investigated to combine the complementary advantages of two SE chemistries [1]. Here, $\text{Li}_9\text{N}_2\text{Cl}_3$ (interphase layer) is in direct contact with the Li-metal anode to take advantage of its relatively irreducible character, while Li_2ZrCl_6 (SE component) is selected for its promising Li-ion transport and cathode-side compatibility. The central objective is to determine whether the $\text{Li}_9\text{N}_2\text{Cl}_3$ | Li_2ZrCl_6 interface is stable (i.e., strongly adhered) and can provide continuous Li-ion transport (low energy barrier).

Results: To generate the DFT training dataset for the SGPR potential, multiple bulk and interface structure models are generated. Reference atomic configurations, energies, forces, and stresses are generated using DFT geometry optimisation and ab initio MD (AIMD) simulations (10-ps trajectory/temperature) over selected temperature conditions (300-2000 K). The optimised SGPR potential is then used for long-timescale (10 ns) MD production runs for different interfacial morphologies such as crystal-crystal, crystal-amorphous, and amorphous-amorphous interface configurations. The resulting MD trajectories are analysed in terms of interfacial reconstruction, cation and anion mobility, ion mixing, Li-ion transport, and transport anisotropy. Overall, this study provides atomistic insights on the interface stability and Li-ion transport behaviour related to anode-side bilayer designs for ASSBs.

Acknowledgements:

This work is supported by COI-NEXT (JPMJPF2016) of JST.

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Keywords:

Nitride-halide interface, machine-learning potential, molecular dynamics

Non-Crystalline Chlorides as New Electrolytes for Sodium-Ion Solid-State Batteries

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Introduction: Na-ion solid-state batteries (Na-SSBs) have recently attracted great interest thanks to the high energy density value and enhanced safety offered by the use of solid-state electrolytes (SSEs). Among all the different families of SSEs, chloride-based Na⁺-conductors are promising candidates thanks to their (electro)chemical compatibility with several positive electrode materials at high potentials.^{1,2} However, the main drawback of these compounds is their low ionic conductivity ($\sim 10^{-5} \text{ mS cm}^{-1}$). Among the different approaches that have been developed to increase their ionic conductivities, the synthesis of non-crystalline chlorides through mechanochemistry is particularly promising.^{3}

Results: In this study, the local structure and Na⁺ mobility in non-crystalline chloride-based conductors will be investigated in details through the case of $x \text{ NaCl-ZrCl}_4$ ($0 < x \leq 2$) system. By varying the amount of NaCl in the initial reactants, non-crystalline compositions possessing high Na⁺ conductivity can be obtained. Interestingly, higher conductivity (up to $7 \cdot 10^{-2} \text{ mS cm}^{-1}$) is achieved in compositions possessing lower sodium content, indicating an enhancement in Na⁺ mobility by varying the initial proportion. Mechanochemistry coupled with operando Raman spectroscopy is employed to obtain insightful information on the reaction mechanism. Raman spectroscopy reveals that depending on the stoichiometric conditions, different Zr-containing fragments are formed that will prevent the formation of crystalline phases and enhance the Na⁺ mobility. Furthermore, pair distribution function analysis, ²³Na ss-NMR, X-ray absorption spectroscopy and Raman coupled with DFT calculations are employed to understand the relations between the composition, local structure and electrochemical performance of these SSEs. Finally, the electrochemical performance of Na-SSBs using these non-crystalline chlorides is demonstrated with a reasonable performance up to C/2.

Acknowledgements: The authors acknowledge the Ph.D funding from the University of Montpellier.

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Figure:

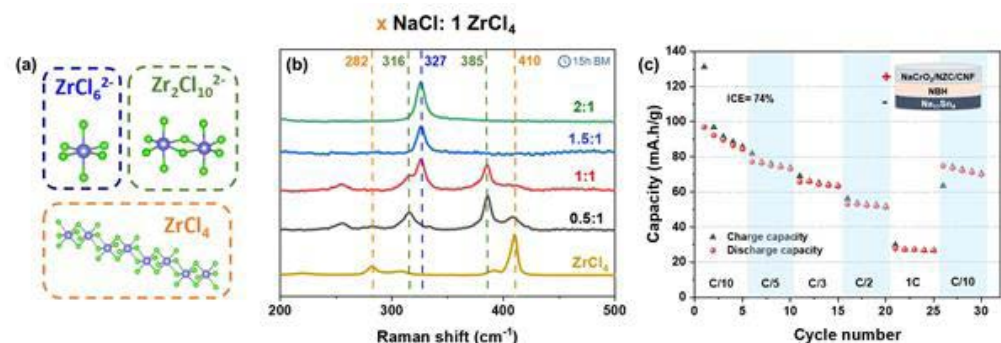


Fig. 1: (a) Zr-containing fragments observed by Raman spectroscopy, (b) Raman spectra of non-crystalline chlorides obtained with different NaCl:ZrCl₄ molar ratio, (c) C-rate study of a Na-SSB employing a non-crystalline chlorided as SSE.

Keywords:

Na-ion, Solid-state battery, Electrolytes, Chlorides

Optimization of Slurry Preparation and Coating Parameters in Ni-Rich NMC/LMFP Blended Cathodes and Their Electrochemical Performance

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Introduction: Lithium-ion batteries (LIB) development is driven by key aspects including energy density, cycling stability, cost-effectiveness, and safety. Among cell components, cathode active materials (CAMs) have a significant impact on these performance aspects. Accordingly, cathode chemistries such as nickel-rich lithium nickel manganese cobalt oxide (Ni-rich NMC) and lithium manganese iron phosphate (LMFP) have attracted increasing attention due to their distinct advantages and limitations. Ni-rich NMC offers high energy density and reversible capacity despite cost, sustainability, and safety concerns [1]. In contrast, LMFP exhibits excellent thermal stability and safety with low cost and environmental benefits but it suffers from structural degradation risk and relatively low capacity [2]. These opposing characteristics indicate that individual cathode chemistries cannot meet all key performance requirements simultaneously, motivating blended strategies combining complementary properties synergistically. However, density or particle size driven phase separation, binder migration, electronic isolation, and tortuosity heterogeneity will need to be revisited in order to get the best performance in the blended cathode systems.

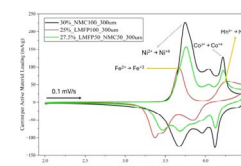
Results: The aim of this study was to investigate the effect of slurry formulation and coating optimization on the electrochemical performance of Ni-rich NMC/LMFP blended cathode electrodes, considering limited understanding of their interactions in blended structures. In particular, the influence of solid-to-liquid ratio during slurry preparation, CAM composition variation (e.g., different NMC/LMFP ratios), and different coating loadings were systematically examined. The resulting electrodes were electrochemically evaluated by cyclic voltammetry (CV), rate capability, electrochemical impedance spectroscopy, and long-term cycling performance to elucidate structure-performance relationships. For instance, CV revealed synergistic redox interactions between Ni-rich NMC and LMFP within the blended cathode structure.

Acknowledgements: This study has received financial support from the European Union through the BATMACHINE project, grant agreement number 101104246.

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Figure:



Keywords:

Blended Cathodes, Slurry and Coating Optimization

Interface Engineering of Micro-Sized Silicon Particles by Atomic Layer Deposited ZnO for Advanced Silicon/Graphite Composite Anodes

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Introduction: Silicon (Si), possessing an exceptionally high specific capacity of ~ 3579 mAh g⁻¹ (Li₁₅Si₄), has emerged as a highly promising anode material for next-generation lithium-ion batteries (LIBs). However, the intrinsic volumetric expansion (>300%) associated with repeated lithiation/delithiation induces pronounced mechanical pulverization and continuous destabilization of the solid electrolyte interphase (SEI).[1] These structural and interfacial degradations ultimately result in accelerated capacity fading and poor cycling stability. Herein, we systematically investigate the physicochemical and electrochemical characteristics of Si particles conformally coated with zinc oxide (ZnO) via atomic layer deposition (ALD). The coated Si was subsequently integrated with commercial graphite (Gr) in a compositional ratio of 20:80 (Si:Gr) to mitigate the severe volumetric changes of Si upon cycling by providing enhanced structural robustness and mechanical stability.[2]

Results: The electrochemical performance of the prepared anode materials was evaluated in which the Si coated with 8 cycles of ALD ZnO demonstrated superior rate capability, delivering a reversible capacity of 640 mAh g⁻¹ at 1C compared to 474 mAh g⁻¹ for the pristine Si/Gr anode. Comprehensive structural and morphological analyses revealed that the conformal ZnO coating effectively mitigates unwanted SEI growth and suppresses crack propagation during cycling, thereby enhancing electrode integrity and charge-transfer kinetics.[2] These findings highlight the effectiveness of ALD-engineered ZnO interfacial layers in improving the cycling stability of high-Si content anodes for advanced LIB applications.

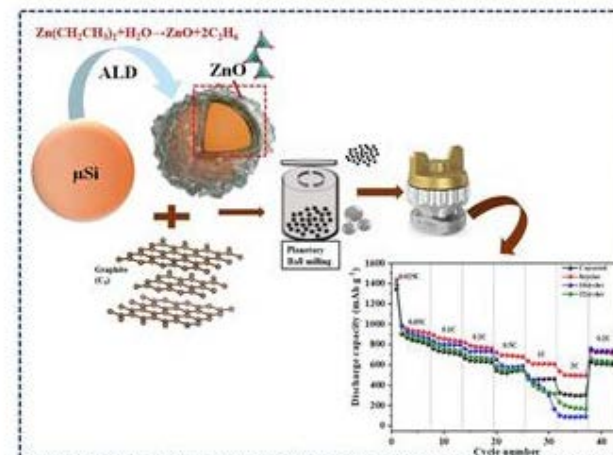
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Figure:



Keywords:

ZnO coated Si powder, Si/Gr, solid-electrolyte-interphase

Lithiophilic Sn@MXene Composite Electrodes as Hosts for Stable Lithium Metal Anodes

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Introduction: Lithium metal batteries (LMBs) are promising candidates to surpass the energy density of conventional lithium-ion batteries (LIBs), owing to the high theoretical specific capacity and low redox potential of lithium metal. These advantages are further enhanced in anodeless configurations, where lithium is plated directly onto a current collector. However, such systems face critical issues, including unstable solid electrolyte interphase (SEI), dendrite formation, and inactive lithium accumulation, leading to rapid capacity decay [1]. To address these challenges, we combined MXene scaffolds with Sn-induced lithiophilicity to regulate lithium nucleation and growth [2,3].

Results: Lithium deposition was investigated on bare copper, pristine Ti₃C₂T_x MXene, and Sn-modified MXene (Sn@MXene) [4]. Electrochemical testing in lithium half-cells, using a stripping-plating reservoir protocol, showed that Sn@MXene significantly improves deposition stability compared to copper and pristine MXene, due to the synergistic effect of homogeneous ion flux provided by the MXene layered structure and reduced nucleation overpotential induced by Sn.

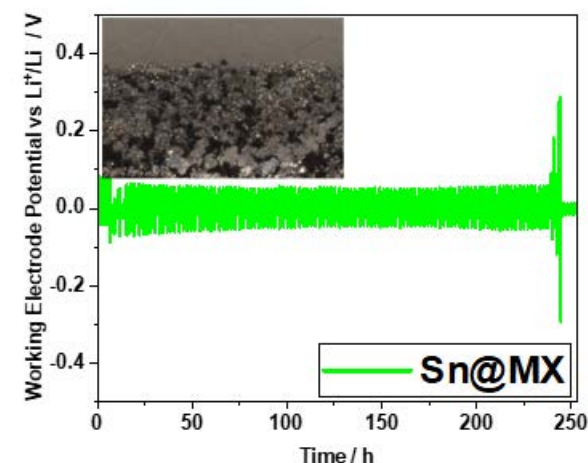
Ex situ characterizations directly correlated electrochemical performance with lithium morphology and interfacial evolution, highlighting the role of substrate composition and electrolyte formulation. This integrated analysis enabled decoupling their contributions and provided insight into the mechanisms governing stable lithium deposition.

Acknowledgements: Moulay Tahar Sougrati is gratefully acknowledged for technical help in the collection of the ¹¹⁹Sn Mössbauer spectra. ANR is acknowledge for funding through the project Labex STORE-EX (Grant ANR-10-LABX- 76-01). This work has been financed by the Research Fund for the Italian Electrical System under the Three-Year Research Plan 2025-2027 (MASE, Decree n.388 of November 6th, 2024), in compliance with the Decree of April 12th, 2024.

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Figure:



Keywords:

Lithium metal; Anodeless; MXene; Tin

Electrolytes and Post-Li-Ion Batteries

Heat-Capacity-Mediated Driving Force Crossover for Solvation-Structure Evolution in Battery Electrolytes

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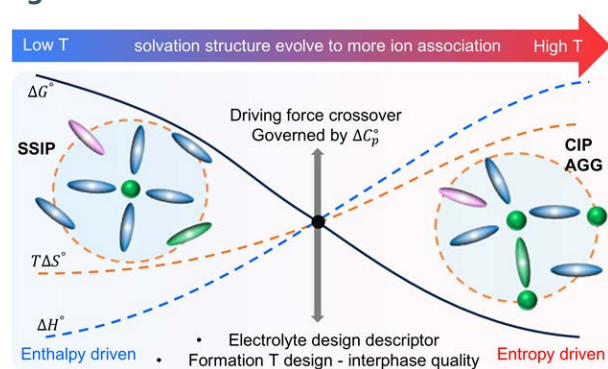
Introduction: Electrolyte solvation structure governs ion transport, interfacial stability, and long-term cycling of rechargeable batteries operated over wide temperature ranges, yet the thermodynamic origin of its temperature dependence remains poorly understood.

Results: We establish a thermodynamic framework for solvation-structure evolution by combining molecular dynamics simulations with graph-based cluster analysis in representative carbonate-based electrolytes. By explicitly incorporating heat-capacity (ΔC_p°) effects, we resolve the temperature dependence of enthalpy and entropy and capture the nonlinear evolution of solvation equilibria. In Li⁺ electrolytes, ion association increases monotonically with temperature and, although endothermic, becomes entropically favored at elevated temperature. More generally, the thermodynamic driving force for solvation-structure evolution is temperature dependent and can crossover between entropy and enthalpy. Importantly, ΔC_p° emerges as a descriptor of thermodynamic sensitivity, quantifying how strongly the solvation free-energy landscape responds to temperature. These thermodynamic regimes also reveal transport behavior: electrolytes with stronger ion association exhibit lower conductivity, greater temperature sensitivity, and higher cation transference numbers. This temperature-dependent crossover is further verified in Na⁺- and K⁺ electrolytes as a general feature. Our work explains why high-temperature formation promotes robust interphase formation and identifies ΔC_p° as a critical design descriptor for high performance electrolyte and battery formation protocols.

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Keywords:

Electrolyte; Solvation structure evolution; Entropy; Thermodynamics

Improving Reversible Deposition of Li for Anode-Free Technology by Tuning Electrolyte Composition

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Introduction: Anode-free lithium metal batteries are an interesting alternative to Li-ion batteries, providing high energy density and simplifying the manufacturing process. Indeed, the cell is assembled without Li metal as negative electrode; instead, the electrode is generated "in situ" during the deintercalation of Li ion from the positive electrode, which is then electroplated onto the negative electrode current collector. Several limitations hinder the development of this technology, the first being the irreversibility of the plating/stripping process and the second being the current collector's properties. The former is generally characterized by a low coulombic efficiency (CE). Deposited lithium metal can react with the electrolyte and be passivated, leading to the formation of mossy and dead Li, which reduces the amount of active Li, reducing the achievable specific capacity [1]. The latter influences the homogeneous deposition of Li onto the current collector, which mainly depends on the current collector's surface lithiophilicity, morphology, and the pressure of the cell.

Results: In this presentation, we focused on the electrolyte formulation by assessing the impact of the salts and their concentrations. We have characterized them electrochemically in half-cells with Cu versus Li metal first, since it allows long-term cycling analyses. We compared the electrochemical performance of the different salts regarding their polarizations, their CE, and the irreversible Li loss during cycling. As can be seen in Figure 1 (a), LiFSI seems to reach higher and more stable CE than LiTFSI or LiPF₆. It could be explained by the formation of a compact [2] passivating layer with LiFSI as Figure 1 (b,c) reveals. It also could be linked to a LiF-enriched layer, which is being studied with XPS.

Acknowledgements: The authors acknowledge financial support from Ampere.

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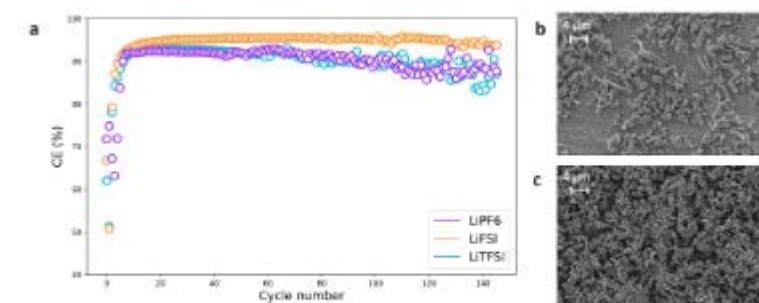


Figure 1 : (a) Coulombic efficiency as a function of cycle number for half-cells with Cu vs. Li metal using different electrolytes. (b, c) SEM images of a Cu electrode which cycled face to Li metal during one cycle and stopped after stripping Li from Cu in an electrolyte based on (b) LiPF₆ and (c) LiFSI salts.

Keywords:

anode-free, electrolyte, lithium plating, salt

Polyimide-Linked Hexaazatriphenylene-Based Porous Organic Polymer With Multiple Redox-Active Sites as a High-Capacity Organic Cathode for Lithium-Ion Batteries

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Introduction: The development of high-capacity, sustainable cathode materials remains a critical challenge in advancing lithium-ion battery technologies for next-generation energy storage. Organic electrode materials (OEMs) represent a promising alternative to conventional inorganic cathodes, owing to their composition from earth-abundant elements and chemically tunable structures that enable high theoretical capacities.¹

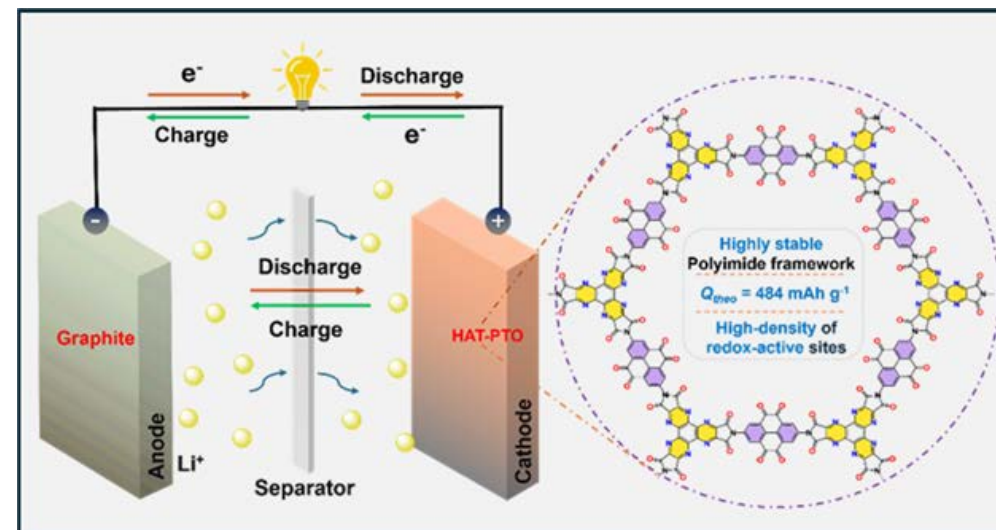
Results: Herein, we report a polyimide-linked porous organic polymer (HAT-PTO) synthesized via a straightforward hydrothermal reaction from redox-active hexaazatriphenylene (HAT) and pyrene-4,5,9,10-tetraone (PTO) building blocks. The resulting HAT-PTO framework incorporates multiple redox-active C=O and C=N centers, delivering a high theoretical capacity of 484 mAh g⁻¹ (Fig. 1). To overcome limitations in electronic conductivity, hybrid materials were synthesized by in-situ growth of HAT-PTO on pristine (CNT) and carboxyl-functionalized carbon nanotubes (cCNT). Notably, the HAT-PTO-cCNT hybrid delivers a high capacity of 397 mAh g⁻¹ at C/10, outstanding rate capability of 225 mAh g⁻¹ at 20C, and long-term cycling stability, retaining 171mAh g⁻¹ after 6000 cycles at 2C. Ex-situ FT-IR, supported by theoretical calculations, confirms the involvement of both HAT and PTO units in the charge storage mechanism.² This work presents a molecular design strategy and scalable synthesis approach toward high-performance organic cathodes, paving the way for durable, high-rate lithium organic batteries.

Acknowledgements: Prof. Manuel Souto acknowledges funding from the European Research Council (ERC) under the European Union's Horizon Europe Framework Programme (ERC-2021-Starting Grant, grant agreement no. 101039748-ELECTROCOFS). This work had also received financial support from the Xunta de Galicia (Centro singular de investigación de Galicia accreditation 2023–2027, ED431G 2023/03) and the Oportunius program (Gain). Dr. Arindam Mal acknowledges the European Union's EU Framework Programme under the Marie Skłodowska-Curie Postdoctoral Fellowships grant agreement 101209009.

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Figure:



Keywords:

Lithium batteries, Organic electrode, Porous materials

Enhancing Energy Density in Non-Aqueous Redox Supercapacitors Through Interfacial Electron-Transfer Control

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Introduction: Redox-active electrolytes have attracted considerable interest as a promising strategy to increase the energy density of supercapacitors beyond that achievable with conventional electrochemical double-layer capacitors. By introducing reversible redox mediators, including metal ions, organic compounds, or redox-active ionic liquids, the electrolyte can directly contribute to charge storage through additional faradaic processes while maintaining the characteristic high-power response of supercapacitors.

Results: In this work, we develop stable and efficient electrolytes based on ionic-liquid-stabilized redox-active species. Particular emphasis is placed on improving electron-transfer kinetics, minimizing self-discharge, and ensuring long-term chemical compatibility with activated carbon electrodes. The ability of different ionic liquids to stabilize redox-active species was evaluated for the fabrication of supercapacitor devices with enhanced capacitance, high energy and power density, and improved cycling stability.

The resulting hybrid systems exhibit a significant increase in energy density, highlighting their potential to narrow the performance gap between batteries and conventional capacitors. Overall, these advances identify redox-active electrolytes as an important platform for the development of next-generation, high-performance, and sustainable energy storage devices.

Acknowledgements: Project CPP2023-010851 (BASSERE), funded by MICIU/AEI /10.13039/501100011033 and by FEDER/EU.

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Keywords:

Redox-active species, Supercapacitors, Non-Aqueous Electrolytes

Ionic Liquids for Next Generation Hydride Batteries. Unlocking the Potential of Mg-Ni-Based Alloys

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Introduction: In recent years, the search for new energy sources has become increasingly important. Amid the ongoing energy crisis, hydrogen has emerged as an attractive alternative fuel, typically stored in electrochemical systems as metal hydrides in the anode material. Although Ni-MH technology is well established, it remains inferior to lithium-ion (Li-ion) batteries. Extensive research has shown that modifications of hydride electrodes and alkaline electrolytes have not significantly improved their performance, mainly due to the severe corrosion of the hydride electrode, which limits both efficiency and cycle life. A promising approach to overcoming these limitations is the use of ionic liquids (ILs) instead of conventional electrolytes. Owing to their high proton conductivity and wide electrochemical window, ILs are attractive candidates for next-generation metal hydride energy storage systems.

Results: The aim of the present study was to evaluate the suitability of selected protic and aprotic ILs as non-aqueous electrolytes in Ni-MH batteries. The hydrogen electrosorption process was investigated using Pd, AB₅, and Mg₂Ni alloy electrodes. In addition, both types of alloys were surface-modified with Pd nanoparticles (PdNPs) using a microwave-assisted polyol method. Electrochemical studies of the unmodified alloys and the PdNP-modified composite electrodes revealed that the use of ILs slows the electrochemical activation of both materials. However, the incorporation of Pd nanoparticles into the alloys enhances the hydrogen storage capacity and improves the stability of the discharge plateau potential, indicating enhanced electrochemical performance of the composite electrodes. The results show that IL-based electrolytes enable hydrogen storage capacities comparable to those achieved in conventional aqueous systems while simultaneously reducing corrosion processes. These findings provide new insights into the behaviour of Mg-based anodes and demonstrate that ILs offer the possibility of achieving high hydrogen storage capacities with significantly suppressed corrosion.

Acknowledgements: The authors acknowledge the support of the National Science Centre, Poland (grant no. 2023/51/D/ST5/01990).

References:

Keywords:

ionic_liquids, AB₅ Mg₂Ni, Pd, hydrogen electrosorption

Posters

Phase-Selective Silicon Degradation and Its Impact on OCV-Based SOC Estimation in Commercial Li-Ion Batteries With SiG Composite Anodes

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Introduction: While Gr/SiOx composite anodes are advantageous for their high specific capacity, their employment in Li-ion batteries also introduces unique degradation mechanisms associated with silicon. Since silicon and graphite contribute to the overall cell voltage at different lithiation potentials, phase-selective degradation of silicon can alter the OCV–SOC relationship throughout battery ageing. This work investigates how SOC-window-dependent degradation affects the evolution of pseudo-OCV profiles and how these changes translate into SOC estimation errors in Li-ion batteries with Gr/SiOx anodes.

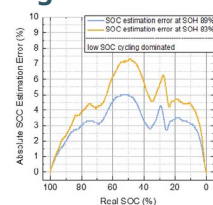
Silicon degradation was selectively induced or suppressed using various SOC cycling regimes, while capacity fade analysis, ICA, and EIS were used to support the interpretation of the resulting degradation behaviour.

Results: The results demonstrate that different cycling histories lead to significantly different pseudo-OCV evolution. When cells cycled under low-SOC-dominated and high-SOC-dominated semi-randomised scenarios were compared near the conventional end-of-life criterion, at SOH ~83%, the mean absolute SOC estimation error was 4.05% and 2.01%, respectively. At advanced degradation, particularly important for second-life applications, the error reached 6.03% at SOH 64%. These findings demonstrate that capacity retention alone does not fully describe the electrochemical state of Li-ion batteries with Gr/SiOx anodes, since cells with similar SOH may exhibit markedly different OCV–SOC relationships depending on their cycling history. The observed degradation-induced pseudo-OCV evolution was shown to introduce substantial SOC estimation errors, particularly in low-SOC-dominated cycling scenarios where the degradation of silicon is most pronounced. At comparable SOH levels, cells subjected to different cycling histories exhibited notably different SOC estimation errors, confirming that the degradation pathway directly influences SOC estimation accuracy.

Acknowledgements: This work was supported by the Scientific Grant Agency of the Ministry of Education, Research, Development and Youth of the Slovak Republic (VEGA), Grant No. 1/0707/24, and by the Slovak Research and Development Agency under Contracts No. APVV-24-0321 and APVV-22-0132.

References:

Figure:



Keywords:

Li-ion batteries; Gr/SiOx anodes; SOC estimation

Engineering Silicon-Graphite Anodes for High-Energy Lithium-Ion Batteries

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Introduction: Lithium-ion (Li-ion) batteries are the leading electrochemical energy storage systems for electric vehicles (EVs) and portable electronics due to their high efficiency, long cycle life, and relatively high energy density. The growing demand for EVs and portable devices has intensified the need for next-generation Li-ion batteries with improved power and energy densities [1]. Silicon has emerged as one of the most promising alternative anode materials because of its exceptionally high theoretical gravimetric capacity (3579 mAh g⁻¹ for Li15Si4), which is nearly ten times higher than that of graphite [2]. Despite these advantages, the practical implementation of silicon anodes remains challenging due to the severe volume expansion (>300 %), particle pulverization, unstable solid electrolyte interphase (SEI) formation, continuous electrolyte consumption, and loss of electrical contact with the current collector, ultimately leading to rapid capacity fading [3].

Results: Different sizes of silicon particles (nano and micro) were investigated, and electrodes were optimised by adding conductive additives. Optimised slurry of micro-sized silicon can perform as well as nano-sized silicon or even better. From a practical perspective, micro-sized silicon is particularly attractive for Li-ion battery manufacturing because it combines the high tap density and low cost, resulting in a scalable anode material with strong efficiency, rate performance, and cycling stability.

Acknowledgement: This project has received funding from the European Union's Horizon Europe programme under the Marie Skłodowska-Curie grant agreement (CEIPEX), supporting the project AURORA, grant number Z907486.g

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Keywords:

Li-ion batteries, Anode material, Silicon anode, Silicon particles

Developing High Energy Density Lithium-Ion Pouch Cell Through Electrolyte Selection

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Introduction: High-energy-density lithium-ion batteries (LIBs) require coordinated optimization of active materials, cell design, and electrolyte chemistry. Silicon-graphite (Si-Gr) anodes and nickel-rich LiNi_{0.8}Mn_{0.1}Co_{0.1}O₂ (NMC811) cathodes can increase cell energy density, but their lifetime is often limited by unstable solid electrolyte interphase (SEI) and cathode electrolyte interphase (CEI) formation. In this sense, electrolyte selection is often treated as secondary once the anode, cathode, and cell design are defined, under the assumption that formulations optimized for standard configurations will translate directly to advanced chemistries. Recent work on NMC811/SiOx-graphite electrolytes [1], aging mechanisms [2], harmonization in larger cell designs [3], blended-salt strategies [4], and transition-metal dissolution control [5] shows that this assumption is not always valid.

Results: This study evaluates electrolyte selection for 1 ampere-hour (Ah) pouch cells with Si-Gr anodes and NMC811 cathodes. Five commercial electrolytes were screened using three replicate cells per formulation. Cells were cycled at 1C, a condition relevant to electric-vehicle duty profiles. Clear performance differences confirmed that electrolyte chemistry strongly affects interfacial stability, capacity retention, and coulombic efficiency. The best formulation exceeded 1000 cycles while maintaining high-capacity retention and coulombic efficiency. These findings highlight the importance of electrolyte optimization in developing LIBs with silicon-containing anodes and high-nickel cathodes. The outcomes support early-stage electrolyte selection for developing durable, high-performance batteries for applications requiring both energy density and longevity.

Acknowledgements: The authors want to acknowledge the financial support of the European Union's Horizon Europe transport program under the project SiGNE (grant agreement No 101069738).

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Keywords:

lithium-ion pouch cell; electrolyte optimization; silicon-graphite anode

Towards Chain Length Dependent CEI Engineering of Ni-Rich NMC Cathodes Using Nitrile Additives

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Introduction: Ni-rich layered oxide cathodes are promising candidates for next-generation lithium-ion batteries owing to their high energy density. However, their practical application is hindered by interfacial instability, transition-metal dissolution, and continuous degradation of the cathode-electrolyte interphase (CEI). Nitrile-based electrolyte additives can coordinate with transition-metal ions through their nitrile ($-C\equiv N$) functional groups, suppressing metal dissolution and promoting interfacial stability. This work investigates the influence of nitrile chain length on the oxidative behaviour and interfacial chemistry of Ni-rich NMC cathodes by comparing succinonitrile (SN), adiponitrile (ADN), and suberonitrile (SUN) in a baseline electrolyte of 1 M LiPF₆ in EC/EMC (30:70 vol%) containing 1 wt% vinylene carbonate (VC) as additive.

Results: Electrochemical evaluation of baseline NMC90||graphite full cells demonstrated stable long-term cycling, achieving 81.9% capacity retention after 1000 cycles at a 1C/1C rate. TOF-SIMS analysis of cycled electrodes revealed a surface-localized CEI enriched in LiF and electrolyte decomposition products, while Ni species detected across the graphite anode confirmed cathode-anode crosstalk as a key degradation pathway [1]. These findings highlight the need to stabilize the cathode interface and suppress transition-metal dissolution.

Density functional theory (DFT) calculations showed that succinonitrile (SN), adiponitrile (ADN), and suberonitrile (SUN) possess lower HOMO energies than conventional carbonate solvents, indicating enhanced oxidative stability under high-voltage operation [2]. To identify optimal additive concentration, SN was selected as model compound and evaluated at 0.3, 0.5, 0.75, and 1.0 wt.%. Among the investigated formulations, 0.5 wt.% SN exhibited the lowest overpotential and the most stable constant-voltage response, indicating an optimal balance between interfacial protection and impedance growth. Ongoing work focuses on long-term cycling and post-mortem CEI characterization of SN, ADN, and SUN containing electrolytes to establish structure-property relationships between nitrile chain length, interfacial chemistry, and electrochemical performance.

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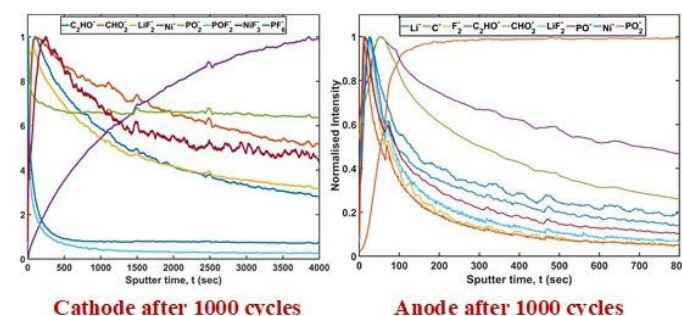


Figure 1. TOF-SIMS depth profiles of the cycled NMC90 cathode (left) and graphite anode (right) after 1000 cycles. The cathode exhibits a LiF-rich, surface-localized CEI together with electrolyte decomposition products, while Ni species detected on the graphite anode confirm cathode-anode crosstalk through transition-metal dissolution.

Keywords:

Ni-rich cathodes, Nitrile-additives, Cathode-electrolyte interphase, TOF-SIMS

Tailoring an Inorganic-Rich Solid Electrolyte Interphase in Lithium-Ion Batteries With Cyclotriphosphazene Electrolyte Additives

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Introduction: The performance and lifetime of lithium-ion batteries depend critically on the electrochemical and mechanical stability of the solid electrolyte interphase (SEI). The conventional amorphous organic-rich SEI layers formed in batteries with carbonate electrolytes exhibit low ionic conductivity and lead to capacity fading, while the inorganic-rich SEI suffers from cracking due to low fracture toughness [1]. We propose utilizing fully inorganic substituted cyclotriphosphazenes as electrolyte additives for the in-situ formation of an inorganic-rich, polymerizable, and passivating SEI layer, which results in improved battery performance.

Results: Electrochemical studies on graphite-lithium half-cells with cyclotriphosphazene additives (N3P3X6, X= Cl, F, Br) showed improved capacity retention over 50 cycles compared to a standard baseline electrolyte (1 M LiPF₆ in ethylene carbonate/ethyl methyl carbonate solvents in 3:7 volume ratio). The first lithiation curve indicates that the N3P3Cl6 additive decomposes at 1.8 V vs Li/Li⁺, prior to solvent reduction (below 1.2 V) and graphite lithiation (below 0.25V), indicating its sacrificial role in SEI formation. Further electrochemical analysis and X-ray photoelectron Spectroscopy (XPS) measurements at excitation energies of 1253, 2003, and 6009 eV on respective graphite anodes confirm the formation of inorganic-rich SEIs containing phosphazene derivatives. Concentration analysis from XPS revealed that a higher fraction of phosphazene content in SEI correlates with improved capacity retention. These results highlight the role of phosphazenes as SEI-forming additives and the importance of a multicomponent SEI in improving battery performance in lithium-ion batteries.

Acknowledgements:

StoreAGE - HORIZON- MSCA Doctoral Networks - Industrial Doctorates
HiKE – KMC 1 beamline, BESSY
EMIL – Energy Materials In-situ Laboratory, HZB

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Keywords:

Inorganic-rich SEI, Cyclotriphosphazene, HAXPES, Graphite SEI

Effect of TMSB and TMSB/TMSP Additives in LP30-Based Electrolytes on the Electrochemical Performance of High-Voltage NMC811/Graphite Prismatic Cells

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Introduction: LiNi_{0.8}Mn_{0.1}Co_{0.1}O₂ (NMC811) is a promising cathode material for next-generation lithium-ion batteries (LIBs) due to its high nickel content, enabling specific discharge capacities approaching 200 mAh g⁻¹ and energy densities exceeding 700 Wh kg⁻¹. However, in NMC811/graphite systems, high energy density is accompanied by accelerated interfacial degradation, mainly driven by cathode instability, electrolyte oxidation, and transition metal dissolution, leading to capacity fading and reduced cycling stability. Electrolyte additives are among the most effective strategies for improving LIBs performance [1]. Therefore, this work investigates the effects of electrolyte additives on Li-ion prismatic cells using LP30 as the baseline electrolyte, and its performance was compared with electrolytes containing 1 wt.% Tris(trimethylsilyl)borate (TMSB) and 1 wt.% TMSB + 1 wt.% Tris(trimethylsilyl)phosphite (TMSP).

Results: Based on the electrochemical results obtained, the cells containing 1 wt.% TMSB exhibited improved capacity compared to the cells with a baseline electrolyte, both after the rate capability tests and following the cycling stability assessment over 1000 charge-discharge cycles. The addition of 1 wt.% TMSB and 1 wt.% TMSP additives to the baseline electrolyte resulted in capacities comparable to those obtained with the baseline electrolyte.

Acknowledgements: This work received funding from the component project PN 23 15 02 02 (PrisPEC) under funding contract 20N/2023. It was also supported by a grant financed by the European Regional Development Fund within the Smart Growth, Digitization and Financial Instruments Programme 2021–2027, as part of the project Romanian Hub for Hydrogen and New Energy Technologies (Ro-HydroHub), under contract no. G 2025-113330 from 30.09.2025 and contract no. G 2024-81692/390006 from 13.11.2024, SMIS code 351358.

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Keywords:

LIBs, NMC811/graphite, Electrolyte additive, Tris(trimethylsilyl)borate, Tris(trimethylsilyl)phosphite.

Plasma-Functionalized Carbon Nanotubes as Conductive Additives for Water-Processed Li-Ion Battery Electrodes

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Introduction: Carbon nanotubes (CNTs) are highly effective conductive additives for Li-ion battery electrodes, forming a percolating conductive network at low loadings that enhances electrode performance [1]. Realizing these benefits sustainably requires moving from N-methyl-2-pyrrolidone (NMP)/polyvinylidene fluoride (PVDF) systems to water-based electrode processing, reducing the cost and environmental footprint of battery production [2]. However, the intrinsic hydrophobicity of the CNT surface limits compatibility with aqueous formulations. This work addresses this challenge through low-pressure plasma functionalization, a scalable, solvent-free surface treatment that improves CNT dispersion and interfacial behavior in water without compromising electrochemical performance.

Results: CNT powders were functionalized under controlled conditions, introducing oxygen-based functional groups onto the surface. Structural and chemical changes were examined by XPS, FTIR, Raman, and TEM, while aqueous dispersibility was evaluated by turbidimetry analysis. Treated CNTs were incorporated as the conductive additive in electrodes prepared via a water-based slurry protocol and assembled into Li-ion half-cells. Plasma treatment increased the surface hydrophilicity and colloidal stability of CNTs in water, with suspensions remaining stable for over 47 days. This improved dispersion translated directly into electrode quality: treated CNT-based electrodes showed better slurry homogeneity than commercial CNTs, enabling uniform coating and higher active-material loading. In half-cells, electrodes containing the functionalized CNTs delivered improved rate capability at high C-rates relative to untreated CNTs, even at a low conductive-additive content of 1%. These results establish plasma functionalization as a scalable, solvent-free route to render CNTs compatible with aqueous electrode processing, enabling greener and more cost-effective Li-ion battery manufacturing.

Acknowledgements: The authors gratefully acknowledge M-ERA.NET for financial support.

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Keywords:

Li-ion, conductive additives, MWCNTs, plasma functionalization

Tailoring Structural Defects in Li-Rich Layered Oxides Through Controlled Sol–Gel Synthesis

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Introduction: Li-rich layered oxides (LROs) are promising cathode materials for next-generation lithium-ion batteries due to their high specific capacity, low cost, and low toxicity. [1] However, their practical application is hindered by voltage decay, capacity fading, and structural degradation caused by irreversible oxygen redox and transition-metal migration. Although stacking faults and oxygen vacancies strongly influence these degradation mechanisms, their simultaneous evolution during synthesis and combined effect on electrochemical performance remain poorly understood.

Results: Li_{1.2}Mn_{0.54}Ni_{0.13}Co_{0.13}O₂ cathodes were synthesized by a sol-gel route using citric or oxalic acid as chelating agents and calcined at 850 °C or 900 °C. Structural evolution and defect formation were investigated using XRD, XAS, STEM-EDX, and EELS. The weaker chelating ability of oxalic acid produced a more heterogeneous precursor matrix, leading to faster, more disordered reaction kinetics and higher concentrations of stacking faults and oxygen vacancies than in citric acid-derived samples.

Despite their higher defect density, oxalic acid-derived materials exhibited improved long-term electrochemical stability. Operando XRD and XAS revealed stable oxygen redox behavior and a larger unit-cell volume after discharge. This expansion, attributed to the migration of oxygen vacancies into the bulk lattice, increases transition-metal layer spacing, suppresses Li/TM intermixing and spinel-like phase formation, and ultimately enhances cycling stability and efficiency.

Acknowledgements: This work was supported by the European Union through the Horizon 2020 DESTINY project (Grant No. 945357) and Horizon Europe (Grant No. 101058414), the Slovenian Research and Innovation Agency (Grants P2-0423, P1-0175, and Project J7-4637), UK Research and Innovation (Grant No. 10039728), and the Swiss State Secretariat for Education, Research and Innovation (Contract No. 22.00187).

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Keywords:

Li-rich oxides, stacking faults, oxygen vacancies

Asynchronous Delithiation Driven by Surface Impurities in Ni-Rich Cathodes

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Introduction: Ni-rich layered oxides, LiNi_xMn_yCo_zO₂ (NMC) are important cathode materials for high-energy-density lithium-ion batteries because of their high theoretical gravimetric capacity (up to ~278 mAh g⁻¹), average operating voltage (~3.8 V), and reduced cobalt content..1 Surface-derived resistive species (e.g., Li₂CO₃) generated during ambient storage are thought to impede local Li⁺ transport, but their impact on particle-resolved reaction kinetics remains unresolved.2 Here, we combine operando charge photometry with nanoscale infrared spectroscopy to correlate surface chemistry with delithiation dynamics in ambient-stored NMC811 cathodes.

Results: We used charge photometry (CP), a laboratory-based optical microscopy technique that tracks ion insertion and removal in individual active particles in real time.3 CP monitors the interference between particle-scattered and reference-reflected light (Figure 1a). Because the scattering response is governed by particle polarizability, changes in CP intensity report local variations in Li concentration and electronic structure. AFM-IR measurements of ambient-stored NMC811 reveal carbonate-related surface species with characteristic O–C=O and O–C–O vibrational modes (Figure 1b).4 During the first charge, CP shows that particles brighten abruptly at distinct potentials, rather than brightening uniformly during homogeneous delithiation (Figure 1c).5 Some particles remain optically inactive until late in the charge, then undergo rapid brightening. These delayed particles remain electrochemically active, indicating kinetic inhibition rather than permanent deactivation. Their abrupt optical transitions are consistent with local Li⁺ extraction being kinetically hindered by surface impurities until a local breakthrough pathway becomes available. Together, these results link ambient-induced surface chemical heterogeneity to asynchronous delithiation in individual NMC811 particles.

Acknowledgements: We would like to acknowledge the funding from the Faraday Institution/LEAP project. W.Z. acknowledges support by the European Commission under the Marie Skłodowska-Curie Programme No.101274888.

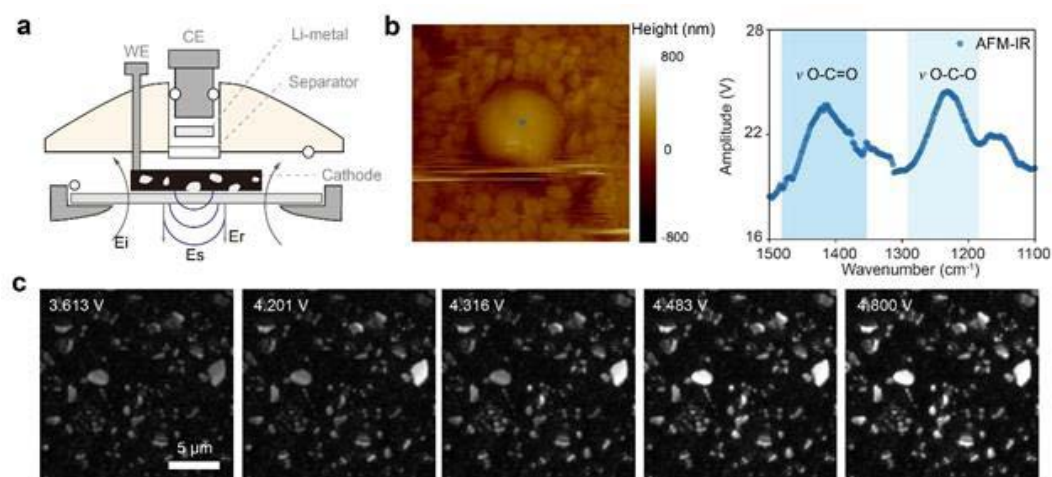
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Figure:



Keywords:

Ni-rich cathode; operando imaging; interphase; degradation

Beyond Al₂O₃: HfO₂ Atomic Layer Deposition Enables Stable Cathode-Electrolyte Interphases in Hybrid LiNi_{0.5}Mn_{1.5}O₄/Graphite Dual-Ion Batteries

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Introduction: Hybrid LiNi_{0.5}Mn_{1.5}O₄ (LNMO)/graphite cathodes have emerged as a promising high-voltage architecture for dual-ion batteries, integrating the Ni²⁺/Ni⁴⁺ redox chemistry of LNMO with reversible PF₆⁻ intercalation in graphite, enabling simultaneous Li⁺ and PF₆⁻ storage within a single electrode. LNMO acts as an internal lithium reservoir that compensates for irreversible lithium consumption and mitigates electrolyte depletion, while the cooperative cation-anion storage mechanism promotes enhanced energy density, reduced polarization, lower charge-transfer resistance, and improved cycling efficiency[1]. Nevertheless, at 5 V, electrolyte decomposition, transition-metal dissolution, and cathode-electrolyte interphase (CEI) degradation accelerate, resulting in rapid capacity fading and continuous impedance growth. Although ALD has proven effective in stabilizing high-voltage cathodes, ultrathin Al₂O₃ coatings may impede Li⁺ transport and provide insufficient long-term protection against HF-induced interfacial degradation, motivating the exploration of more chemically robust alternatives[2].

Results: Ultrathin HfO₂ coatings deposited by ALD are investigated as an artificial protective interphase for hybrid LNMO/graphite dual-ion cathodes. The HfO₂ nanolayer suppresses the parasitic electrolyte oxidation, mitigates transition-metal dissolution, and regulates CEI evolution during repeated Li⁺/PF₆⁻ intercalation/deintercalation. Electrochemical results indicate enhanced cycling stability and improved capacity retention compared with Al₂O₃-coated reference electrodes. Comprehensive operando and post-mortem characterization are currently being conducted to correlate structural evolution, interfacial chemistry, and charge-transfer kinetics with the improved electrochemical performance. This work highlights HfO₂-based interface engineering as a promising strategy for developing durable high-voltage hybrid dual-ion batteries.

Acknowledgements: Support and funding from VEGA 2/0135/26 and M-ERA.NET SusHiBatt.

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Keywords:

Dual-ion batteries, HfO₂, ALD, CEI

Exploring the Potential of High Entropy Oxides With Spinel Structure for Lithium-Ion Batteries

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Introduction: In recent years, high entropy oxides (HEO) have become as a promising type of material for Li-ion battery applications. HEOs typically contain five or more metal elements distributed within a single crystal structure [1]. Their stability is achieved through high configurational entropy, indicating the formation of a single-phase structure [1]. These materials often show high capacity and excellent cycling stability [2]. In this context, HEOs represent a promising alternative for energy storage.

Results: Based on our previous work [3], we successfully prepared novel HEOs with a spinel structure, i.e. $(\text{Zn}_{0.25}\text{Mg}_{0.25}\text{Co}_{0.25}\text{Cu}_{0.25})\text{Fe}_2\text{O}_4$ (HEOFe), as well as their lithiated oxyfluoride and lithiated oxychloride derivatives, i.e. $\text{Li}_{0.5}(\text{Zn}_{0.25}\text{Mg}_{0.25}\text{Co}_{0.25}\text{Cu}_{0.25})_{0.5}\text{Fe}_2\text{O}_3.5\text{F}_{0.5}$ (LiHEOFeF) and $\text{Li}_{0.5}(\text{Zn}_{0.25}\text{Mg}_{0.25}\text{Co}_{0.25}\text{Cu}_{0.25})_{0.5}\text{Fe}_2\text{O}_3.5\text{Cl}_{0.5}$ (LiHEOFeCl) by ball milling followed by heat treatment. The as-prepared materials exhibit particles with an average crystallite size of 50-200 nm. The average elemental composition of the samples was in good agreement with the nominal composition. Electrochemical measurements performed in 2032 coin cells with a lithium-metal anode have demonstrated specific capacities of 450, 694, and 593 mAh g⁻¹ for HEOFe, LiHEOFeF, and LiHEOFeCl, respectively. Moreover, galvanostatic charge-discharge measurements at a 1C rate revealed high charge capacity; however, the capacity decreased over 100 cycles. Electrochemical impedance spectroscopy showed that LiHEOFeCl exhibited the lowest initial charge-transfer resistance. During galvanostatic charge-discharge cycling, the charge-transfer resistance decreased for both LiHEOFeCl and LiHEOFeF, whereas HEOFe showed a slight increase over 100 cycles, reflecting differences in the electrochemical reduction mechanism.

Acknowledgements: Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project SUNFLOWERS No. 09I02-03-V01-00022. O. P. acknowledges Štefan Schwarz Postdoc Fellowship No. 2024/OV1/003.

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Keywords:

high entropy oxide, capacity, Li-ion batteries,

Shape-Controlled, Green-Synthesized Noble Metal Nanoparticles as Functional Modifiers of Lithium-Ion Battery Anode Materials

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Introduction: Improving the electrochemical performance of lithium-ion batteries (LIBs) requires advanced anode materials with enhanced electrical conductivity, structural stability, and cycling performance. This preliminary study focuses on the green synthesis and characterization of noble metal nanoparticles as functional modifiers of LIB anodes. Their size, morphology, and surface properties can influence electron transport and interfacial processes within electrode materials. Green synthesis provides an environmentally friendly route while enabling control of nanoparticle properties through simple parameters such as pH, reducing agent composition, and extract concentration [1,2]. The synthesized nanoparticles will subsequently be incorporated into carbon-based anodes to evaluate the relationship between nanoparticle morphology and electrochemical performance.

Results: Gold and silver nanoparticles were synthesized using environmentally friendly biological routes employing plant extracts as reducing and stabilizing agents. By controlling synthesis conditions, nanoparticles with spherical, triangular, rod-like, and anisotropic morphologies were obtained. Transmission electron microscopy and UV-Vis spectroscopy confirmed that nanoparticle size and morphology can be effectively tuned by synthesis parameters. Previous studies demonstrated excellent stability and low environmental toxicity, making these nanoparticles suitable candidates for electrode modification. The synthesized nanoparticles are currently being incorporated into carbon-based anode materials to investigate their influence on electrical conductivity, charge-transfer processes, SEI formation, specific capacity, rate capability, and long-term cycling stability (Fig. 1). This approach aims to establish correlations between nanoparticle morphology and electrochemical performance, providing guidelines for the design of high-performance LIB anodes.

Fig. 1 Schematic Overview of Green Synthesis and Application of Noble Metal Nanoparticles in Lithium-Ion Battery Anodes

Acknowledgements: The authors thank to the Slovak Grant Agency VEGA (No. 1/0091/26) and the Slovak Research and Development Agency (Contract No. VV-MVP-24-0264).

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Figure:

**Keywords:**

AuNPs; AgNPs; morphology; lithium-ion batteries; anode

Green Silver Nanoparticles Modification of Biomass-Derived Carbon Anodes for Lithium-Ion Batteries

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Introduction: Biomass-derived carbon materials have emerged as promising alternatives to graphite anodes for lithium-ion batteries (LIBs) owing to their porous structure and sustainability. However, their practical application is limited by insufficient electrical conductivity, unstable solid electrolyte interphase (SEI), and rapid capacity fading during long-term cycling [1]. Silver nanoparticles (AgNPs) modification have attracted considerable attention because it can improve electrical conductivity, facilitate charge transfer, and mitigate structural degradation during repeated lithiation/delithiation processes [2]. This work presents a sustainable strategy for improving biomass-derived carbon anodes through in situ deposition of AgNPs synthesized via a green reduction process using *Rosmarinus officinalis* extract.

Results: Carbon obtained by pyrolysis of cotton cellulose was modified with AgNPs synthesized directly on the carbon surface without synthetic reducing agents or stabilizers. The concentration of the Ag precursor was systematically varied to investigate its influence on electrochemical performance. The results revealed a non-linear relationship between AgNP content and anode properties. An intermediate precursor concentration (approximately 250 mg/L) provided the optimal balance between electrical conductivity, pore accessibility, and structural stability, leading to improved reversible capacity, high coulombic efficiency, and enhanced cycling stability. In contrast, excessive Ag loading promoted nanoparticle aggregation and partial pore blockage, reducing lithium-ion transport and electrochemical performance. The proposed material combines renewable biomass, environmentally friendly nanoparticle synthesis, and scalable processing, offering a sustainable route towards high-performance LIB anodes.

Acknowledgements: This work was supported by the Slovak Research and Development Agency under Contract No. VV-MVP-24-0264.

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Keywords:

LIBs; biomass-derived carbon; AgNPs; anode materials

Synthesis Challenges and Electrochemical Characterization of Al-Containing Medium-Entropy Spinel Oxides for Lithium-Ion Batteries

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Introduction: Lithium-ion batteries dominate energy storage, but commercial graphite anodes are limited by low specific capacities. High-capacity alternative anodes can reduce electrode mass and elevate overall cell energy density. Recently, the high-entropy concept has been integrated into battery research, yielding materials with high capacities and exceptional cycling stability driven by configurational entropy [1]. While high-entropy oxides occupy single-phase structures with synergistic multi-cation effects, the medium-entropy oxide (MEO) regime remains largely underexplored. Spinel structures offer a distinct advantage over rock-salt by providing two Wyckoff sites, further increasing entropy [2]. Furthermore, incorporating electrochemically inactive cations can enhance cycling stability via the spectator effect, which preserves the host framework during cycling [3].

Results: In this work, we present a synthesis method for a four-component medium-entropy spinel oxide, $(\text{AlCrMnFe})\text{O}_4$, as a lithium-ion anode. The MEO was synthesized via high-temperature calcination of binary oxides. Due to the low diffusivity of aluminum, elevated temperatures were required to achieve a single-phase spinel structure. The resulting oxide was structurally characterized, and its electrochemical performance, cycling stability, and kinetics were comprehensively analyzed using cyclic voltammetry, electrochemical impedance spectroscopy, and galvanostatic charge/discharge testing.

Acknowledgements: This work was funded by the Recovery and Resilience Plan for Slovakia under the project SUNFLOWERS no. 09I02-03-V01-00022.

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Keywords:

lithium; high-entropy oxides; medium-entropy oxides; spinel

DRT-Assisted Impedance Analysis of Nano-Silicon Anodes

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Introduction: In lithium-ion batteries, silicon is a promising alternative to graphite owing to its high specific capacity ($\approx 3579 \text{ mAh g}^{-1}$), natural abundance, and low lithiation potential [1]. However, practical application is limited by large volume changes during lithiation, leading to mechanical degradation, unstable solid-electrolyte interphase (SEI) formation, and rapid capacity fading. Nanostructuring silicon can mitigate these issues by shortening Li^+ diffusion pathways and better accommodating volume changes [2].

Electrochemical impedance spectroscopy (EIS) combined with distribution of relaxation times (DRT) analysis is increasingly used to separate overlapping electrochemical processes in battery electrodes. Nano-silicon-containing anodes were cycled in coin half-cells and subsequently characterized by EIS at lithiated states. DRT analysis was performed using DRTtools [3, 4].

Results: A temporary impedance maximum was observed around the 10th cycle, followed by an impedance decrease and stabilization. DRT analysis indicates that this behavior is not associated with a single elementary process. The strongest changes appear in interfacial contributions associated with SEI evolution and in low-frequency contributions related to ion diffusion, suggesting coupled SEI growth, surface restructuring, and changes in transport pathways during early cycling. These results show that DRT combined with EIS is a useful qualitative approach for separating overlapping processes with different time scales and for guiding equivalent circuit interpretation of nano-silicon anodes.

Acknowledgements: Supported by TA ČR project TS01030029 (SILION) and SUNFLOWERS project 09I02-03-V01-00022, funded by the EU NextGenerationEU Recovery and Resilience Plan of Slovakia.

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Keywords:

nanostructures; silicon; lithium-ion batteries; EIS; DRT

Low-Frequency Resistance Derived Using Analytical Impedance Theory as a Simplified Battery Model

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Voltage losses in batteries arise from ionic and electronic transport, charge-transfer kinetics, and concentration gradients in the electrolyte and active material. Although the pseudo-two-dimensional (P2D) Newman model [1-2] captures these processes, it is governed by more than 30 parameters that do not directly correspond to the physically meaningful resistances and capacitances commonly used in electrochemical analysis. In this work, we reformulate the P2D model under small-current assumption in terms of independent lumped parameters comprising ionic and electronic transport resistances, charge-transfer resistance, electrolyte [3] and solid-state Warburg resistances, double-layer and solid-phase capacitances, and diffusion time constants. An analytical expression for the impedance is derived directly from the reformulated governing equations and is expressed entirely in terms of these lumped resistances, time-constants and capacitances. The framework can be directly applied to evaluate impedance of electrodes with particle-size distributions, and composite active materials, and spatially varying tortuosity. We further derive the low-frequency limit of the impedance, yielding the total direct-current (DC) resistance (R_{total}) of battery, expressed solely in terms of physically meaningful resistances and capacitances. R_{total} adjusted for non-linearity and non-stationary effects, predicts the cell voltage, and plating potential at rates up to 0.5C rate, while being computationally much faster than numerical P2D simulations.

Acknowledgement:

The author acknowledges the Ministry of Education, Government of India, for financial support through the PhD Teaching Assistantship, and the Institute of Eminence (IoE), IIT Bombay, for providing travel support to attend the conference.

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Keywords:

Impedance, Resistance, Capacitance, Analytical, Modeling

Direct Determination of Tortuosity of Ni-Rich NMC Electrodes via Full Insertion Transmission Line Modeling

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Introduction: Electrochemical impedance spectroscopy (EIS) is a powerful tool for battery research, but interpreting the spectra of porous electrodes is challenging due to the overlap of transport and kinetic processes. Conventional methods for extracting electrode tortuosity require reaction-blocking conditions (non-intercalating salt) or extreme states of charge, which are not representative of a functioning battery. This work introduces a robust fitting procedure to determine tortuosity of Ni-rich NMC cathodes using a Full Insertion Transmission Line Model (TLM).

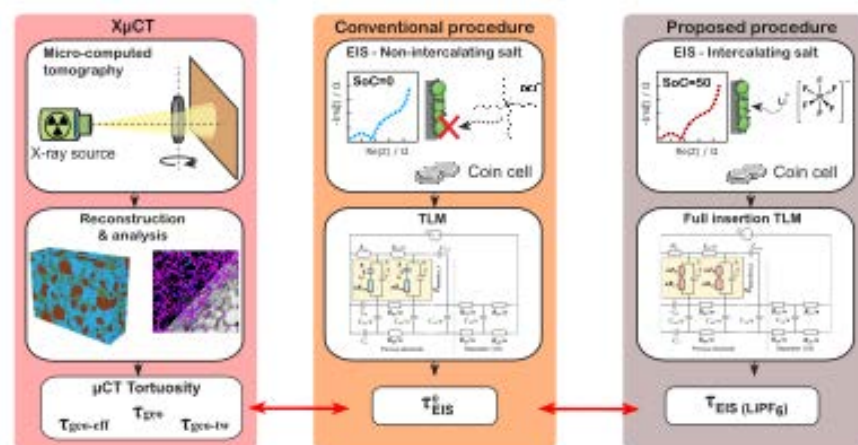
Results: The method was validated on Ni-rich NMC cathodes via a three-way comparison: X-ray micro-computed tomography ($X\mu\text{CT}$), EIS in symmetric cells using a non-intercalating salt and the proposed TLM with a standard LiPF_6 -based electrolyte. Tortuosity values obtained from all three methods were comparable within experimental error and in good agreement with literature reports for porous NMC electrodes. The Full Insertion TLM approach is applicable across various states of charge, enabling tortuosity determination in cells operating under realistic conditions. Beyond tortuosity, the model also provides access to charge-transfer resistance, contact resistance, and double-layer capacitances. The analysis further revealed an important practical consideration: vacuum sealing in pouch cells causes solvent evaporation, artificially inflating apparent tortuosity compared to coin cells, as confirmed by vacuum tests. This finding underscores the importance of rigorous experimental control when comparing results across different cell formats.

Acknowledgements: The authors acknowledge the Slovenian Research Agency (projects J2-4463, P2-0423, P2-0393, P2-0273) and the M-Era.net project InCoatBat (No. 10341) for financial support.

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Figure:

**Keywords:**

Tortuosity, NMC, Li-ion batteries, EIS, TLM

Geometry-Induced Impedance Artifacts in Through-Plane Tortuosity Measurements of Porous Electrodes

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Introduction: Electrochemical impedance spectroscopy (EIS) with symmetric cell setup is one of the widely used technique to determine ionic transport resistance and tortuosity in porous battery electrodes [1,2]. However, impedance measurements can contain additional contributions [3] associated with cell geometry. In coin cell geometry, the electrodes are typically smaller in diameter than the spacer disks, leaving an exposed area of spacer in contact with the electrolyte. This conductor-electrolyte interface can introduce an additional capacitive pathway that can influence the measured impedance and its effect on the tortuosity measurements has not been systematically examined.

Results: COMSOL model was developed to investigate the origin of the additional impedance contribution in coin cell symmetric cell setup. Simulations with different electrode diameters show a systematic change in the impedance response as the exposed spacer area is varied. Experimentally, we demonstrate the corresponding features in the impedance spectra and systematically examine their dependence on electrode diameter. Based on these results, we propose a one-dimensional equivalent circuit that explicitly captures the additional capacitance contribution to the measured impedance. These results demonstrate that the exposed spacer interface contributes measurably to symmetric coin cell impedance and should be accounted when calculating ionic resistance and tortuosity from such measurements.

Acknowledgments: The authors gratefully acknowledge the Ministry of Education, Government of India, for the financial support throughout the Ph.D. and the Institute of Eminence (IoE), IIT Bombay for the conference funding.

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Keywords:

Impedance spectroscopy, Ion transport, Tortuosity, Stray Capacitance, Coin Cell Geometry

Advanced Diagnostics: Embedded Printed Sensors for Transition Metal Dissolution Detection in Lithium-Ion BatteriesP-19

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Introduction: Lithium-ion batteries (LIBs) are widely used in portable electronics and electric vehicles due to their high energy density and efficiency. However, their long-term performance is limited by degradation processes such as transition metal dissolution from cathode materials from spinel LiMn_2O_4 (LMO) or layered $\text{LiNi}_x\text{Mn}_x\text{Co}_x\text{O}_2$ (NMC) cathodes. Dissolved transition metal ions (e.g., Mn and Ni) can migrate through the electrolyte and deposit on the anode, promoting side reactions, increasing resistance, and reducing battery lifetime.

Results: In this study, we present an integrated sensor platform for real-time detection of dissolved transition metals. The sensor consists of two symmetrical glassy carbon-based electrodes printed on a glass fiber separator and connected by a functional sensing layer. Using a Mn(II) ion-imprinted polymer-based sensing layer, changes in impedance response enable the detection of Mn ions in the electrolyte. Building on previous work demonstrating Mn detection from LMO cathodes (1), this study focuses on quantitative Mn analysis using a fully printed sensor system. In addition, the adaptability of the platform is explored by developing selective sensing layers for other transition metals, such as Ni from NMC cathodes.

This approach offers a promising tool for advanced battery diagnostics, enabling real-time monitoring of degradation processes and supporting the development of safer, more reliable, and longer-lasting LIBs.

Acknowledgements:

Authors acknowledge the financial support of the Slovenian Research and Innovation Agency (ARIS), through MSCA-COFUND - Scientists4Future (12181).

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Keywords:

LIBs, TM dissolution, printed sensor, real-time battery diagnostics

Advanced AFM Characterisation Tools for Battery-Related Materials

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Introduction: Continuous expansion of our understanding of Li-based batteries as well as the next-generation beyond-Li technologies (such as Mg-S batteries) is central to the ongoing energy transition. For their further development, however, the electrode-electrolyte interfaces (EEI) and interphases and their crucial role in battery performance must be further studied and understood. The inter-phase's development is influenced by charge transfer reactions occurring at the EEI, which can trigger various degradation processes. While there is considerable understanding of anode-electrolyte interphases (SEI), the mechanisms behind cathode-electrolyte interphases (CEI) are less explored. This knowledge gap is partly due to the lack of effective techniques for characterizing CEI properties at different scales and conditions. Achieving a more comprehensive understanding of the CEI formation processes at micro- and nanoscales as well as exploring roles of other active interfaces in battery systems is crucial for making progress towards more stable battery performance.

Results: Advanced Atomic force microscopy (AFM) techniques, such as conductive AFM (C-AFM) and C-AFM Topography, have enabled substantial advances in understanding the tight relationship between surface topography, flow of the electric current and mechanical properties. In my pre-sented research, I will demonstrate the results and lessons learned from the process of establishing the complementary C-AFM/XPS characterization platform in our lab. AFM measurements performed in argon atmosphere can bring valuable data in many different battery-related applications on various samples in order to access additional information not available by other characterization techniques, providing much-needed tool for multi-scale in-depth analysis of the EEI.

Acknowledgements:

References:

Keywords:

AFM, C-AFM, CEI, characterisation

Impact of Slurry Composition and Coating Thickness on the Electrochemical Performance of (CrMnFeCoNi)3O4 Anodes

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Introduction: Since the high-entropy concept for lithium-ion battery anodes was introduced in 2018 [1], extensive research has explored its utility in energy storage. Incorporating multiple equimolar cations maximizes configurational entropy, which stabilizes single-phase structures at elevated temperatures [2]. While high-entropy oxides (HEOs) offer capacities two- to three-fold higher than graphite [3], optimizing electrode processing is often overlooked. Due to poor electronic conductivity, HEO active content in slurries is typically restricted to 60–80 wt.%, adding electrochemically inactive mass and reducing energy density. Optimizing wet film thickness is therefore critical to tailoring electrodes for high-rate or high-energy density applications.

Results: This work systematically investigates the influence of wet film thickness and active material loading on the performance of spinel (CrMnFeCoNi)3O4. At 100 µm thickness, increasing loading from 70 to 90 wt.% decreased initial Coulombic efficiency and reversibility. Although 80 wt.% yielded the highest specific capacities, the 70 wt.% electrode showed superior capacity recovery during rate-capability testing. At a higher thickness of 150 µm, trends were more pronounced: the 70 wt.% electrode delivered the best overall performance, exceeding the performance of its 100 µm counterpart. Balancing active material loading and film thickness is vital to mitigating poor HEO conductivity while maximizing electrode-level energy and power densities.

Acknowledgements: This work was funded by the Recovery and Resilience Plan for Slovakia under the project SUNFLOWERS no. 09I02-03-V01-00022.

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Keywords:

LIB; high-entropy oxides; spinel; anode

PBM Techniques for Enhanced Particle Dynamics Modelling of Slurry Mixing: Viability and Outlooks

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Introduction: Lithium-ion batteries are critical for meeting global sustainable development goals [1]. Refining the early roll-to-roll processing stages, specifically slurry mixing and drying, offers substantial opportunities to reduce energy consumption [1, 2]. Furthermore, particle size distribution (PSD) after mixing directly impacts subsequent steps of manufacturing and cell performance [2, 3]. However, the lack of detailed experimental data focussing on PSD during mixing has prevented the development of accurate models.

In this research, population balance modelling (PBM) techniques are assessed for the viability of coupling with computational fluid dynamics (CFD) to model electrode slurry mixing and bridge Eulerian hydrodynamics with PSD evolution.

Results: Slurry mixing is either continuous and rigid or batched and flexible; all methods induce PSD evolution through aggregation. We evaluated several leading semi-analytical PBM techniques applied to Smolochowski's aggregation equation (equation 1). Performance was measured using relative error and computational time for different temporal conditions (Δt) and number of terms in the solution (N). Results indicate that the modified variational iteration method (MVIM) has the greatest accuracy for extended temporal conditions but also the greatest computational expense.

Acknowledgements: This research is supported by project no. CZ.02.01.01/00/22 008/0004617 by Programme Johannes Amos Comenius, call Excellent Research; specific graduate research of the Brno University of Technology No. FEKT-S-23-8286.

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Figure:

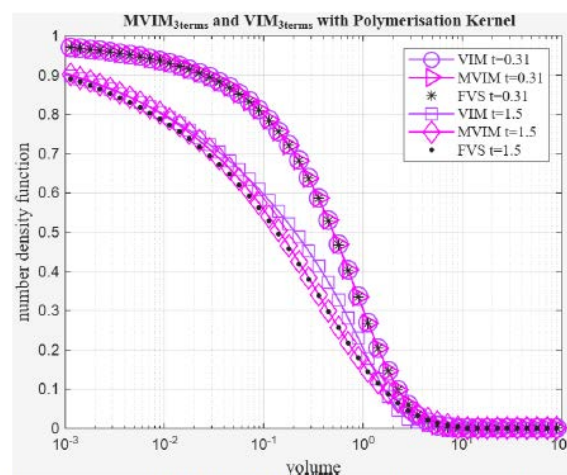


Figure 1: Comparison of VIMHe and MVIM using polymerisation kernel to model PSD against the finite volume scheme (FVS)

Keywords:

Population Balance Modelling, Slurry Mixing, Hydrodynamics

Engineering High Solid Loading Electro Slurries for Sustainable Lithium-Ion Batteries Manufacturing

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Introduction: Lithium-ion batteries are currently most advanced commercially available energy storage technology. To meet with the growing demands from the transportation and electronics industries, significant improvements in battery manufacturing processes are required. Among these, electrode slurry preparation plays critical role, as it directly influences the processability, coating quality, electrodes microstructure, and electrochemical performance. Engineering high solid loading offers a promising route to increase in production rate while reducing solvent consumption and drying requirements. However, achieving stable and processable slurries at high solid content remains challenge.

Results: In this work, NMC cathode slurries with solid loading ranging from 50 to 80 wt.% were prepared through careful optimization of mixing process protocol combined with impeller design and dispersant content. Firstly, the rheological behaviour of the prepared slurries was evaluated using rotational rheometry, which was followed by electrode production, including coating and drying. The resulting electrodes were submerged to electrochemical testing in two electrode half cells using lithium metal as both the counter and reference electrode. In addition, physical characterization of electrodes, including 180o peel of test, contact angle and scanning electron microscopy (SEM), were used to evaluate adhesion, wettability, surface tension, and electrode microstructure.

Developed electrode formulation and mixing protocol demonstrates that NMC cathode slurries can be manufactured with exceptionally high solid loadings of 80 wt.% without compromising slurry processability and electrode performance. Presented 80 wt.% slurry exhibited rheological properties similar to 50 and 60 wt.%, which are commonly referred to as industry standard. These results open the possibility for more sustainable and economical efficient lithium-ion battery manufacturing.

Acknowledgements: This work was funded by European Union within the project „Development of advanced coating technologies“ PK1.1.12.0319

References:

Keywords:

lithium-ion batteries, NMC, slurry, electrode manufacturing

Impact of Cell Ageing on the Thermal Behaviour of Battery Energy Storage Systems

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Introduction: Second-life electric vehicle (EV) lithium-ion cells in stationary storage vary in state of health (SoH). Aged cells generate more heat [1], forming hotspots that can trigger thermal runaway [2,3]. Unlike fresh cells [4], mixed-ageing packs remain little studied.

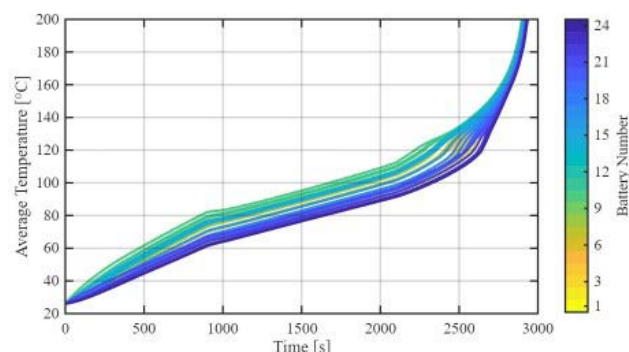
Results: An electro-thermal model in ANSYS Fluent couples equivalent circuits with Arrhenius thermal runaway kinetics for an 8s3p nickel manganese cobalt pouch-cell pack under EV charging support and high-power loads. For SoH of 0.90-0.80, higher internal resistance increases heat generation in the most degraded cells, widening the temperature spread (Figure 1). As reaction rates rise steeply with temperature, these cells self-heat first. Ageing thus narrows the thermal safety margin, set by the weakest cells.

Acknowledgment: This publication was supported by the project "The Energy Conversion and Storage", funded as project No. CZ.02.01.01/00/22_008/0004617 by Programme Johannes Amos Comenius, call Excellent Research and also by the BUT specific research programme (project No. FEKT-S-26-8946).

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Figure:



Keywords:

Second-life battery; Cell ageing; Electro-thermal modelling; Thermal runaway; Battery energy storage system

Environmental and Morphological Evaluation of Controlled Thermochemical Processing for the Sustainable Pre-Treatment of Spent Battery Electrodes

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Introduction: The scaling transition toward circular lithium-ion battery recycling requires pre-treatment methods that simultaneously optimize material separation and minimize environmental burdens. This study links multi-analytical structural characterization with input-output mass flow calculations to evaluate the thermochemical behaviour of spent NMC622 and graphite electrodes at 500 °C under oxidative (air), inert (argon), and reductive (hydrogen) atmospheres [3].

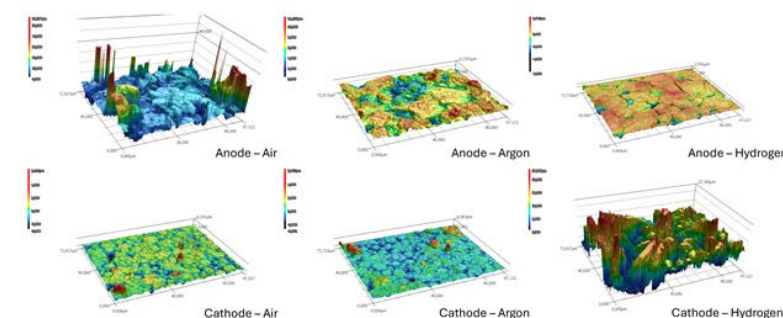
Results: Oxidative roasting causes non-selective graphite combustion (mass loss >11%), generating substantial direct CO₂ emissions and necessitating resource-intensive primary graphite replacement [1]. Inert pyrolysis successfully preserves the carbon fraction (mass loss 2–4%) but forms a carbonaceous char that traps 19.3 wt.% fluorine, severely threatening downstream hydrometallurgical ecotoxicity. Deploying a reductive hydrogen atmosphere resolves these challenges, achieving exceptional defluorination (reducing surface fluorine to 3.4 wt.%) while driving a radical morphological metamorphosis. Cathode particles restructure into high-relief acicular formations, accompanied by an 8.1 wt.% lattice oxygen reduction [2]. This structural "opening" and chemical pre-activation substantially lower downstream chemical leaching intensity, offering a significantly purer and energetically optimized pathway for critical raw material recovery.

Acknowledgements: This work was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project SUNFLOWERS No. 09I02-03-V01-00022.

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Figure:



Keywords:

lithium-ion battery; recycling; pre-treatment; pyrometallurgy

Membrane Configurations for Lithium-Cobalt Separation by Reverse Electrodialysis

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Introduction: Reverse electrodialysis (RED) is an electro-membrane technology that uses ion exchange membranes to transport ions while simultaneously converting the chemical potential of ion concentration gradient into electrical energy. Ion exchange membranes (IEMs) are designed to selectively transport specific ions while blocking others, enabling controlled ion separation processes. In this study, RED was used to investigate the selective separation and recovery of lithium from simulated battery leached solutions. Different ion exchange membrane configurations including bipolar and monovalent-selective membranes were investigated to evaluate how membrane properties influence ion transport, separation efficiency and the electrochemical performance of the RED system. Electrochemical performance was evaluated by measuring the open-circuit voltage (OCV) and polarization curves, enabling the assessment of the electrical response and power output of the RED stack. XPS analysis was performed to identify functional groups. SEM analysis was carried out to investigate membrane surface morphology and pore structure. To understand how the membrane surface interacts with water, the contact angle measurements were performed. ICP-OES was used to determine metal ion concentrations.

Results: The standard AEM-CEM configuration achieved the highest ion transport, transferring approximately 60% of lithium and 66% of cobalt, and produced the highest OCV (1,6V). Replacing the anion exchange membrane with a bipolar membrane reduced cobalt transport by 10% without affecting lithium transport, whereas the monovalent membrane reduced the transport of both ions by nearly 50% due to its smaller pore size. Contact angle measurements confirmed the hydrophilicity of all membranes, while XPS identified characteristic sulfonic, carboxylic, and amine functional groups corresponding to their ion exchange functionalities.

These findings demonstrate that membrane configuration plays a key role in balancing lithium selectivity, ion transport, and energy generation in RED systems.

Acknowledgements: We would like to acknowledge support from MVZI Slovenia through Just Transition Funds and Batmass project (I3 programme under grant agreement No 101115058).

References:

Keywords:

Reverse electrodialysis, lithium recovery, ion-exchange membranes

From Cathode Scrap to Battery-Grade Materials: A Low-Cost Approach for Reintegrating Lithium Iron Phosphate Scrap Into Cell Production

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Introduction: Lithium iron phosphate (LFP) batteries are widely utilized due to their low cost, long cycle life, and high safety. However, the increasing volume of end-of-life batteries presents significant environmental and economic challenges. Various recycling approaches, including pyrometallurgical, hydrometallurgical, and direct regeneration methods, have been developed to recover valuable materials. Despite notable progress, lithium-ion battery recycling remains an evolving field, requiring further research to improve sustainability, recovery efficiency, and safe management of hazardous waste streams generated during recycling processes [1].

Results: This work presents a safe and environmentally friendly recycling strategy for spent lithium iron phosphate (LFP) cathodes using water-based deep eutectic solvents (DESs) combined with an oxidative pretreatment. Oxidation at 700°C transformed the cathode material into soluble phases, enabling efficient lithium recovery and selective separation of iron and phosphorus. Under optimized conditions (oxidation at 700°C for 3 h, leaching at 90°C for 30 min, and a solid-to-liquid ratio of 60 g/L), high leaching and recovery efficiencies were achieved. Electrochemical characterization further confirmed the structural stability and performance of the recovered materials, demonstrating the potential of this sustainable recycling approach for LFP battery waste.

The results demonstrate that recycling and reusing spent cathode materials is a sustainable and environmentally friendly approach, offering simple operation, scalability, and cost-effective processing.

Acknowledgements: This work received funding from the component project PN 23 15 02 02 (PrisPEC) under funding contract 20N/2023. It was also supported by a grant financed by the European Regional Development Fund within the Smart Growth, Digitization and Financial Instruments Programme 2021–2027, as part of the project Romanian Hub for Hydrogen and New Energy Technologies (Ro-HydroHub), under contract no. G 2025-113330 from 30.09.2025 and contract no. G 2024-81692/390006 from 13.11.2024, SMIS code 351358.

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Keywords:

LIBs, DES, Priority recovery, Recycling processes

Electrochemical Viability of Harvested Electrode Materials in Direct Lithium-Ion Battery Recycling Frameworks

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Introduction: Recycling spent lithium-ion batteries is critical for resource sustainability [1]. Traditional pyrometallurgical and hydrometallurgical processes are highly demanding, consume excessive energy, use harsh chemicals, and generate a significant amount of wastewater [1, 2]. These conventional routes destroy the structures of synthesized electrode materials, reverting them to baseline precursors that require resource-intensive remanufacturing. Conversely, direct recycling preserves the existing architecture to leverage its remaining electrochemical potential [2]. This work presents a preliminary "electrode-to-electrode" feasibility study to directly evaluate this intact potential. This approach represents a downcycling pathway due to geometric constraints in the cell, as smaller harvested electrode fragments cannot be assembled into larger formats. This electrochemical baseline is a critical gatekeeper; without viability, complex downstream processes like extracting active masses for new slurries are technically and economically unjustified.

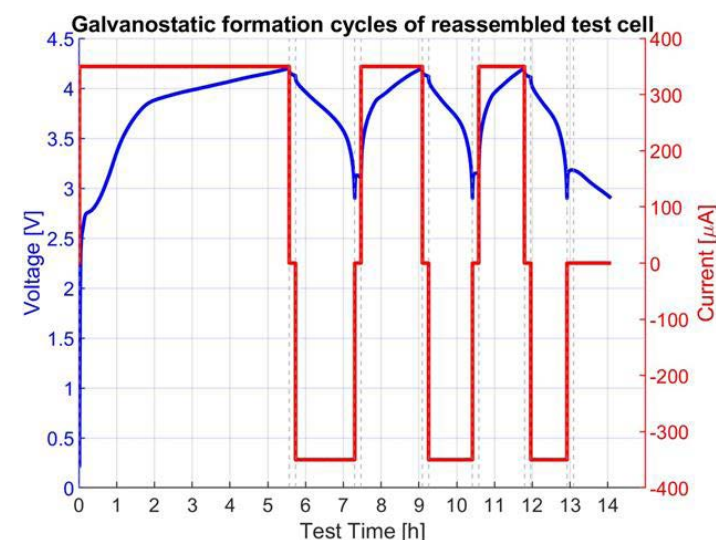
Results: Initial test cells exhibited voltage instability and potential drops during relaxation, indicating internal soft short circuits. However, the baseline electrochemical potential of the material remains highly visible; the gap between charge and discharge capacities narrowed significantly, with the third cycle showing the highest efficiency. The cell's Coulombic efficiency increased from 28.24% in the first cycle to 71.61% in the second and reached 79.31% by the third cycle. This progressive narrowing of the capacity gap confirms that the underlying material retains substantial electrochemical reversibility despite the assembly challenges.

Acknowledgements: This work was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project SUNFLOWERS No. 09I02-03-V01-00022.

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Figure:



Keywords:

Direct recycling, Battery sustainability, Feasibility assessment

Preparation of Prussian-Blue-Based Cathodes for Sodium Batteries: Impact of Non-Conventional Enabling Technologies

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¹Centro Ibérico De Investigación En Almacenamiento Energético (CIIAE), Cáceres, Spain, ²Universidad de Extremadura (UEX), Badajoz, Spain

Introduction: Sodium-ion batteries have gained broad interest for energy storage in view of the higher natural abundance and lower cost of sodium resources relative to lithium. Current challenges involve the development of devices with competitive electrochemical performance and enhanced thermal stability. Among the cathode components, Prussian blue analogs (PBAs) constitute attractive candidates due to their compatibility with aqueous electrolytes, low environmental impact and their 3D open-framework facilitates ion diffusion for reversible sodium intercalation [1].

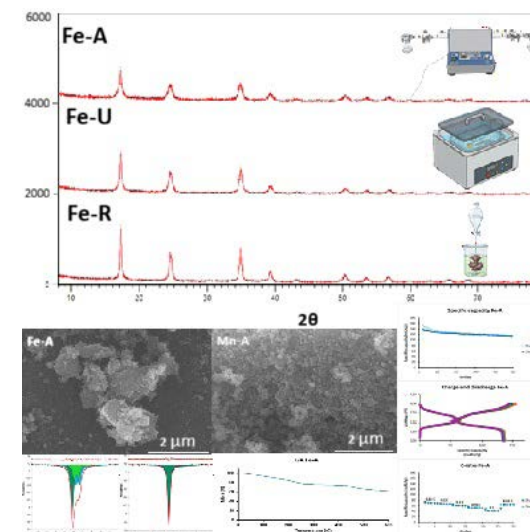
Results: In line with the UN Sustainable Development Goals, in particular affordable and clean energy and responsible consumption/production, we have applied a series of enabling technologies to obtain PBAs, namely ultrasound, microwaves, and mechanochemistry, as well as the use of Deep eutectic solvents (DES) and supercritical fluids as neoteric media, to improve the overall synthetic protocols relative to conventional precipitation or hydrothermal methods [2]. The relationships between structural changes and/or morphology generated under such conditions with electrochemical performance have been evaluated in detail (Figure 1). It is noteworthy that mechanical vibration leads to specific capacities comparable to those obtained by conventional routes.

Acknowledgements: We thank the financial support from the Junta de Extremadura-Fondo Europeo de Desarrollo Regional (Grant IB24126).

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[2] P. Sanz Camacho et al., ACS Appl. Mater. Interfaces 2021, 13, 42682-42692.

Figure:



Keywords:

sodium-ion-batteries, Prussian-blue-analogs, electrochemical-performance, enabling-technologies, sustainable methods

A Sulfonato-Catecholate Framework for High-Voltage Sodium-Ion Storage

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Introduction: The push toward sustainable, high-performance sodium-ion batteries (SIBs) has spotlighted organic cathode materials (OCM) favored for their lightweight, structural tunability, and eco-friendly composition.

Results: In this work we aim to develop a stable, high-performance OCM derived from a monohydrated catechol derivative for SIBs. We explored how variables such as solvent, temperature and atmosphere control influence the deprotonation of hydroxy groups by sodium ions. The synthesized molecule in electrochemical evaluation as a cathode material exhibited a promising first cycle specific capacity of 128 mAh/g (approximately equal to 80% of its theoretical capacity), indicating its potential as a high-capacity OCM for SIBs. However, the half-cell configurations tested showed rapid capacity decay during cycling, pointing to persistent stability challenges such as active material dissolution in electrolytes. Systematic optimization efforts-including electrolyte amounts, electrolyte salts, mixed solvents and modified voltage windows could not significantly suppress capacity decay. Building on these results, our future studies will focus on exploring ionic liquid electrolytes and use of modified separators for the electrochemical evaluation to effectively suppress the dissolution of active material.

Acknowledgements: This work received funding from the Romanian Ministry of Research, Innovation and Digitalization under Romania's National Recovery and Resilience Plan (PNRR) – Pillar III, Component C9, Investment I8 (PNRR/2022/C9/MCID/I8), through grant no. 760113/23.05.2023 (ToNaBatt). The work was also supported by a grant financed by the European Regional Development Fund within the Smart Growth, Digitization and Financial Instruments Programme 2021–2027, as part of the project Romanian Hub for Hydrogen and New Energy Technologies (Ro-HydroHub), under contract no. G 2025-113330 from 30.09.2025 and contract no. G 2024-81692/390006 from 13.11.2024, SMIS code 351358. Additional support was provided through the component project PN 23 15 02 01 (BatNaS) under funding contract 20N/2023.

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1. P. Poizot et al., Chem. Rev., 2020, 120, 6490–6557, DOI: 10.1021/acs.chemrev.9b00482.

Keywords:

Sodium-ion batteries, cathode materials, separator modification.

A NaFePO₄ Comparative Study on Different Synthesis Precursors and His Battery Performances

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Introduction: In recent years, research interest in more sustainable energy storage systems, such as sodium-ion batteries, has increased.

Regarding the cathode, the most promising approaches include various sodium-adapted analogues of lithium-ion chemistries, such as layered oxides and polyanionic compounds [1].

Among polyanionic materials, NaFePO₄ has received limited attention from researchers because it crystallizes in the maricite structure, which is electrochemically inactive. However, in contrast to earlier assumptions, other studies report that the electrochemical activity of NaFePO₄ is strongly dependent on its nanostructure. Kim et al. [2] demonstrated that all Na ions can be deintercalated from nanosized maricite, leading to the formation of amorphous FePO₄. Quantum mechanical calculations revealed that the remarkable electrochemical activity of NaFePO₄ is related to the significantly enhanced mobility of Na ions in the amorphous phase.

Results: In this work, NaFePO₄ was synthesized, and the experimental conditions were systematically investigated to achieve a balance between material performance and process sustainability. A preliminary study of the synthesis conditions was conducted via thermogravimetric analysis to identify the optimal parameters for obtaining amorphous NaFePO₄, specifically the firing temperature and heat-treatment atmosphere.

NaFePO₄ materials were obtained by thermal treatment of different precursors via a solid-state synthesis route. The structural analysis of the materials obtained was carried out using X-ray diffraction, and the materials were electrochemically characterized as cathodes versus Na metal in half-cells.

One of the featured materials was able to deliver 150 mAhg⁻¹ at C/10 rate. Considering an average discharge voltage of 2.4 V, the specific energy of the material was about 360 Whkg⁻¹.

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Keywords:

Cathode materials, sustainability, Na-ion batteries, amorphous.

Sodium Storage and Co-Intercalation Phenomena in Vapor-Grown Carbon Fibres

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¹Centre for Organic and Nanohybrid Electronics (CONE), Silesian University Of Technology, Gliwice, Poland

Introduction: Sodium-ion batteries (SIBs) have attracted significant attention as a sustainable and cost-effective alternative to lithium-ion batteries[1]. Among various anode materials, carbon-based structures are particularly promising due to their tunable morphology, good electronic conductivity, and compatibility with sodium storage mechanisms. Moreover, the discovery of reversible Na⁺/glyme co-intercalation in graphitic carbons has opened new opportunities for the development of high-rate sodium-ion energy storage systems[2].

Results: In this work, fibrous carbon synthesized by chemical vapor deposition (CVD) was investigated as negative electrode for sodium-ion batteries operating in ether-based electrolytes. Material characterization was performed using transmission electron microscopy (TEM), Fourier-transform infrared spectroscopy (FTIR), Raman spectroscopy, and electrochemical techniques. The sodium storage mechanism was further analyzed by in situ Raman spectroscopy. Changes in the intensities and positions of the G and D bands were systematically examined and compared with those of conventional hard carbon and graphite electrodes, with particular emphasis on Na⁺/solvent co-intercalation phenomena.

The fibrous carbon electrodes exhibited stable cycling performance and improved rate capability at current densities up to 10 A/g. Furthermore, full sodium-ion cells were assembled using a Na_{0.67}Ni_{0.33}Mn_{0.67}O₂ positive electrodes and the developed carbon negative electrodes to evaluate the practical applicability of the proposed electrode system. The results provide new insights into the relationship between carbon structure, co-intercalation processes, and electrochemical performance, highlighting the vapor-grown carbons as advanced negative electrode materials for sodium-ion batteries.

Acknowledgements: UMO Research funded by the National Science Centre (NCN) under the project OPUS-27 -2024/53/B/ST5/03414.

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Keywords:

sodium storage, co-intercalation, carbon nanomaterials, glyme

Sustainable Engineering of Hard Carbon From Spent Coffee Grounds for Advanced Sodium-Ion Battery Anodes

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Introduction: Sodium-ion batteries (SIBs) have emerged as promising alternatives to lithium-ion batteries owing to the natural abundance, low cost, and favorable electrochemical properties of sodium.[1] Among various anode materials, hard carbon (HC) is considered one of the most viable candidates; however, achieving high initial coulombic efficiency (ICE) while maintaining an optimized pore structure remains a significant challenge[2]. In this context, the development of sustainable, high-performance HC derived from waste resources is of considerable interest.

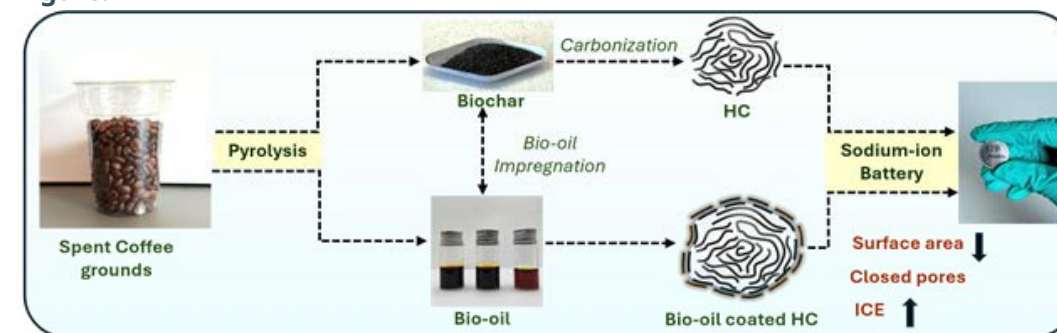
Results: Herein, we report a sustainable approach for synthesizing hard carbon from spent coffee grounds (SCG), an abundant biowaste resource. Raw SCG is first converted into biochar, followed by controlled processing to obtain novel HC materials. Additionally, bio-oil generated during the pyrolysis process is utilized as a surface-modifying agent to tailor the physicochemical properties of the hard carbon. This strategy aims to reduce the specific surface area, regulate surface defects, and increase closed pore volume, thereby enhancing sodium storage characteristics, particularly ICE[3]. Furthermore, prior optimization studies using commercial hard carbon provide a valuable benchmark for evaluating and improving the synthesized materials. The developed waste-derived HC is expected to deliver enhanced capacity, improved rate capability, and stable cycling performance. Overall, this work presents a scalable and sustainable route for converting biomass waste into value-added electrode materials, offering a promising pathway toward advanced sodium-ion battery technologies.

Acknowledgements:

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Figure:



Keywords:

Sodium-ion batteries, Hard carbon, Bio-oil modification

SiOC/Sn Composite Anodes for Advanced Na-Ion Batteries

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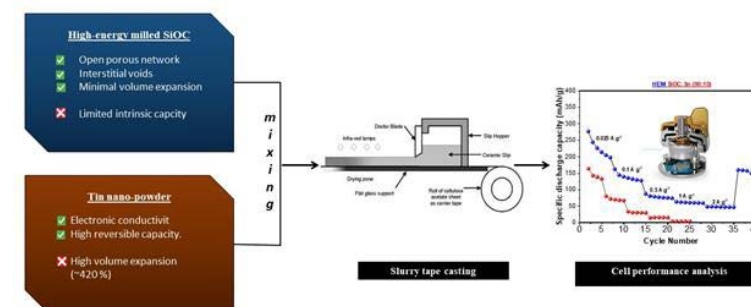
Introduction: Growing global energy demand and vehicle electrification require more efficient energy storage technologies. With limited lithium reserves constraining lithium-ion batteries (LIB) scalability, sodium ion batteries (SIB) have gained strong momentum as a greener, more sustainable, and cost effective alternative. Unlike conventional LIB anodes such as graphite and silicon, which suffer from insufficient interlayer spacing and unstable alloying reactions with Na, silicon oxycarbide (SiOC) has emerged as a promising anode material for SIBs. The amorphous, open network of SiOC provides large interstitial sites and disordered voids that can host Na ions, but its intrinsic capacity remains limited. Combining the SiOC matrix with a high-capacity anode, such as Sn, enhances electronic conductivity and reversible capacity, while the SiOC framework buffers the volume expansion of Sn (~420%) during cycling, thereby maintaining structural integrity.

Results: In this work, high-energy-milled SiOC was mixed with varying Sn content to prepare the SiOC/Sn composite anodes, followed by the fabrication of SiOC/Sn half-cells (SiOC/Sn vs Na metal). Galvanostatic charging/discharging was carried out in the voltage range of 0.005-2.5 V at room temperature, with current densities ranging from 0.25 A/g to 2 A/g. The rate performance of SiOC anodes improved with Sn addition, with a specific discharge capacity increase from 67 mAh/g to 135 mAh/g at 0.1 A/g. Long-term cycling test showed a capacity retention of 63% after 200 cycles at 0.5 A/g. Electrochemical impedance spectroscopy (EIS) has revealed a decrease in the charge-transfer resistance, accelerating electronic and ionic transport across the electrode interface. Post-cycling XPS data confirm minimal degradation of Sn after 200 cycles of charging and discharging.

Acknowledgements: The work was supported by projects VEGA 2/0128/25, APVV-23-0474, and the Slovak Recovery and Resilience Plan project „ENSAMAT“ (category: Decarbonization) and Matching grant “SASIBA” 09I01-03-V04-00093/2025/VA.

References:

Figure:



Keywords:

SiOC/Sn anode, Na-ion batteries, discharge capacity

Direct Recycling and Scale-Up Regeneration of Prussian Blue Analogues for Circular Sodium-Ion Batteries

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Introduction: Sodium-ion batteries (SIBs) are promising alternatives to lithium-ion batteries due to the abundance and low cost of sodium resources. Prussian Blue Analogues (PBAs) are attractive cathode materials because of their open-framework structure, high theoretical capacity, and fast sodium-ion transport [1]. However, recycling strategies for PBAs remain largely unexplored [2].

Results: In this work, a closed-loop recycling route was developed for a commercial sodium-rich PBA (nominally $\text{Na}_2\text{Fe}_2(\text{CN})_6$) containing approximately 4 wt.% Mn through selective alkaline decomposition. This process enabled the recovery of $\text{Na}_4\text{Fe}(\text{CN})_6$ with yields exceeding 90%, while selectively removing Mn-containing species through phase partitioning. The recovered precursor was subsequently reused for the resynthesis of a new PBA (Re-PBA) using L-ascorbic acid under reflux conditions.

XRD and Raman analyses verified the formation of the regenerated Fe-Fe PBA framework from the recovered precursor, while SEM revealed a more homogeneous particle morphology. Furthermore, the recycling route effectively removed Mn-containing impurities, yielding a purified sodium-rich PBA phase [3].

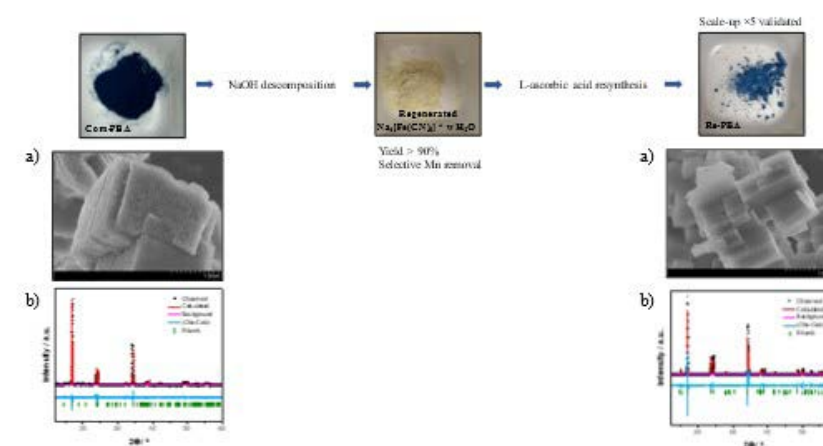
The recycling protocol was successfully scaled up by a factor of five while maintaining precursor recovery, structural integrity, and reproducibility. These results demonstrate the feasibility of a scalable closed-loop recycling strategy for PBA cathodes and highlight the potential of direct regeneration approaches to support the circular economy of sodium-ion batteries.

Acknowledgements: Funded by the European Union (RENOVATE, 101137745). Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

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- [2] Mashfy et al., Next Energy, 2026, 10, 100478.
- [3] Sanz-Camacho et al., ACS Applied Materials & Interfaces, 2021, 13 (36), 42682–42692.

Figure:



Keywords:

SIBs, PBAs, closed loop recycling, resynthesis

Synthesis of High Mass Loading Na₃V₂(PO₄)₃ Cathode via Dry-Process for Sustainable Anode Free Sodium Metal Batteries

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Introduction: High mass loading electrodes fabricated via a slurry-based process often suffer from weaker mechanical properties, heterogeneity issues, and lower electrochemical performance. Dry-processing have shown promise in overcoming these challenges, with strong potential to produce high-loading solvent free electrodes [1].

Results: In this study, free-standing solvent-free Na₃V₂(PO₄)₃ (NVP) cathodes were fabricated via dry processing. This approach entails mixing the NVP active material and conductive additives with the polytetrafluoroethylene (PTFE) binder in a completely dry state under a shear force. As a result, thick NVP films were obtained, reaching very high mass loadings of up to 80 mg cm⁻².

The electrochemical performance of the fabricated solvent-free NVP in half cell configuration exhibited good cycling stability over 90 cycles with a Coulombic efficiency of 97%. More impressively, when this cathode was paired with a commercial copper current collector as an Anode Free Sodium Metal battery (AFSMB), the cell retained 68% of its initial capacity after more than 50 cycles in coin and pouch cells. This study demonstrates the potential of dry processing for next-generation sodium battery technology.

Acknowledgements: This work received funding from the Romanian Ministry of Research, Innovation and Digitalization under Romania's National Recovery and Resilience Plan (PNRR) – Pillar III, Component C9, Investment I8 (PNRR/2022/C9/MCID/I8), through grant no. 760113/23.05.2023 (ToNaBatt). The work was also supported by a grant financed by the European Regional Development Fund within the Smart Growth, Digitization and Financial Instruments Programme 2021–2027, as part of the project Romanian Hub for Hydrogen and New Energy Technologies (Ro-HydroHub), under contract no. G 2025-113330 from 30.09.2025 and contract no. G 2024-81692/390006 from 13.11.2024, SMIS code 351358. Additional support was provided through the component project PN 23 15 02 01 (BatNaS) under funding contract 20N/2023.

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Keywords:

NVP Cathode, High mass-loading, Solvent-free, AFSMB

Electrolyte Engineering and Stable Interfacial Chemistry for Anode-Free Sodium Metal Batteries

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Introduction: Anode-free sodium metal batteries offer high energy density and low cost but suffer from rapid sodium (Na) inventory loss due to unstable Na plating/stripping and parasitic interfacial reactions. This results in poor Coulombic efficiency (CE) and cycling stability. We therefore aim to develop optimized electrolyte formulations while elucidating interfacial chemistries to improve cell performance.

Results: Different single salts (NaPF₆, NaBF₄ and NaCF₃SO₃) and their combinations were examined in single/binary ether-based solvents. Preliminary electrochemical data indicate how current collector's surface chemistry and electrolyte's solvation environment critically influence Na nucleation and initial CE. Additionally, the choice of salt anions governs the composition and stability of the interphases. Electrolytes containing associative salts like NaCF₃SO₃ and NaBF₄ are expected to promote stable, contact-ion-pair-dominated solvation structure, leading to anion-derived, inorganic component-rich interphases which minimizes early polarization fluctuations and improves cycle life. These electrolyte formulations were also studied with Na₃V₂(PO₄)₃ and high-voltage Na₃V₂(PO₄)₂F₃ cathodes. Moving forward, our target is to perform controlled experiments to optimize the testing protocols and employ advanced characterizations to analyze the interphases in details, to understand the interfacial phenomena precisely and obtain a suitable electrolyte formulation.

Acknowledgements: This work received funding from the Romanian Ministry of Research, Innovation and Digitalization under Romania's National Recovery and Resilience Plan (PNRR) – Pillar III, Component C9, Investment I8 (PNRR/2022/C9/MCID/I8), through grant no. 760113/23.05.2023 (ToNaBatt). The work was also supported by a grant financed by the European Regional Development Fund within the Smart Growth, Digitization and Financial Instruments Programme 2021–2027, as part of the project Romanian Hub for Hydrogen and New Energy Technologies (Ro-HydroHub), under contract no. G 2025-113330 from 30.09.2025 and contract no. G 2024-81692/390006 from 13.11.2024, SMIS code 351358. Additional support was provided through the component project PN 23 15 02 01 (BatNaS) under funding contract 20N/2023.

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Keywords:

Anode-free battery, electrolytes, sodium plating, interphase

Substrate Engineering for Na Anode-Free Cells: From Protocol Development to Performance Ranking

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Introduction: Sodium anode-free batteries offer higher energy density and reduced costs compared to conventional sodium-ion configurations, but their performance is critically dependent on the current collector substrate, which must support uniform sodium nucleation and efficient plating/stripping over extended cycling. [1]

Results: A standardized electrochemical protocol was developed and applied to copper and aluminum-based substrates, consisting of a formation cycle at 3 mAh followed by 100 galvanostatic cycles at 2 mAh and 1 mA/cm², with stripping to 1.0 V vs Na/Na⁺ without capacity limitation. Substrates were tested in 1M NaPF₆ and mixed 0.9M NaPF₆ + 0.1M NaBF₄ in diglyme. Carbon-coated aluminum demonstrated the highest Coulombic-efficiency across both electrolytes, with stable cycling and clean depletion profiles. CuHCl degraded severely in the mixed electrolyte due to BF₄⁻ interactions, while untreated Cu produced the cleanest profiles in the entire dataset.

These results demonstrate that substrate selection and electrolyte composition are strongly interdependent in Na anode-free cell design. Al/C emerges as the most robust candidate for prototype integration, and the standardized protocol developed here provides a reproducible benchmarking directly supporting the development of high-CE sodium cells.

Acknowledgements: This work received funding from the Romanian Ministry of Research, Innovation and Digitalization under Romania's National Recovery and Resilience Plan (PNRR) – Pillar III, Component C9, Investment I8 (PNRR/2022/C9/MCID/I8), through grant no. 760113/23.05.2023 (ToNaBatt). The work was also supported by a grant financed by the European Regional Development Fund within the Smart Growth, Digitization and Financial Instruments Programme 2021–2027, as part of the project Romanian Hub for Hydrogen and New Energy Technologies (Ro-HydroHub), under contract no. G 2025-113330 from 30.09.2025 and contract no. G 2024-81692/390006 from 13.11.2024, SMIS code 351358. Additional support was provided through the component project PN 23 15 02 01 (BatNaS) under funding contract 20N/2023.

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Keywords:

anode-free, sodium, plating, stripping, coulombic efficiency

Mn-Doped NFPP: Structural and Electrochemical Study for Aqueous Sodium-Ion Batteries

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Introduction: Mixed phosphate-pyrophosphate compounds have emerged as promising cathode materials for different metal-ion battery systems owing to their favourable structural and electrochemical properties. Among them, Na₄Fe₃(PO₄)₂P₂O₇ (NFPP) is particularly attractive because it can deliver near-theoretical capacities even at relatively high current densities [1,2]. Nevertheless, its practical electrochemical performance remains limited by low electronic conductivity and a relatively low operating voltage. Partial substitution of Fe with transition-metal cations, such as Mn, has therefore been explored as an effective strategy to enhance charge-transport properties in NFPP and increase its operating voltage.

Results: In this work, Mn was incorporated into the NFPP structure by partial substitution of Fe using the glycine-nitrate combustion method. The influence of Mn incorporation and critical synthesis parameters, including precursor type, mixing sequence, pH, and annealing conditions, on phase evolution was systematically investigated. The optimised synthesis conditions resulted in a Mn-doped NFPP phase with suppressed secondary-phase formation, as evidenced by X-ray diffraction and Fourier transform infrared spectroscopy. Electrochemical evaluation in an aqueous Na⁺ electrolyte revealed that appropriate Mn incorporation enhances both the reversible capacity and the operating voltage of NFPP. The results provide practical guidelines for the synthesis of Mn-doped NFPP and identify the optimal Mn content for maximising electrochemical performance while preserving the Fe- and Mn-based redox activity.

Acknowledgements: This material is based upon work supported by the Air Force Office of Scientific Research under award number FA8655-25-1-7015.

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Keywords:

NFPP, Mn doping, Na⁺ aqueous electrolyte

Solvation Dynamics and NMR Relaxation in Sodium Battery Electrolytes via Machine Learning

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Introduction: Sodium-ion batteries offer potential advantages in resource availability and low cost, but the larger atomic mass and ionic radius adversely affect theoretical energy density. In practice, battery performance also depends on electrolyte properties such as ionic transport, desolvation kinetics, and interfacial stability.¹ Understanding Na⁺ solvation and dynamics in liquid electrolytes is important because these processes influence ion transport and interfacial behaviour. However, NMR relaxation and spectral line shapes reflect multiple molecular motions, making their microscopic interpretation nontrivial.² Here, we combine solution NMR with machine-learning molecular dynamics (MLMD) to connect Na⁺ coordination and solvation shell exchange with electric-field-gradient (EFG) fluctuations and quadrupolar relaxation.³

Results: MLMD trajectories of NaPF₆ carbonate electrolytes are used to characterize Na⁺ solvation structure and exchange dynamics.³ Coordination analysis identifies the local solvation environment, while survival functions quantify the persistence and exchange of Na⁺-solvent and Na⁺-anion contacts. In parallel, time-dependent EFG tensors at the quadrupolar nuclei ²³Na and ¹⁷O are used to obtain correlation functions and spectral densities for calculating quadrupolar relaxation. Comparing solvation structures, exchange timescales, and EFG fluctuations across electrolyte formulations allows us to examine how local coordination and molecular dynamics are reflected in quadrupolar NMR relaxation. This provides a molecular interpretation of the NMR differences between electrolyte formulations.

Acknowledgements: We sincerely thank Dr. Feng Wang for providing the universal machine-learning potential and Dr. Mohammed Zabara for helpful discussions. We also thank Prof. Clare Grey, Prof. Jun Cheng, and Prof. Fujie Tang for their support and guidance.

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Keywords:

Electrolytes, Machine learning, NMR relaxation

EnGOAT: An Automated Computational Framework for Investigating Ion Transport in Solid-State Electrolytes

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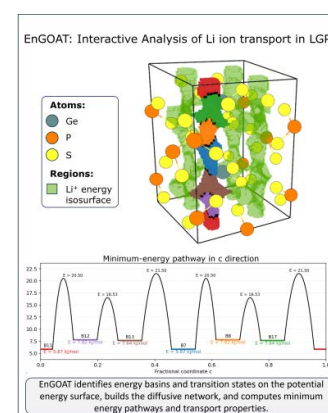
Introduction: The development of high-performance solid-state electrolytes requires computational methods that accurately predict ion transport while remaining sufficiently efficient for high-throughput materials screening. We present the Energy Geometry Analysis Toolkit (EnGOAT), an automated computational framework for analysing potential energy surface (PES) landscapes of mobile ions in crystalline solid-state electrolytes.

Results: EnGOAT extracts physically meaningful energetic and geometric descriptors directly from the complete PES and computes ion transport properties without requiring prior knowledge of diffusion pathways or crystal topology. By representing the PES as a network of energy basins and transition states, the framework provides automated and efficient computation of host-structure descriptors, minimum-energy pathways, and ion self-diffusion coefficients, while predicting transport properties several orders of magnitude faster than state-of-the-art molecular dynamics. The physically grounded descriptors generated by EnGOAT provide a compact representation of the energy landscape that is well suited for high-throughput screening, physics-informed machine-learning models, and the discovery of structure-transport relationships in solid-state electrolytes. In addition, EnGOAT incorporates an interactive graphical interface for visualization of potential-energy landscapes, diffusion networks, transition states, and minimum-energy pathways, enabling intuitive exploration of ion migration mechanisms and accelerating the analysis and design of next-generation battery materials.

Acknowledgements:

References:

Figure:



Keywords:

Solid-state electrolytes, ion transport, high-throughput screening

Insights Into the Enhanced Oxidative Stability of Localized High Concentration Electrolytes From Ab Initio Molecular Dynamics

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Introduction: Localized high-concentration electrolytes (LHCEs) have emerged as promising electrolytes for lithium batteries because they offer good electrochemical stability and sufficiently fast ionic transport. Their design involves diluting a conventional electrolyte with a non-solvating diluent to form extended ionic networks while maintaining a relatively low salt concentration. Fluorinated cyclic ethers and acetals have attracted attention as particularly effective diluents,[1] although the origin of their performance remains insufficiently understood. In this work, we investigate LHCEs based on 2,2-bis(trifluoromethyl)-1,3-dioxolane (BTFMD) as the diluent, 1,2-dimethoxyethane (DME) as the solvent, and lithium bis(fluorosulfonyl)imide (LiFSI) as the salt using ab initio molecular dynamics.[2] In ongoing work, we are extending our investigation to the electrode–electrolyte interface to gain insight into how bulk solvation structure influences interfacial structure and reactivity.

Results: The simulations indicate that Li⁺ ions are coordinated exclusively by FSI[−] anions and DME molecules, while the BTFMD concentration regulates the competition between these coordinating species within the Li⁺ first solvation shell. The local Li⁺ solvation environment is directly connected to the electronic structure of the electrolyte. Increasing BTFMD concentration reduces the density of electronic states near the valence band maximum due to the depletion of non-solvating DME molecules, while no significant changes occur at the conduction band minimum. These results are conceptually consistent with the experimentally observed improvement in oxidative stability. Overall, this study suggests that electrochemical response can be tuned by controlling the local Li⁺ solvation structure in LHCEs.

Acknowledgements: The research was funded by the Slovenian Research and Innovation Agency (P2-0423, P2-0152, GC-0004, J2-70085, I0-0039).

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Keywords:

LHCE, lithium battery, AIMD, electronic structure

Microscopic Insights Into Water-in-Salt Electrolytes: Combining NMR Relaxation With Molecular Dynamics

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Water-in-salt electrolytes (WISEs) have emerged as promising candidates for safer, high-voltage lithium-ion batteries, thanks to their ability to combine the safety of aqueous systems with an extended voltage window suitable for high-energy batteries. Despite some early studies on the structural and transport properties of WISEs, a detailed understanding of the lithium-ion dynamics at the microscopic level remains incomplete. In these regards, NMR relaxation provides a powerful approach to probe the local collective dynamics around nuclei, though modelling becomes critical in order to interpret experiments in terms of microscopic motion. For lithium, like many other alkali cations, relaxation is dominated by a quadrupolar mechanism arising from the coupling between the nuclear quadrupolar moment and fluctuations of the local electric field gradient (EFG).

Understanding the relaxation of lithium therefore requires a detailed description of the time-dependent EFG fluctuations generated by the surrounding environment. In this work, we combine atomistic simulations and experimental measurements to investigate the microscopic origin of the quadrupolar relaxation of ⁷Li⁺ in aqueous LiTFSI, from dilute to WISEs. By integrating electronic effects via the Sternheimer approximation

with classical molecular dynamics (MD), our computational approach captures both fast local fluctuations and slower collective motions, bridging the gap between atomistic-scale dynamics and macroscopic transport phenomena. Overall, we demonstrate that the steep increase in the ⁷Li⁺ relaxation rates with concentration is primarily driven by a slowdown in the collective EFG dynamics, where the slow collective relaxation becomes increasingly dominant in the concentrated electrolyte. The fast inertial contribution associated with short-time local motions remains instead largely unaffected. Our analysis further reveals the role of increasingly correlated ion–solvent and ion–ion dynamics at high salt concentration, consistent with the emergence of ionic liquid-like behaviour in water-in-salt electrolytes.

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DFT Study of Metal-Modified Graphite Surfaces for Vanadium RFB Electrodes

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Introduction: Renewable energy integration requires scalable energy-storage technologies. Vanadium redox flow batteries (VRFBs) are promising for stationary storage because power and energy can be independently scaled, while vanadium species in both half-cells limit irreversible cross-contamination [1]. Their performance is restricted by sluggish vanadium redox kinetics on carbon electrodes and parasitic hydrogen and oxygen evolution, which reduce Coulombic efficiency and disturb electrolyte balance [1,2]. Modifying graphite with p-block elements may tune its electronic and adsorption properties, promote vanadium reactions, and suppress gas evolution [2,3].

Results: Graphite surfaces modified with bismuth (Bi), indium (In), tin (Sn), and lead (Pb) were investigated using density functional theory (DFT). Four-layer graphite models containing 200 atoms were structurally optimised, and changes in local geometry, electronic structure, and charge redistribution were evaluated. Stable configurations were obtained for Bi-, Pb-, and Sn-modified surfaces, revealing element-dependent interactions and structural rearrangements. Further calculations compare adsorption energetics of species relevant to the V^{3+}/V^{2+} and VO_2^+/VO^{2+} redox couples and hydrogen- and oxygen-evolution intermediates. The aim is to identify modifications that favour vanadium redox reactions while suppressing parasitic gas evolution.

Acknowledgements: This work was funded by NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the SUNFLOWERS project No. 09I02-03-V01-00022.

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Keywords:

RFBs, DFT, graphite electrode, energy storage

Exploring New Redox Chemistries for Flow Battery Applications: From Vanadium to Organic Molecules

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Introduction: Vanadium redox flow batteries (VRFBs) are a mature technology for large-scale energy storage; however, the high cost of vanadium has stimulated the development of alternative redox-active materials. Among these, organic molecules have attracted considerable attention due to their tunable electrochemical properties and potential for low-cost, sustainable energy storage applications [1]. The development of organic redox flow batteries requires redox-active molecules with favorable electrochemical characteristics, high solubility, good stability, and minimal crossover through the membrane [2]. This work presents a preliminary electrochemical evaluation of selected organic redox-active molecules as potential electrolyte materials for aqueous redox flow battery applications. The growing interest in organic redox species stems from their structural tunability, potential cost-effectiveness, and prospects for sustainable energy storage.

Results: Electrochemical characterization revealed distinct redox behaviour and varying degrees of reversibility among the investigated organic compounds. Diffusion coefficients and heterogeneous electron-transfer rate constants were determined from cyclic voltammetry measurements, providing insight into the mass transport and charge-transfer kinetics of the studied systems. The obtained electrochemical parameters enabled a preliminary comparison of the investigated molecules and the identification of promising candidates for further testing under redox flow battery operating conditions.

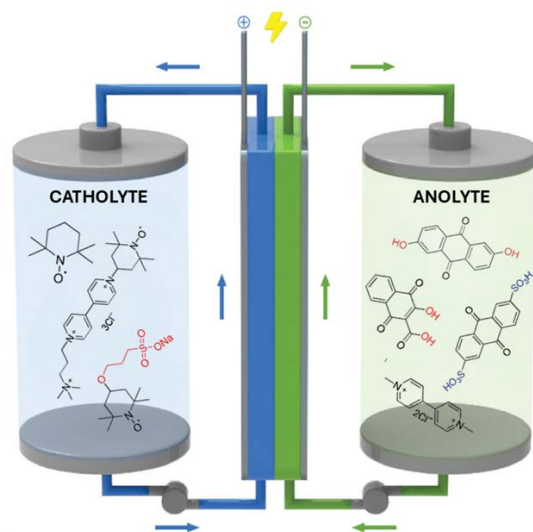
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Figure:

**Keywords:**

redox-flow battery, organic molecules, vanadium electrolyte

ZnV₂O₆-Dominated Composite: Structural Evolution and Charge Storage Mechanism in Aqueous Zn-Ion Electrolyte

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Introduction: Recently, a CaV₂O₆-dominated composite (CaVO/C) synthesized via a malonic acid-assisted solution combustion method showed high electrochemical activity and structural stability, enabling efficient storage of Ca²⁺ / Zn²⁺ ions [1,2] and highlighting the versatility of the CaV₂O₆ host structure for multivalent charge storage.

Results: In this study, a ZnV₂O₆-dominated composite (ZnVO/C) was synthesized using the same approach and investigated in a saturated Zn(NO₃)₂ aqueous electrolyte using cyclic voltammetry and chronopotentiometry, followed by ex-situ X-ray powder diffraction (XRPD) to gain insight into structural evolution during charge storage. The results revealed that, upon cycling, ZnV₂O₆ remained structurally stable, whereas the secondary phases present in ZnVO/C (Zn₂V₂O₇ and Zn₃V₃O₈) gradually dissolved, identifying ZnV₂O₆ as the dominant electrochemically active phase governing Zn²⁺ storage. Furthermore, the results indicated that ZnVO/C enabled efficient charge storage through simultaneous Zn²⁺ and H⁺/H₂O insertion, delivering a high specific capacity of ≈198 mAh g⁻¹ at 1000 mA g⁻¹. Since both Zn²⁺ and protonic species contribute to the charge-storage mechanism, ZnVO/C was additionally investigated in Zn(NO₃)₂ electrolytes with controlled acidity to evaluate the role of proton insertion and its influence on short- and long-term stability. Finally, structural evolution and electrochemical activity of ZnVO/C during cycling were compared with the previously investigated CaVO/C system to elucidate the influence of pre-inserted metal ions on charge-storage mechanisms and electrochemical performance in aqueous Zn-ion electrolytes.

Acknowledgements: This material is based upon work supported by the Air Force Office of Scientific Research under award number FA8655-25-1-7015. This research is also supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia through contract No. 451-03-33/2026-03/200146.

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Keywords:

Aqueous zinc-ion batteries; ZnV₂O₆/C; Co-insertion; Stability

Multicomponent Aqueous – Non-Aqueous Electrolytes for Zinc-Metal Batteries

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Introduction: Rechargeable aqueous zinc batteries are considered promising energy storage systems for large scale applications due to their safety, low cost, and environmental sustainability. However, conventional aqueous electrolytes suffer from parasitic side reactions, including hydrogen evolution and non-uniform zinc deposition leading to dendrite formation, which limit cycling stability and Coulombic efficiency [1]. Mixed aqueous-organic electrolytes have recently attracted considerable attention as an effective strategy to regulate the Zn²⁺ solvation structure, suppress interfacial side reactions, and promote more reversible zinc plating/stripping, improving the electrochemical performance and long-term stability of zinc batteries [2].

Results: A systematic solvent optimization strategy was carried out for multicomponent aqueous–organic electrolytes based on 0.5 M Zn(OTf)₂ and various mixtures of water, acetone, acetonitrile, ethylene glycol, and other organic solvents. The reversibility of Zn deposition from the electrolytes was evaluated in Zn || Zn and Zn || Cu cells using galvanostatic cycling to assess cycling stability and Coulombic efficiency. Selected electrolyte solutions, and zinc deposition process were further characterized by optical microscopy, atomic force microscopy (AFM), X-ray diffraction (XRD), and Fourier-transform infrared spectroscopy (FTIR). Electrochemical screening allowed to identify combinations of solvents which resulted in enhanced cycling stability and high Coulombic efficiency. Eventually, the criteria for co-solvent selection, zinc deposition, and full-cell stability, and their interrelations, are discussed.

Acknowledgements: This research was funded by the National Science Center (NCN) under the OPUS 27 project (No. 2024/53/B/ST5/03414).

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Keywords:

zinc-metal batteries, multicomponent electrolytes, aqueous electrolytes

Ethylene Glycol-Modified ZnSO₄ Electrolytes for Stable Zinc Deposition in Aqueous Zinc-Ion Batteries

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Introduction: Aqueous zinc-ion batteries (AZIBs) have attracted significant attention as safe and cost-effective energy storage systems. In this work, ethylene glycol (EG) was introduced into ZnSO₄-based electrolytes to investigate its influence on electrolyte solution solvation structures and electrochemical performances. We compared the performances of electrolytes containing different ZnSO₄ molar concentrations (0.25 M, 0.5 M and 1 M) and water-to-EG volume ratios (1:1, 1:3 and 1:4).

Results: The incorporation of EG significantly changed the zinc ion solvation structure in aqueous electrolytes. The presence of EG in the first solvation shell of zinc ion thermodynamically promoted the smooth zinc deposition during charging. Our Zn || Zn symmetric cells exhibited reduced voltage polarization and prolonged cycling stability compared with pure ZnSO₄ aqueous electrolytes. Analysis on solid electrolyte interphases after cycling demonstrated more uniform zinc deposition and effective suppression of dendritic growth. The modified electrolytes were also evaluated in Zn || V₂O₅ full cells to investigate practical battery performance. Cells employing EG-containing electrolytes showed improved cycling stability relative to the aqueous ZnSO₄ baseline. We proved introducing EG in water effectively modified electrolyte pH, viscosity, water activity and ionic conductivity. We performed a series of stability tests and confirmed these modifications suppressed chemical corrosions and hydrogen evolutions.

Acknowledgements: This work was supported by Dr. Georgios Nikiforidis from University College London. We would also like to thank all academic and research staffs in UCL Institute for Materials Discovery for their assistance, and the UCL East Teaching Wet Lab for providing resources.

References:

Keywords:

Zinc-ion batteries; Ethylene glycol; Zinc sulphate

Ethanol-Assisted, Phase-Engineered Hydrothermal Synthesis of Molybdenum Disulfide for Aqueous Supercapacitors

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Introduction: Molybdenum disulfide (MoS₂) is a promising electrode material for aqueous supercapacitors. Its charge storage is primarily governed by the balance between the semiconducting 2H and the metallic 1T phases, ion access to the interlayer galleries, and the presence of active edge sites [1]. However, sheet restacking and 1T metastability limit performance. This makes synthetic routes that enrich the 1T fraction and widen the interlayer spacing highly desirable. Here, we investigate an ethanol-assisted hydrothermal approach [2], combined with reducing-agent and multi-step processing, as a route to phase-engineered MoS₂ electrodes.

Results: Across the prepared series, scanning electron microscopy reveals a clear morphological evolution and X-ray diffraction a progressive change in stacking order, while Raman spectroscopy indicates that the multi-step ethanol treatment promotes conversion toward the metallic 1T phase. Electrochemical testing in a neutral 1 M Na₂SO₄ electrolyte shows that the ethanol-treated material delivers a substantially higher specific capacitance than the additive-free and single-step samples, and kinetic analysis links this enhancement to improved interlayer access rather than to surface area alone. Furthermore, scanning electrochemical microscopy (SECM) is utilized to map the local electroactivity across these electrodes.

Acknowledgements: This work was supported by the Scientific Grant Agency of the Ministry of Education, Research, Development and Youth of the Slovak Republic (VEGA) under Grant No. 1/0707/24, by the Slovak Research and Development Agency under Contracts No. APVV-24-0321 and APVV-22-0132, and by the STU Grant Scheme to Support Excellent Teams of Young Researchers (HYBNiMo).

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Keywords:

MoS₂; hydrothermal synthesis; supercapacitor; interlayer engineering.

Precipitation-Grown Ni-Ni(OH)₂ Core-Shell Electrodes for Asymmetric Supercapacitors

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Introduction: The growing demand for high-performance energy storage has driven research into advanced electrode materials for supercapacitors, which offer rapid charge-discharge rates and high power density but remain limited by relatively low energy density. Nickel hydroxide is a particularly attractive candidate owing to its high theoretical capacitance, reversible faradaic redox activity in alkaline electrolytes, and cost-effectiveness [1]. In this work, binder-free Ni-Ni(OH)₂ core-shell electrodes were fabricated via a precipitation method on nickel foam substrates, followed by annealing in forming gas and electrochemical activation in 1 M KOH, yielding a nanostructured high-surface-area active layer.

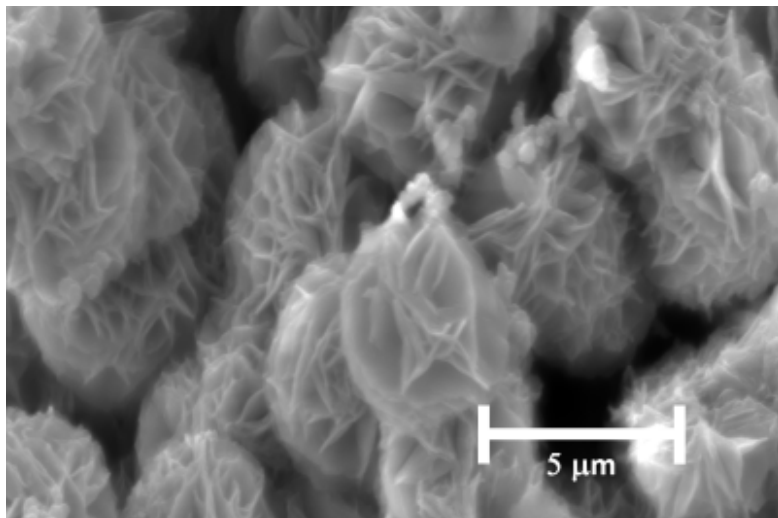
Results: Structural characterization by SEM confirmed that the Ni(OH)₂ nanoflake morphology was preserved throughout all preparation steps. EDS analysis verified the compositional transformation from metallic Ni after annealing to a Ni(OH)₂/NiOOH-rich surface following electrochemical activation, evidenced by a shift in the Ni-to-O atomic ratio from 12.5:1 to 3.6:1. This finding was also supported by EIS measurements throughout the activation process. Electrochemical testing of the electrode in a three-electrode configuration demonstrated outstanding pseudocapacitive behavior, with a specific capacitance of 3490 F/g at 1 A/g. When assembled into an asymmetric supercapacitor paired with a binder-free activated carbon negative electrode in a CR2032 coin cell, the device achieved a low equivalent series resistance of 0.48 Ω, a wide operating voltage window of 1.6 V, and excellent cycling performance, with a capacity retention of 72% after 10,000 cycles.

Acknowledgements: This work was supported by the Scientific Grant Agency of the Ministry of Education, Research, Development and Youth of the Slovak Republic (VEGA), Grant No. 1/0707/24, and by the Slovak Research and Development Agency under Contracts No. APVV-24-0321 and APVV-22-0132.

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Figure:

**Keywords:**

nickel hydroxide, supercapacitors, core-shell electrode, binder-free

Tailoring the Charge Storage Behaviour of Polyaniline Through MAX Phase Incorporation

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Introduction: Increasing electrical conductivity does not necessarily improve charge storage in polymer-based composite electrodes. This study examines how the content and distribution of the conductive Ti₃AlC₂ MAX phase affect the electrochemical response of polyaniline (PANI), linking structural and morphological features with electrode and full-cell performance.

Results: Structural characterization indicates that the characteristic features of the conductive emeraldine salt are preserved following Ti₃AlC₂ incorporation. Changes in the optical response are consistent with modifications in the electronic environment of PANI, accompanied by increased electrical conductivity. The Cyclic Voltammograms measured in an acidic aqueous electrolyte show the typical redox behavior of PANI. The addition of the MAX phase reduces the potential difference between the anodic and cathodic peaks, indicating improved reversibility of the redox process. The most favorable electrochemical response of the studied compositions is exhibited by the composite with 5 wt.% Ti₃AlC₂, which combined the highest specific capacitance and the best capacitance retention at increasing scan rates. Morphological studies reveal that this composition has a good distribution of MAX particles in the polymer matrix, which favors electron transport and access to the PANI surface. At higher loadings, increased surface exposure and local agglomeration of MAX particles, together with a lower polymer mass fraction, may limit the benefits of improved conductivity. Electrochemical testing is also extended to full-cell configurations to assess charge-discharge behaviour and long-term cycling performance.

Acknowledgments: This material is based upon work supported by the Air Force Office of Scientific Research under award number FA8655-25-1-7015. This research was supported by the Science Fund of the Republic of Serbia, #372, Harnessing Machine Learning for Green Energy Materials: Insights into Mxene/Polyaniline Composite Surface-GEMComp.

Keywords:

Polyaniline; MAX Phase; Supercapacitors; Electrochemical Performance

Tuning Palladium Nanoparticle Decoration of AB₅-Type Alloys: From Precursor to Performance

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Introduction: The growing demand for sustainable energy storage drives the development of more efficient battery technologies. Among currently used systems, nickel-metal hydride (Ni-MH) batteries stand out due to their safety, thermal stability, and long cycle life [2]. Their operation relies on reversible hydrogen absorption/desorption in metal hydride-forming alloys used as anodes. Improving the performance of these materials, namely their capacity, corrosion resistance, and kinetics of hydrogen electrosorption, still remains a key challenge. One of the possible strategies involves surface modification with palladium nanoparticles (Pd-NPs), which act as catalysts, enhancing charge transfer kinetics and promoting faster activation of hydrogen-absorbing alloys [1].

Results: Pd nanoparticles were deposited on an AB₅-type alloy (LaMmNi_{4.1}Al_{0.3}Mn_{0.4}Co_{0.45}) using microwave-assisted polyol reduction method with various palladium precursors. Electrochemical (CV, CA, CP) and physicochemical (SEM, N₂ adsorption, Raman, XRD) analyses revealed a strong correlation between Pd nanoparticle structure and electrode performance.

Among the tested precursors, palladium(II) trifluoroacetate provided the most significant improvement, yielding the highest initial discharge current, indicative of enhanced hydrogen desorption kinetics. The precursor type influenced nanoparticle size, with smaller Pd nanoparticles, characterized by higher surface area, leading to superior hydrogen sorption properties. Additionally, pre-treatment of the AB₅ alloy surface further enhanced electrochemical performance.

Acknowledgements: The authors acknowledge the support of the National Science Centre, Poland (grant no. 2025/57/B/ST11/01263).

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Keywords:

AB₅ alloy, palladium nanoparticles, hydrogen electrosorption

Uniform and Scalable Sm³⁺- and Nd³⁺-Doped Ceria Nanocatalysts Deposited on Bifunctional Oxygen Electrodes for High-Performance Reversible Solid Oxide Electrochemical Cells

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Introduction: Solid oxide electrochemical cells (SOCs) are promising energy conversion devices because they can operate in both fuel cell and electrolysis modes. However, lowering the operating temperature significantly increases oxygen electrode polarization resistance, resulting in performance degradation. In this work, highly conductive Sm³⁺/Nd³⁺ co-doped ceria (SNDC) nanoparticles were uniformly deposited onto LSCF-GDC oxygen electrodes using an ultrasonic spray infiltration technique to enhance catalytic activity while maintaining scalability for commercial applications.

Results: Uniformly distributed 20–50 nm SNDC nanoparticles increased oxygen vacancies and active reaction sites on the electrode surface. Electrochemical impedance spectroscopy revealed reduced polarization resistance through enhanced oxygen surface exchange, charge transfer, and oxygen-ion incorporation. The optimized SNDC@LSCF-GDC electrode achieved a maximum power density of 1.97 W cm⁻² at 750°C in fuel cell mode and an electrolysis current density of 1.72 A cm⁻² at 750°C. Furthermore, ultrasonic spray infiltration was successfully applied to a 10 × 10 cm² commercial cell, delivering 38.7 W output and stable operation for 960 h, demonstrating excellent scalability and long-term durability.

Acknowledgements: This work was supported by the National Research Foundation of Korea (NRF), the Korea Institute of Planning and Evaluation for Technology in Food, Agriculture, and Forestry (IPET), and the Korea Institute of Energy Research (KIER).

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Keywords:

RSOCs, Ultrasonic spray infiltration, SNDC

Modification of the Electrolyte to Improve the Cycle Performance of Aqueous Al Battery

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Introduction: Aqueous aluminum metal batteries have attracted widespread attention due to their high specific capacity. However, the high susceptibility of aluminum metal to corrosion greatly limits their practical applications.

Results: To improve the rate performance and cycling stability of aluminum metal batteries, we have modified the aqueous electrolyte by adding organic and inorganic salts such as LaL_3 and the amino acid. These modifications significantly enhance the stability of the aluminum metal surface, extending the cycling life from only 50 cycles to over 1000 cycles[1]. The application of this strategy provides a potential feasible solution for the practical implementation of aqueous aluminum metal batteries and offers valuable insights for future large-scale deployment of such battery systems.

Acknowledgements: The authors were grateful for the financial support from the NCN, Poland, UMO-2020/39/B/ST8/02937 and Project Number 101092189 (Acronym: HEDAsupercap) under the framework of HORIZON-CL4-2022-RESILIENCE-01, funded by European Commission.

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Keywords:

Al battery, LaCl_3 , cycle performance

Nanostructured Polyimide Organic Cathodes for Fast and Stable Aluminium Metal Batteries

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Introduction: Aluminium metal batteries have attracted growing interest as a post-lithium technology owing to aluminium's natural abundance, low cost, and multi-electron redox capacity. Among various cathode materials under investigation, redox-active organic compounds have attracted considerable attention because their amorphous structures and molecular tunability enable efficient accommodation of charge-dense multivalent ions and cationic complexes. However, they often suffer from dissolution and side reactions, as well as high overpotentials and moderate rate performance.[1]

Results: Here, we report a nanostructured polyimide synthesized from naphthalene tetracarboxylic dianhydride and hydrazine, with multiwalled carbon nanotubes incorporated during polymerization. The resulting composite exhibits a theoretical capacity of 200 mAh g^{-1} and delivers approximately 175 mAh g^{-1} at C/2, corresponding to nearly 90% active-material utilization. Long-term cycling demonstrates excellent stability, with only ~6% capacity loss after 1500 cycles. In conventional Al half-cells, the material operates at an average discharge voltage of approximately 1.5 V versus Al/Al^{3+} with a small polarization of around 80 mV, placing it among the highest-performing linear organic cathodes reported for aluminium batteries.

To distinguish intrinsic cathode behaviour from limitations imposed by the metal anode, we employed symmetric polyimide/polyimide cells in addition to conventional half-cells.[2] While half-cell performance rapidly deteriorates at high current densities, symmetric-cell measurements reveal that the organic cathode maintains capacities of around 120 mAh g^{-1} up to 5 A g^{-1} , indicating that high-rate performance is primarily limited by Al plating and stripping rather than by the polyimide electrode. Ex-situ infrared spectroscopy, X-ray photoelectron spectroscopy, and X-ray Raman spectroscopy further confirm a reversible redox mechanism involving AlCl_2^+ coordination.

Acknowledgements: This work was supported by the Slovenian Research and Innovation Agency (research program P2-0423, project J2-70086).

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Keywords:

Al-metal batteries, polyimide electrodes, nanostructured composites

A Systematic Study of Fluorination Degree in Alkoxyaluminate-Based Magnesium Electrolytes

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Introduction: Although magnesium metal batteries are considered a promising alternative to lithium-ion batteries, a major challenge for their practical applicability is the design of a cathode-compatible electrolyte with high Mg plating/stripping efficiency. A promising class of Mg-based electrolytes contains weakly coordinating anions (WCAs), where CF₃ groups withdraw charge from the central anion atom and reduce the strength of cation-anion interactions. The most prominent representative of alkoxyaluminate-based WCAs is the [Mg(DME)₃][Al(hfip)₄]₂/G2 electrolyte due to its excellent ionic conductivity, high plating/stripping efficiency, and compatibility with different cathode materials. Despite their potential, alternative alkoxyaluminate salts remain underexplored.

Results: In this study, we synthesized alkoxyaluminate-based Mg salts with varying degrees of fluorination using different alcohol ligands: 2,2,2-trifluoroethanol (tfe, one CF₃ group), 1,1,1,3,3,3-hexafluoro-2-propanol (hfip, two CF₃ groups), perfluoro-tert-butanol (pftb, three CF₃ groups), and perfluoropinacol (pfp, bidentate donor, four CF₃ groups). An increase in the fluorine content in WCAs raises the anion's electronegativity, resulting in weaker cation-anion interactions and enhanced salt dissociation, while also modifying the salt's oxidative and reductive stability.

The synthesized salts were characterized by infrared (IR) and nuclear magnetic resonance (NMR) spectroscopy. Mg plating/stripping in different electrolytes was evaluated using various electrochemical techniques, including conventional galvanostatic cycling, macrocycling, and LSV to determine the oxidative and reductive stability of the electrolytes. Electrochemical tests were complemented by SEM and XPS to analyze the morphology and interphase composition of the metal deposits. Finally, the applicability of these electrolytes was examined by pairing them with different cathode materials. This study highlights the promising nature of alkoxyaluminate-based electrolytes and addresses performance differences associated with variable fluorine content, indicating that moderate fluorination provides the optimal balance of properties among the investigated electrolytes.

Acknowledgements: The authors acknowledge financial support from the Slovenian Research and Innovation Agency (ARIS) through the Scientists4Future Slovenia project (MSCA-COFUND-SE/2023) and programs P2-0423 and J2-70086.

References:

Keywords:

WCAs, alkoxyaluminates, Mg fluorinated electrolyte, plating/stripping

Cryogenic XPS for Reliable Characterization of Magnesium-Sulfur Battery Interphases

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Introduction: Interfacial reactions govern the performance, stability and lifetime of rechargeable batteries. Consequently, X-ray photoelectron spectroscopy (XPS) has become one of the most widely employed techniques for investigating electrode-electrolyte interphases. In lithium-based battery systems, the development of cryogenic characterization methods has enabled more reliable analysis of highly reactive electrode surfaces and interphases by minimizing sample degradation during transfer and measurement [1]. Despite the growing interest in magnesium batteries, the influence of X-ray irradiation and ion sputtering on magnesium battery interphases remains largely unexplored, and most studies continue to rely on room temperature XPS measurements.

Results: Here, we systematically investigate beam- and sputter-induced transformations in magnesium deposits formed from Mg(TFSI)₂-MgCl₂ in digylme electrolyte, both in absence and presence of dissolved sulfur species. Electrodeposited magnesium was characterized by XPS under room temperature and cryogenic (-150 °C) conditions, while the effects of gas cluster ion beam (GCIB) depth profiling were evaluated over extended sputtering times. Repeated room-temperature X-ray exposure resulted in pronounced chemical transformations, including decomposition of TFSI-derived species and progressive formation of MgF₂-rich surface layers. Additionally, changes in sulfur speciation were also detected during measurements and sputtering. In contrast, cryogenic conditions substantially suppressed these transformations. These results demonstrate that conventional room temperature XPS can significantly alter the chemistry of magnesium interphases during analysis, potentially leading to misinterpretation of both electrolyte decomposition pathways and sulfur reaction mechanisms. Cryogenic XPS combined with GCIB depth profiling therefore provides a more reliable platform for investigating magnesium battery interfaces and Mg-S electrochemistry.

Acknowledgements: The authors acknowledge financial support from the Slovenian Research and Innovation Agency (ARIS) through the research core funding program P2-0423.

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Keywords:

Cryogenic XPS, Depth profiling, Magnesium batteries

Dynamic Electrochemical Impedance Spectroscopy Reveals Magnesium Anode Stabilization by Fluorinated Ether Additives in Mg Metal Batteries

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Introduction: Magnesium (Mg) metal batteries are attracting increasing attention owing to their high energy density and low cost. However, their practical development remains limited by electrode passivation, poor cycling performance, and the scarcity of suitable Mg electrolytes. In this work, we investigate fluorinated ether additives for Mg electrolytes and elucidate the interfacial mechanisms responsible for their enhanced electrochemical performance.

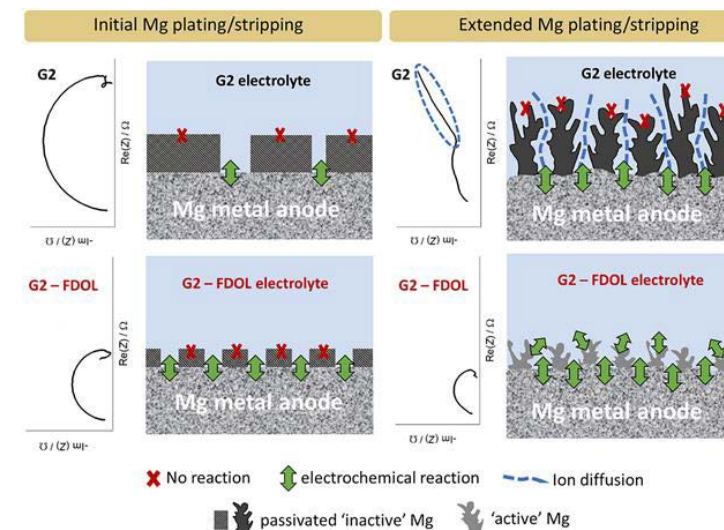
Results: The addition of 10 vol.% fluorinated cyclic ether, FDOL, particularly in combination with weakly coordinating Mg salts, improves the Mg^{2+} solvation structure and Mg metal reversibility. Coulombic efficiency increases from 98.2% to 99.4%, while cycling life in $\text{Mg} \parallel \text{Pt}$ cells is extended from 15 to 120 cycles at 2 mA cm^{-2} and 2 mAh cm^{-2} . [1] To understand the origin of this improvement, electrochemical impedance spectroscopy (EIS) was performed under dynamic (operando) conditions and complemented by scanning electron microscopy and X-ray photoelectron spectroscopy. The results reveal that, without the fluorinated ether additive, the Mg metal anode undergoes incomplete activation, resulting in high-surface-area deposits and subsequent passivation. In contrast, the optimized electrolyte enables stable Mg plating/stripping. Furthermore, it supports long-term cycling of a $3.5 \text{ V Mg} \parallel \text{polyaniline}$ battery, delivering 75% capacity retention after 500 cycles at 1 C. These findings demonstrate that fluorinated ether additives significantly improve Mg metal stability and provide mechanistic insights for the rational design of advanced electrolytes for next-generation high-voltage rechargeable Mg batteries.

Acknowledgements: This work has received funding from the European Union Horizon 2020 research and DESTINY-MSCA PhD programme under Grant Agreement No. 945357. Co-financing from the Slovenian Research and Innovation Agency (ARIS) through core programme P2-0423 is gratefully acknowledged

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Figure:



Keywords:

Mg metal anodes, EIS, Electrolytes, Mechanisms

A Fluorine-Free Electrolyte for Calcium Metal Batteries

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Introduction: Calcium metal batteries (CMBs) are promising next-generation energy storage systems due to the high abundance of Ca, reduced dendrite formation, and potential for multi-electron redox.⁽¹⁾ However, their development is hindered by the highly reducing nature of calcium, which promotes the formation of passivating interphases that impede Ca^{2+} transport and desolvation at the electrode/electrolyte interface. Since the first demonstration of reversible Ca plating/stripping in 2016, electrolyte engineering has focused on tailoring the solid electrolyte interphase (SEI) to improve Ca^{2+} mobility.⁽²⁾ Hydride-rich SEIs formed from $\text{Ca}(\text{BH}_4)_2$ -based electrolytes enable room-temperature cycling⁽³⁾ but suffer from poor anodic stability, whereas fluorinated salts such as $\text{Ca}[\text{B}(\text{hfp})_4]_2$ and $\text{Ca}[\text{Al}(\text{hfp})_4]_2$ extend the electrochemical stability window but are costly, synthetically demanding, and environmentally undesirable.⁽⁴⁾ More recently, high donor solvents such as dimethylacetamide (DMAc) combined with $\text{Ca}(\text{TFSI})_2$ enabled reversible calcium cycling with low polarization; however, long-term performance remains limited by TFSI^- decomposition and CaF_2 accumulation at the interface.⁽⁵⁾ To address these challenges, we synthesized $\text{Ca}(\text{MSI})_2$, a fluorine-free analogue of $\text{Ca}(\text{TFSI})_2$, via a one-step mechanochemical process and investigated its electrochemical performance in a DMAc-based electrolyte.

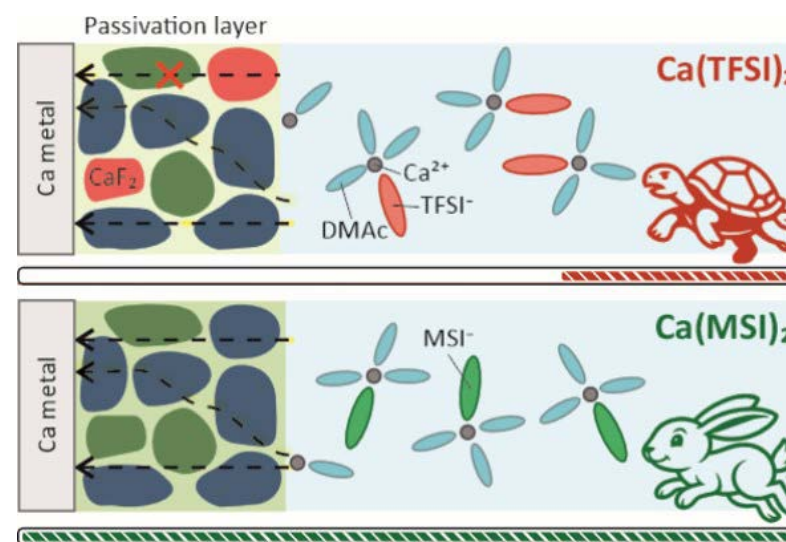
Results: The $\text{Ca}(\text{MSI})_2/\text{DMAc}$ electrolyte delivered lower polarization (0.82 V vs. 0.95 V for $\text{Ca}(\text{TFSI})_2$) and stable Ca plating/stripping for over 1600 h at 0.02 mA cm^{-2} . A thinner, more uniform SEI with reduced interfacial decomposition was observed. Unlike fluorinated electrolytes, the fluorine-free $\text{Ca}(\text{MSI})_2$ avoids CaF_2 -rich interphases, promoting a more homogeneous and ion-conductive passivation layer. These results demonstrate enhanced interfacial stability and Ca^{2+} transport while eliminating fluorine-derived degradation products, providing a promising design strategy for CMBs and other emerging battery.

Acknowledgements: FWO and F.R.S.-FNRS under the EOS program (40007515), and M-ERA.NET/F.R.S.-FNRS project (COBRA).

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Figure:



Keywords:

sustainable electrolytes, multivalent batteries, calcium bis(methanesulfonimide)

Influence of Synthesis Routes on Electrochemical Performance and Interphase Formation in Calcium Metal Batteries

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Introduction: Calcium metal batteries are promising candidates for next generation energy storage owing to calcium's high natural abundance and low reduction potential. However, their practical implementation is limited by the lack of electrolytes capable of sustaining reversible Ca plating/stripping without forming passivating interphases that inhibit Ca²⁺ transport. Among the currently available electrolytes CaBhfp has emerged as a benchmark system due to its high oxidative stability, ability to support reversible Ca plating/stripping, and non-nucleophilic character. Recent advances have introduced a cation replacement synthesis route that uses Zn(BH₄)₂ as the precursor instead of the conventionally employed Ca(BH₄)₂, offering a more cost-effective and potentially scalable approach to CaBhfp.[1]

Results: This work aims to establish a direct comparison between synthesis routes and electrolyte performance by preparing CaBhfp through three different pathways: the conventional Ca(BH₄)₂ route, cation replacement using Zn(BH₄)₂, and synthesis from a BH₃·THF precursor. The resulting electrolytes were electrochemically evaluated to investigate the relationship between the synthesis route, electrolyte purity, and Ca plating/stripping performance. The electrolytes prepared from salts synthesized via different routes exhibited distinct electrochemical behavior. While CaBhfp synthesized from Ca(BH₄)₂ and BH₃·THF enabled limited cycling up to 30 cycles, CaBhfp obtained via Zn(BH₄)₂ showed significantly improved performance, exceeding 400 cycles with CE values above 90%. The enhanced performance could be contributed to presence of Na impurities which were confirmed by ICP-OES analysis, as previous studies have demonstrated improved Ca cycling performance upon Na addition.[2] Further, the composition and morphology of cycled electrodes were characterized using SEM-EDS and XPS.

Acknowledgements: Authors acknowledge that this work was done in the scope of the COBRA project (M-ERA.NET call 2023, C3360-25-452015) through the financial support of ARIS and F.R.S.-FNRS.

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Keywords:

Ca batteries, WCAs, synthesis, electrochemistry

Electrochemical Performance of Self-Standing Electrodes Based on Amorphous Coordination Polymers for Calcium-Ion Storage

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Introduction: Calcium batteries offer a promising alternative to conventional lithium-based batteries, primarily due to their greater natural abundance, lower cost and enhanced sustainability. Nevertheless, their practical application is still limited by the scarcity of suitable cathode materials that can efficiently host divalent Ca²⁺ ions while ensuring reversible ion transport and structural stability over prolonged cycling. The large ionic radius and high charge density of Ca²⁺ require flexible and disordered host frameworks that can facilitate ion mobility and reversible storage. In this context, coordination polymers (CPs), have emerged as promising alternative organic cathode materials to traditional phosphate-based compounds in calcium-ion battery technology [1-4]. These materials consist of metal ions linked by organic ligands, forming extended network structures that facilitate efficient calcium ion intercalation and reversible redox processes.

Results: This study investigates the development of the amorphous Ca-Zn-PTtSA coordination polymer and the optimization of the dry-processing method for fabricating high mass loading self-standing electrodes. Electrochemical characterization was performed in coin-cell configuration, demonstrating stable capacity retention over more than 200 charge–discharge cycles. The obtained results were further validated through the design and assembly of laboratory-scale Ca-ion pouch cell prototypes.

Acknowledgements: This work was supported by a grant from the Romanian National Authority for Scientific Research and Innovation, UEFISCDI, under project ERANET-M3-COBRA (67/2024).

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Keywords:

calcium-ion battery, cation-reservoir, coordination polymers, solvent-free

How Improper Use of Activated Carbon Leads to Biased Data Interpretation in Post-Li Battery Systems

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Introduction: Activated carbon counter electrodes are increasingly used for electrochemical evaluation of post-lithium battery materials because they avoid the interfacial instability and passivation issues associated with metal anodes. [1,2] However, their improper use can introduce significant artefacts, leading to inaccurate electrochemical interpretation.

Results: Using a calcium organic cathode as a model system, we systematically investigated the influence of activated carbon counter electrodes on electrochemical measurements. We demonstrate that insufficient counter electrode balancing, electrolyte composition, activated carbon type, and self-discharge substantially affect electrode polarization, leading to artificial voltage shifts, distorted diffusion coefficients, and erroneous attribution of electrolyte decomposition to electrode redox activity. Practical guidelines are proposed to optimize cell balancing, minimize polarization, and ensure reliable electrochemical characterization. Although demonstrated for calcium batteries, these recommendations are broadly applicable to post-lithium battery chemistries employing activated carbon counter electrodes. [3]

Acknowledgements: The authors acknowledge the financial support of FWO, F.R.S.-FNRS, WEL Research Institute, M-ERA.NET 3, and the European Union's Horizon Europe programme.

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Keywords:

Post-lithium, Methodology, Activated Carbon, Energy Storage

Electrochemical Investigation of Sulfur Encapsulation Matrices for Lithium–Sulfur Battery Cathodes

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Introduction: Lithium–sulfur (Li–S) batteries are regarded as one of the most promising post-lithium-ion energy storage technologies owing to their high theoretical specific capacity (1675 mAh g⁻¹), theoretical energy density of approximately 2500 Wh kg⁻¹, natural abundance of sulfur, and low material cost [1]. Despite these advantages, their practical implementation is hindered by the intrinsically low electronic conductivity of sulfur and lithium sulfide, significant volume variation during cycling, and dissolution and migration of lithium polysulfides, commonly referred to as the shuttle effect [1–3]. To overcome these limitations, considerable attention has been devoted to sulfur host matrices capable of physically confining sulfur species, chemically adsorbing polysulfides, and promoting rapid charge transfer. Carbon-based porous materials, heteroatom-doped carbons, and polar inorganic hosts have emerged as the most promising matrix materials due to their combined conductive framework and strong interactions with lithium polysulfides [2–4].

Results: Biomass-derived porous carbons, graphene oxide-based materials, conductive polymers, and metal–organic frameworks (MOFs) are being electrochemically evaluated as sulfur-host matrices. Cyclic voltammetry and galvanostatic charge–discharge measurements are used to assess sulfur redox reversibility, reaction kinetics, discharge capacity, capacity retention, and cycling stability. The study compares conductive carbon hosts with polar MOF and polymer matrices to determine how electrical conductivity and chemical affinity toward lithium polysulfides affect sulfur utilization and shuttle suppression. The aim is to identify matrices that combine rapid electron transport with effective sulfur confinement and polysulfide immobilization, thereby improving long-term electrochemical performance.

Acknowledgements: This work was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project SUNFLOWERS No. 09I02-03-V01-00022.

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Keywords:

lithium–sulfur batteries; sulfur-host matrices; polysulfide shuttle

Separator Engineering Using Waste Plastic-Derived MOF-Carbon for Advanced Lithium-Sulfur Batteries

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Introduction: The growing plastic pollution crisis calls for high-value, eco-friendly recycling strategies. Meanwhile, lithium-sulfur batteries (LSBs) face the shuttle effect that hinders their commercialization. Here, we convert waste plastic into MOF-derived carbon materials for LSB separator modification.

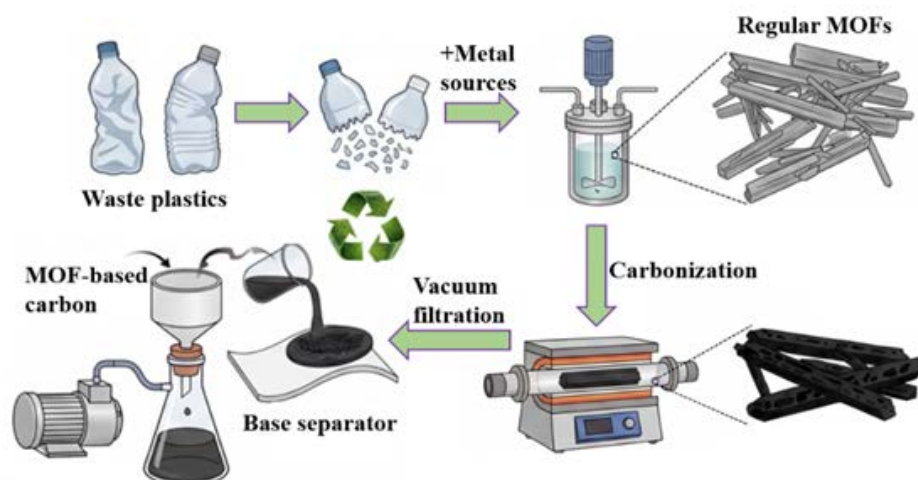
Results: The modified separator suppresses the shuttle effect and reduces charge transfer resistance. At 1 C, the battery delivers an initial capacity of 810 mAh g⁻¹ and retains 503 mAh g⁻¹ after 300 cycles. This work offers a dual-benefit strategy: high-value plastic recycling and advanced LSB development.

Acknowledgements: The authors gratefully acknowledge the OPUS, UMO-2023/51/B/ST11/00504.

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Figure:



Keywords:

Recycling of waste plastics; LSBs, Separator

Impact of a High-Entropy (CrMnFeCoNi)3O4 Spinel Catalyst on the Cycling Stability and Capacity Recovery of Composite Sulfur Cathodes

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Introduction: The rising demand for high energy density storage drives the development of post-lithium-ion technologies such as lithium-sulfur (Li-S) batteries. Li-S systems are promising due to sulfur's exceptional theoretical capacity (1675 mAh g⁻¹), abundance, and low toxicity. However, commercialization is hindered by large volumetric changes and the shuttle effect, where soluble lithium polysulfides migrate between electrodes, causing capacity fade. Beyond binders [1] and electrolyte additives [2], introducing high-entropy oxides (HEOs) as polar electrocatalytic hosts [3] represents a promising strategy to chemically anchor polysulfides and promote their conversion.

Results: In this work, we integrate a high-entropy spinel oxide, (CrMnFeCoNi)3O4, into sulfur cathodes to mitigate polysulfide shuttling. Cyclic voltammetry revealed a more stable and reproducible redox profile for the composite electrodes compared to pure sulfur. During rate-capability testing, the composite cathode exhibited slightly lower high-rate capacity due to reduced electronic conductivity from replacing conductive carbon with HEO; however, it showed improved capacity recovery at lower rates. Most notably, long-term cycling showed severe capacity fade for conventional sulfur electrodes, whereas the HEO-modified cathode delivered improved capacity retention and more stable cycling behavior, suggesting enhanced polysulfide conversion kinetics and improved electrode stability.

Acknowledgements: This work was funded by the Recovery and Resilience Plan for Slovakia under the project SUNFLOWERS no. 09I02-03-V01-00022.

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Keywords:

lithium-sulfur batteries; high-entropy oxides; spinel; catalyst

Sulfur Host Matrices for Enhanced Electrochemical Performance of Lithium–Sulfur Batteries

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Introduction: Lithium–sulfur (Li–S) batteries have attracted considerable attention as promising next-generation energy storage systems owing to their high theoretical specific capacity (1675 mAh g⁻¹), high energy density, low cost, and the natural abundance of sulfur [1]. Practical implementation of Li–S batteries is nevertheless limited by the poor electrical conductivity of sulfur and Li₂S, the dissolution and migration of lithium polysulfides (the shuttle effect), and significant volume changes during cycling, leading to rapid capacity fading and poor cycling stability [1,2]. To address these challenges, sulfur host matrices based on conductive carbon materials have been extensively studied [2,3]. In this work, an S/Super P/GO/PVDF composite was developed as a sulfur host matrix, and its electrochemical behavior was evaluated to assess its suitability for Li–S battery applications.

Results: The electrochemical performance of an S/Super P/GO/PVDF composite cathode was evaluated by cyclic voltammetry and galvanostatic charge–discharge measurements. Galvanostatic cycling at 0.1 C delivered an initial discharge capacity of approximately 663 mAh g⁻¹, demonstrating effective sulfur utilization. These preliminary results suggest that the incorporation of graphene oxide together with conductive carbon provides a suitable sulfur host matrix for improving the electrochemical performance of Li–S batteries.

Acknowledgements: This work was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project SUNFLOWERS No. 09I02-03-V01-00022.

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Keywords:

Li-S batteries, energy storage, cathode

A Single-Phase Mixed Ion-Electron Conducting Metal–Organic Framework

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Introduction: Mixed ionic–electronic conductors (MIECs) are highly sought after for electrochemical systems because they support concurrent charge and mass transport. Yet, structurally well-defined single-phase MIECs remain scarce, as most systems rely on physical mixtures of ionic and electronic conductors.

Results: Here, we introduce a cation-rich design strategy to realize solid-state mixed Li⁺–electronic conduction in a two-dimensional copper–catecholate metal–organic framework, Cu₃(HOTAT)₂, built from the 3-fold symmetric new ligand 2,3,7,8,12,13-hexahydroxytriazatruxene (HHTAT, HOTAT³⁻ in its coordinating form). Owing to the combined redox activity of Cu²⁺/Cu⁺ and HOTAT ligand, controlled fractional reduction generates a family of Li_xCu₃(HOTAT)₂ (0 ≤ x ≤ 7.50) phases with tunable transport properties, in good agreement with electronic-structure calculations. The Li-rich phase Li_{7.5}Cu₃(HOTAT)₂ exhibits intrinsic mixed conduction at room temperature, with an electronic conductivity of 2.8 × 10⁻³ S cm⁻¹, and solid-state Li⁺ conductivity of 1.1 × 10⁻³ S cm⁻¹. As a proof of concept, Li_{7.5}Cu₃(HOTAT)₂ operates as a homogeneous cathode in all-solid-state Li batteries, delivering 100 mAh g⁻¹ after 100 cycles with ~99.8% coulombic efficiency, indicative of highly reversible electrochemical behavior. These results establish cation-rich reduction of redox-active 2D MOFs as an efficient route to engineer solid-state mixed Li⁺–electronic conductors, opening a pathway toward dual-conducting porous materials for solid-state electrochemical technologies.

Acknowledgements: European Research Council under the European Union's Horizon 2020 research and innovation program (grant agreement No. 770870, MOOIRE).

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Keywords:

Mixed ion-electron conductors, Metal-organic frameworks

Redox Control in a Conducting MOF Through Coupled Electronic–Vibronic Effects

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Introduction: Redox control in electrically conducting metal–organic frameworks (MOFs) requires understanding how intercalated cations reshape both electronic structure and lattice thermodynamics.

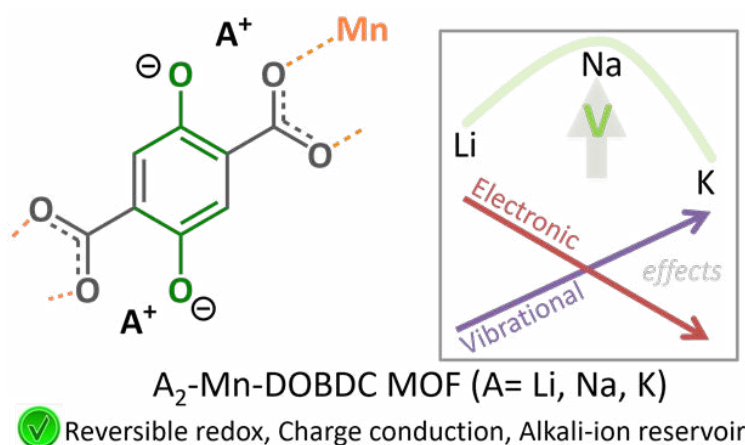
Results: In the nominal A₂-Mn-DOBDC anionic framework (A = Li⁺, Na⁺, K⁺), redox potentials and electronic conductivities follow K < Li < Na, contradicting an electrostatic polarization model. Finite-temperature free-energy partitioning shows competing contributions: ΔFEL (electronic term) decreases along Li > Na > K, whereas ΔFVIB (vibrational term) increases along Li < Na < K, producing a maximum stabilization that favors Na and rationalizes the non-intuitive potential ordering. FTIR band shifts track cation-induced systematic mode shifts consistent with cation-dependent vibrational reorganization, and DFT vibrational densities of states with Helmholtz free energies reproduce ΔFVIB trends. Mixed-valence charge transfer with cation-modulated electronic coupling accounts for the conductivity ordering. Na₂-Mn-DOBDC delivers a median discharge voltage of ~3.0 V vs Na⁺/Na while retaining measurable electronic conductivity, providing a general electronic–vibronic route to tune redox energetics in conducting MOFs.

Acknowledgements: This work was supported by F.R.S.-FNRS, the European Research Council (ERC, Horizon 2020), WEL Research Institute, M-ERA.NET 3, the Romanian Ministry of Research, Innovation and Digitalization, and Romania's National Recovery and Resilience Plan (PNRR).

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Figure:



Keywords:

Electrical-conductivity, cathodes, Metal-organic frameworks, Redox reactions

Phenazine-2,3,7,8-Tetramine-Derived Organic Cathode Materials With Pyrazine and Quinone Redox Motifs for Zn- and Li-Organic Batteries

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Introduction: Small organic molecules (SOMs) are emerging as alternatives to conventional inorganic electrode materials for rechargeable batteries due to their abundance and structural tunability, which simplifies optimization. However, SOM-based electrodes often suffer from low-capacity utilization and rapid capacity fading, primarily due to their insulating nature and high solubility in electrolytes.

Results: In this work, we present a facile synthesis strategy that incorporates pyrazine and quinone units from commercially available precursors, yielding materials with stable electrochemical performance, enabled by strong π-π stacking, and redox-inactive benzene rings that suppress solubility in the electrolyte, and high capacities. The cathode materials were obtained via a condensation reaction and evaluated in Lithium and Zinc batteries. Specifically, 2,3,7,8-phenazine-tetramine-based HATBH cathodes containing pyrazine and quinone motifs demonstrated good cycling stability over hundreds of cycles at a current density of 100 mA g⁻¹, along with moderate capacity of 148 mAh/g and 301 mAh/g for HATBH and HATBH-O, respectively. Furthermore, the capacity was significantly enhanced by the addition of redox active quinone groups by an additional oxidation step using potassium dichromate. This treatment nearly doubled the capacity (increasing the theoretical value from 275 to 413 mAh g⁻¹), although it led to a decrease in cycling stability.

Acknowledgements: This work was financially supported by Slovenian Research Agency (ARIS) under research program P2-0423 and P2-0145, GC-004, NK-60003 and Ministry of Education, Science and Sport (MIZS) for funding M.Era-net project InsBioration (call 2021).

References:

Figure:



Keywords:

Organic cathodes, pyrazine, quinone, Zn battery

Towards Bulk Liquid Redox-Active Organic Materials for Energy Storage

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Introduction: Redox-Active Organic Materials (ROMs) emerged as a promising alternative to current battery technologies to meet the needs in sustainability, elemental abundance, low-cost production, and recyclability. However, their implementation in batteries remains a challenge, as achieving high energy densities requires high concentrations of ROMs. Moreover, at high concentrations, limitations related to charge transport, solubility, phase behavior, and material utilization become crucial.[1] In solid-state systems, achieving high energy densities is limited by the poor charge transport of solid ROMs, requiring dilution with conductive carbon additives.[2] In redox flow batteries (RFBs), increasing the volumetric energy density remains a topical challenge given otherwise prohibitive system costs.[3, 4] Therefore, understanding the limiting processes and properties of ROMs at high concentrations is essential.[5]

Results: Herein, we explore the behavior of ROMs in highly concentrated systems to understand how concentration and state of charge influence their physicochemical properties. We study known moieties, which have not been investigated in their bulk liquid state, and we introduce new classes of n- and p-type molecules. The oxidized states of p-type ROMs were synthesized with different counter ions (bis(trifluoromethanesulfonyl)imide [TFSI-], and tetrafluoroborate [BF₄-]). The physicochemical properties across the state of charge, including solubility, phase behavior, viscosity, conductivity, chemical stability, and reversibility, were systematically analyzed and compared. Our results highlight that exploiting the full potential of ROMs requires understanding limiting processes across the full state of charge, given that major changes occur between discharged and charged states.

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Keywords:

Organic Active Materials, limiting battery processes

Cation-Size-Independent Electrochemical Storage of Li⁺ to Cs⁺ in an Amorphous Sulfonamide Coordination Polymer

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Introduction: Next-generation batteries beyond lithium demand electrode materials capable of accommodating a wide range of cations. Most hosts suffer from size-dependent limitations: material utilization and cycling stability typically degrade as cation size increases[1]. Amorphous frameworks offer greater structural flexibility than crystalline analogs, but organic systems combining broad cation compatibility with fast kinetics and stable cycling remain scarce[2]. Conjugated sulfonamide (CSA) coordination polymers derived from benzene-1,2,4,5-tetrayltetakis(methylsulfonylamide) (H₄-PTtSA) have previously demonstrated versatile divalent cation storage[3]. Here we extend this platform to the full alkali-metal series, from Li⁺ to Cs⁺.

Results: The amorphous Ca-Zn-PTtSA coordination polymer was used as a universal starting electrode. Upon galvanostatic cycling in electrolytes containing 1 mol L⁻¹ MTFSI (M⁺ = Li⁺, Na⁺, K⁺, Rb⁺, Cs⁺) in propylene carbonate (PC), Ca²⁺ is quantitatively replaced by M⁺ via in situ electrochemical exchange, confirmed by inductively coupled plasma-optical emission spectrometry (ICP-OES) yielding M⁺/Zn²⁺ ≈ 1.95 for all cations. Remarkably, all systems deliver ~95 mAh g⁻¹ specific capacity with nearly identical redox potentials (~-0.55 V vs. Fc/Fc⁺), low polarization (~70 mV), and no solvent co-intercalation. Galvanostatic intermittent titration technique (GITT) analysis reveals diffusion coefficients of ~2 × 10⁻⁹ cm² s⁻¹, invariant across the cation series. Long-term cycling at 1C yields capacity retention and coulombic efficiency both exceeding 99.9%. This cation-size independence originates from the framework's amorphous flexibility and delocalized sulfonamide electronic structure, enabling weak, reversible metal-ligand interactions. Direct chemical synthesis of Na₂-Zn-PTtSA and Cs₂-Zn-PTtSA confirmed equivalent electrochemical performance[4].

Acknowledgements: Supported by F.R.S.-FNRS (EOS 40007515), WEL Research Institute (X.9008.25-HECTOR), ERC (No. 770870, MOOIRE), and M-ERA.NET 3 (GA No. 958174).

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Figure:



Keywords:

organic-electrode, coordination-polymer, alkali-metal-cations, amorphous-framework, post-lithium-batteries, sulfonamide

A Hexaanionic Carboxyphenolate Framework for High-Energy Mono- and Divalent Cation Storage

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Introduction: Organic positive electrode materials offer a sustainable pathway toward next-generation rechargeable batteries, yet simultaneously achieving high capacity and high voltage remains challenging. Here, we explore conjugated carboxyphenolate frameworks for alkali- and calcium-ion storage, demonstrating how redox-active ligands, spectator cations, and structural disorder can enable high-energy-density electrochemical performance.

Results: Achieving both high capacity and high voltage in organic positive electrodes remains a significant challenge. Here, we demonstrate the versatility of the conjugated carboxyphenolate ligand H6THBPD for both alkali- and calcium-ion storage. The pre-metallated Li6THBPD, Na6THBPD, and K6THBPD electrodes exhibit nearly four-electron redox utilization, delivering capacities of 313, 244, and 200 mAh g⁻¹ at average voltages of 2.85, 2.40, and 2.50 V vs. Li⁺/Li, Na⁺/Na, and K⁺/K, respectively. Extending this chemistry to calcium batteries, amorphous Ca₂-M-THBPD (M = Mg²⁺, Ca²⁺, Ba²⁺) frameworks enable reversible Ca²⁺ storage above 3.5 V vs. Ca²⁺/Ca, delivering up to 120 mAh g⁻¹ with 99.8% Coulombic efficiency and 75% capacity retention after 200 cycles. These results establish conjugated carboxyphenolate frameworks as a promising platform for high-energy alkali- and alkaline-earth-ion batteries, highlighting the importance of inductive effects, spectator cations, and framework disorder in tuning electrochemical performance.

Acknowledgements: This work was supported by FWO and F.R.S.-FNRS through the Excellence of Science (EOS) program – ECOBAT (Grant No. 40007515). B.V.R., F.R.S.-FNRS for Chargé de Recherche (CR) fellowships (Grant Nos. 40023657).

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Figure:

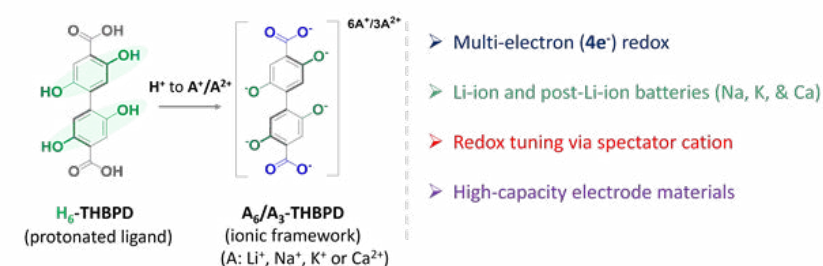


Figure1: Schematic illustration of the redox mechanism and charge storage properties of H₆THBPD. The conjugated carboxyphenolate framework undergoes reversible multi-electron (4e⁻) redox, enabling Li-, Na-, K-, and Ca-ion storage. Spectator cation effects modulate the electronic structure, leading to tunable redox behavior and high-capacity electrode performance.

Keywords:

Carboxyphenolate frameworks; mono and divalent-ion storage

Rational Design of Pyrazine–Quinone Hybrid Organic Cathode Materials for Lithium and Zinc Batteries

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Introduction: Organic cathode materials that integrate pyrazine and quinone motifs have emerged as one of the most promising research directions for developing high-energy-density organic electrode materials. Despite the rapid growth in reports of novel small-molecule cathodes for lithium-ion and zinc-ion batteries, simultaneously achieving high energy density and long-term cycling stability remains a significant challenge.

To address this challenge, we report a facile and sustainable synthetic strategy based on reaction of aromatic diamines and a biomass-derived sodium rhodizonate precursor, which enables the simultaneous incorporation of both pyrazine and quinone structural motifs into the target molecules.

Results: In lithium-battery configurations, the resulting materials exhibit an outstanding energy density of up to 860 Wh kg⁻¹ and superb cycling stability (82% capacity retention over 400 cycles at 50 mA g⁻¹). While this high-energy-density profile (280 Wh kg⁻¹) is successfully translated to aqueous zinc-ion configurations, we identify and address the subsequent stability challenges by introducing novel hexaazatriphenylene (HAT)-derived architectures. These novel materials deliver exceptional practical reversible capacities of up to 503 mAh g⁻¹ in zinc-ion batteries.

Crucially, this electrochemical performance is supported by a rigorous, in-depth analysis of the underlying redox mechanisms and degradation processes, providing vital insights for the advancement of sustainable organic batteries.

Acknowledgements: The authors acknowledge the financial support from the Slovenian Research Agency young researcher scheme, ARRS research projects N2-0214, N2-0279 and N2-0165, research programs P2-0423 and P2-0145, Ministry of Education, Science and Sport (MIZS) for funding M.Era-net project InsBioration (call 2021) and Honda R&D Germany.

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Menart, Svit, et al. "Design of organic cathode material based on quinone and pyrazine motifs for rechargeable lithium and zinc batteries." *ACS applied materials & interfaces* 16.13 (2024): 16029-16039.

Menart, Svit, et al. "Bipyrazinoquinone based organic cathode material for lithium, zinc, and proton batteries", submitted

Keywords:

organic electrodes, zinc, lithium, pyrazine, quinone

Exploring Charge Transport and Electrochemical Capacitance in 2D Conductive MOFs: Effects of Nitrogen-Rich Ligand and Interlayer Spacing

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Introduction: Two-dimensional electrically conductive metal-organic frameworks (2D EC-MOFs) are emerging as versatile materials for energy storage, combining high porosity with tunable electronic properties. Here we show that post-synthetic functionalization can precisely tune conductivity in triazatruxene-based 2D MOFs, Ni₃(HITAT)₂, by controlling interlayer spacing and orbital overlap.

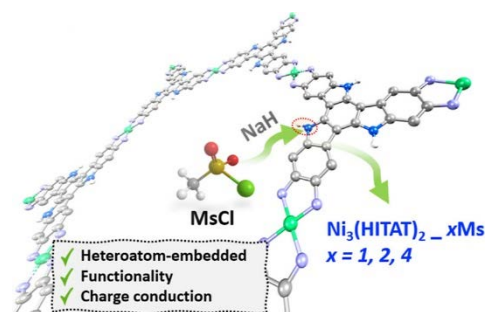
Results: Alkyl functionalization modulates charge storage behavior in electrochemical capacitors: expanding the interlayer distance gradually shifts the mechanism from electric double-layer to pseudocapacitive storage, enhancing specific capacitance. Partial exfoliation further increases ion accessibility and amplifies faradaic activity. Together, these results establish a strategy for designing porous, functional materials with tailored charge transport and energy storage properties.

Acknowledgements: V.F. acknowledge the FNRS (FRIA) for the PhD scholarship. D.T. and Y.Z. acknowledge the China Scholarship Council for the PhD scholarship. A.V. is indebted to the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement no. 770870), as well as for the partial support from F.R.S.-FNRS through F.4552.21-P-MIS-CSA-LION grant. Research in the Dinca lab was supported by the U.S. Department of Energy, Office of Science, Basic Energy Sciences, under award #DE-SC0023288. The computational resources in Mons are supported by the FNRS "Consortium des Equipements de Calcul Intensif-CECI" program grant no. 2.5020.11 and by the Walloon Region (ZENOBIE Tier-1 supercomputer, under grant 1117545). X.L. acknowledges financial support from the Marie Skłodowska-Curie Actions (grant agreement no. 101064286) for his postdoctoral fellowship. S.M.G. and D.R. are Chargé de Recherche-FNRS, and DB is Research Director-FNRS.

References:

J. Am. Chem. Soc. 2023, 145, 45, 24669–24677

Figure:



Keywords:

2D c-MOF, Energy Storage, Electrochemistry, Supercapacitors

Design Principles of Quinone Redox Systems for Sulfide-Based All-Solid-State Lithium-Organic Batteries

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Introduction: Coupling high-capacity organic small molecules, such as quinone derivatives, with the sulfide solid electrolyte Li₆PS₅Cl provides a promising route toward all-solid-state batteries with high energy density, improved safety, and sustainability [1]. However, practical development is limited by complex interfacial reactions between quinone molecules and Li₆PS₅Cl, whose mechanisms and products remain poorly understood [2]. This knowledge gap hinders the rational design of stable interfaces and high-performance solid-state organic batteries. Understanding the interfacial reaction mechanism and identifying descriptors governing (electro)chemical compatibility are therefore essential.

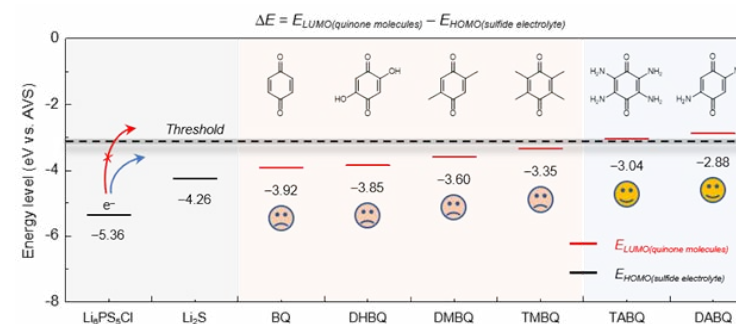
Results: Here, based on molecular orbital theory, we identify the lowest unoccupied molecular orbital (LUMO) energy level of organic molecules as a key descriptor for compatibility with Li₆PS₅Cl [3]. Combining systematic experiments with density functional theory calculations, we reveal the reaction pathways, products, and energy-level alignment at quinone/Li₆PS₅Cl interfaces. We further establish a molecular design criterion: the LUMO of the organic molecule should be at least 2.32 eV higher than the highest occupied molecular orbital (HOMO) of Li₆PS₅Cl to ensure interfacial chemical stability. Guided by this principle, two quinone molecules, 2,3,5,6-tetraamino-1,4-benzoquinone (TABQ) and 2,5-diamino-1,4-benzoquinone (DABQ), were designed and applied in solid-state batteries. These cells deliver high energy densities of 718 and 803 Wh kg⁻¹, respectively, with nearly 100% active material utilization, excellent rate capability, and long-term cycling stability. This work establishes a general energy-level matching principle and a molecule-electrolyte co-design strategy, providing theoretical guidance for interfacial engineering and molecular design in solid-state organic batteries.

Acknowledgements: The authors acknowledge F.R.S.-FNRS, ERC, and Marie Skłodowska-Curie Actions for financial support.

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Figure:



Keywords:

lithium organic batteries; solid-state batteries

Interfacial Engineering of Lithium Metal Anodes Using ALD Al₂O₃ for Stable Cycling and Improved Coulombic Efficiency

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Introduction: Lithium metal is considered an ideal anode for next-generation batteries due to its ultrahigh theoretical capacity and low electrochemical potential; however, its practical implementation is hindered by dendritic growth, unstable interfacial chemistry, and poor coulombic efficiency [1]. In this work, a conformal Al₂O₃ protective layer was deposited on lithium metal via atomic layer deposition (ALD) using 100 cycles to regulate lithium deposition behavior and stabilize the electrode-electrolyte interface.

Results: Electrochemical impedance spectroscopy (EIS) and Li|Li symmetric cell measurements demonstrate that the Al₂O₃-coated lithium exhibits a more stable interface and improved cycling stability compared to bare lithium, indicating enhanced interfacial compatibility and suppressed degradation.

To further elucidate the role of the Al₂O₃ layer in lithium nucleation, Li-Cu cells were systematically investigated using both Al₂O₃-coated lithium and Al₂O₃-coated copper substrates. The results reveal reduced nucleation overpotentials for lithium ions in the presence of Al₂O₃, more uniform lithium deposition, and significantly lower polarization in coated Li-Cu cells, confirming that the ALD coating effectively regulates initial nucleation and growth.

Coulombic efficiency measurements over 200 cycles show significantly improved reversibility for the coated systems, suggesting minimized side reactions and the formation of a more stable solid electrolyte interphase (SEI).

Finally, the Al₂O₃-coated lithium anode was used in lithium-sulfur (Li-S) cells, delivering enhanced cycling stability and improved capacity retention compared to bare lithium anode cells over 200 cycles.

Overall, this study demonstrates that ultrathin ALD-engineered Al₂O₃ coatings play a crucial role in stabilizing lithium metal anodes by simultaneously enhancing interfacial stability and controlling lithium nucleation, offering a promising strategy for advancing high-performance Li-S batteries.

Acknowledgements: The authors gratefully acknowledge funding support from the European project ANGeLiC (HORIZON-CL5-2022-D2-01) and the Slovak VEGA 2/0135/26 project.

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Keywords:

ALD, Nucleation, solid-electrolyte-interface, interfacial engineering, Li-S

Poly(ionic liquid) (PIL)-Based Solid Polymer Electrolytes for Structural Batteries

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Introduction: The emergence of next-generation structural batteries represents a major step toward lightweight, energy-dense, and multifunctional devices that can simultaneously store energy and bear mechanical loads. Such technologies are particularly crucial for aerospace, electric vehicles, and portable electronic applications, where weight savings directly translate into improved performance and efficiency. However, achieving high ionic conductivity and mechanical stiffness in a single material remains a significant challenge, as these properties are typically inversely related. Bridging this gap requires the development of new polymer systems that can maintain efficient ion conduction without sacrificing structural performance [1].

Results: To develop a structural polymer electrolyte with improved electrochemical and mechanical performance, an epoxy-based system was formulated using LiTFSI as the lithium-ion conducting salt and diglycidyl ether of bisphenol A (DGEBA) as the thermosetting polymer matrix. DGEBA was selected because of its widespread use in structural composites and epoxy-based solid electrolytes. To overcome the drawbacks associated with free ionic liquids (ILs), the IL was combined with a poly(ionic liquid) (PIL) containing quaternary ammonium groups along its backbone and carbonyl functional groups. The carbonyl groups facilitated lithium-ion hopping and coordination, while the quaternary ammonium groups effectively trapped the ionic liquid within the polymer structure, preventing leakage and phase separation. The resulting polymer electrolytes exhibited a storage modulus of approximately 0.5 GPa and an ionic conductivity of about 0.1 mS cm⁻¹, demonstrating a balanced combination of mechanical strength and ionic transport. These properties approach the requirements of multifunctional structural electrolytes, highlighting the potential of PIL-modified thermoset polymer systems for use in next-generation solid-state energy storage devices.

Acknowledgements: This work was supported by the Scientific and Technological Research Council of Turkey. (code: 121M552)

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Keywords:

Energy storage, polymer electrolyte, Lithium battery

Mitigating Plasticizer-Induced Interfacial Degradation in Solid-State Lithium Batteries via Protective Polymer Coatings

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Introduction: The metallic lithium (Li) anode represents the ultimate choice for next-generation energy storage, particularly when paired with solid polymer electrolytes (SPEs). To enhance bulk ionic conductivity and enable moderate-temperature operation, liquid plasticizers like tetraethylene glycol dimethyl ether (TEGDME) are frequently incorporated into the polymer matrix. However, these volatile components severely compromise the reactive Li interface, accelerating cell degradation.

Results: Here, we mitigate these interfacial side reactions using an in-house developed protective polymer coating composed of PEO, LiTFSI, and LiNO₃. Our study utilizes a three-electrode solid-state configuration with a Li reference electrode, enabling independent monitoring of individual plating and stripping overpotentials. While the coating significantly improves electrochemical performance and delays short-circuits, traditional ex situ scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS) analysis proved insufficient to fully correlate surface chemistry with electrochemical impedance spectroscopy (EIS) trends. A definitive understanding was achieved via cryo-plasma focused ion beam (cryo-pFIB) cross-sectional milling, which uniquely preserved the intact interface prior to cell disassembly. This approach revealed a thick, porous, and degraded interphase in non-coated baseline cells driven by continuous TEGDME consumption. Conversely, coated cells maintained excellent mechanical contact with the SPE and exhibited a compact, thin interphase [1]. Ultimately, targeted polymer coatings effectively decouple bulk transport from interfacial reactivity, offering a crucial strategy for practical Li-metal batteries.

Acknowledgements: This work was funded by the European Union's Horizon Europe Research and Innovation programme under the project PSIONIC (Grant Agreement No. 101069703), with additional financial support from the Slovenian Research and Innovation Agency (ARIS) through core program funding P2-0423.

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Keywords:

Lithium-metal, polymer-electrolytes, Interfacial-protection, Three-electrode, Cryo-pFIB

Polyethylene Oxide-Based Electrolytes Containing Ionic Liquid Excess With Improved Electrochemical Properties

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Introduction: The development of solvent-free polymer electrolytes (SPEs) that satisfy requirements related to safety, environmental sustainability and cost-effectiveness represents a serious challenge for the scientific community and opens new perspectives to applications in electrochemical devices.

SPEs minimize the dendritic growth onto the lithium anode, avoid liquid leakage, resulting much safer than the liquid ones because of the absence of volatile and flammable organic solvents. The use of ionic liquids (ILs) as co-salts was found as one of the most successful approaches for overcoming the conductivity limitation of SPEs [1] and for relevantly improving the performance at ambient temperature [1]. Polyethylene oxide (PEO) is a water-soluble, highly biocompatible and non-toxic polymer. Despite its promise for lithium polymer batteries, PEO-based SPEs degrade at high voltages (3.7–3.8 V).

Results: In the present study we have properly designed and developed SPEs based on PEO incorporating large fraction of N-methyl-N-propylpyrrolidinium bis(fluorosulfonyl)imide, PYR13FSI, and/or ethyl-methyl-imidazolium bis(fluorosulfonyl)imide, EMIFSI. Lithium bis(trifluoromethane-sulfonyl)imide (LiTFSI) was chosen as the lithium salt. The purpose is to promote IL exudation (due to its high excess); the IL film released acts protecting the polymer host from high voltage cathode material, thus extending the operative voltage of SPEs and improving interfacial compatibility with the electrodes. Moreover, the high IL amount promotes the creation of 3-D conductive networks, enhancing the ion transport properties of SPEs [2]. Our investigations show that the developed PEO-based electrolytes are able to combine fast ion transport properties with improved electrochemical stability.

Acknowledgements: Three-Year Research Plan 2025-2027 (D.M. n.388/2024) financed by the Research Fund for the Italian Electrical System (MASE)

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Keywords:

PEO electrolytes, Ionic liquids, Phase separation

Operando Tracking of Bulk Lithium Delamination During Stripping of Li-Metal Solid-State Batteries

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Introduction: Understanding what limits lithium stripping is essential for achieving high-capacity, long-cycle lithium metal anodes in solid-state batteries. In this study, we used operando electrochemical impedance spectroscopy (EIS) together with a three-electrode cell configuration to investigate lithium stripping in symmetric Li|Li₇P₃S₁₁|Li cells. An embedded gold micro-reference electrode enabled independent monitoring of the working and counter lithium electrodes during extended stripping and plating.

Results: The effect of stack pressure on stripping stability was evaluated at 1, 3, 9, and 18 MPa. The critical stripping capacity was defined as the capacity at which the working electrode potential increased to three times its initial polarization. Increasing the stack pressure consistently increased the critical stripping capacity. Operando impedance measurements showed a gradual increase in the bulk lithium resistance before failure occurred. Post-mortem FIB-SEM analysis of cells cycled under high stack pressure showed that the lithium|solid electrolyte interface remained intact despite severe polarization. Instead, failure originated within the lithium metal, where voids propagated into the bulk and merged, causing loss of electronic contact and lithium delamination. EDS analysis detected oxygen- and nitrogen-containing species inside the void regions, suggesting that trapped gases, originating from residual porosity in the solid electrolyte pellet or from the glovebox atmosphere during cell assembly, may contribute to this failure mechanism. To investigate this, the solid electrolyte powder was vacuum-pressed before pellet fabrication, and symmetric cells were vacuum-cycled at 1 MPa without external stack pressure. Under these conditions, the critical stripping capacity decreased by a factor of three, while post-mortem EDS no longer detected oxygen- or nitrogen-containing species in the void regions. These results reveal a previously unrecognized stripping-induced failure mechanism in solid-state lithium metal batteries and the affect of residual atmosphere on the operation of Li-metal SSBs.

Acknowledgements: This research was funded by the M-ERA.NET network under the project "FUNCY-SSB"

References:

Keywords:

Operando Impedance, Solid-state batteries, Li-metal batteries

Optimization of Stacking Pressure in Anode-Free Sodium-Metal Pouch Cells Using a Pressing Device With Silicone Pads

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Introduction: The performance of anode-free sodium-metal batteries are strongly influenced by the pressure applied to the electrode stack [1]. A precision mechanical device designed for testing pouch-type cells was designed, prototyped, and validated. The system incorporates a clamping mechanism based on calibrated compression springs distributed across five strategic points, enabling fine-tuning and precise force control. To correct surface imperfections and ensure uniform pressure distribution across the entire active area of the electrodes, silicone pads were introduced at the contact interface between the pressure plates and the pouch cell.

Results: Comparative analysis revealed that rigid metal plates cause localized mechanical stress, promoting uneven sodium deposition and dendrite penetration. Integrating silicone pads into the 5-point mechanical press uniformly distributed pressure and absorbed manufacturing tolerances. Consequently, anode-free cells exhibited significantly reduced failure rates, superior cycling stability, high coulombic efficiency, and improved plating/stripping reversibility. Ultimately, this 5-point press with silicone membranes provides a robust, reproducible platform for controlling stacking pressure and mitigating premature degradation in pouch cells.

Acknowledgements: This work received funding from the Romanian Ministry of Research, Innovation and Digitalization under Romania's National Recovery and Resilience Plan (PNRR) – Pillar III, Component C9, Investment I8 (PNRR/2022/C9/MCID/I8), through grant no. 760113/23.05.2023 (ToNaBatt). The work was also supported by a grant financed by the European Regional Development Fund within the Smart Growth, Digitization and Financial Instruments Programme 2021–2027, as part of the project Romanian Hub for Hydrogen and New Energy Technologies (Ro-HydroHub), under contract no. G 2025-113330 from 30.09.2025 and contract no. G 2024-81692/390006 from 13.11.2024, SMIS code 351358. Additional support was provided through the component project PN 23 15 02 01 (BatNaS) under funding contract 20N/2023.

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Keywords:

sodium, pressure, silicone-pads, pouch-cell, pressing device

Study of Pressure and Temperature in Solid Electrolytes for All-Solid-State Lithium-Sulfur Batteries

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Introduction: The first studies of lithium-sulfur batteries date back to 1962, when sulfur-based positive electrodes were used[1]. In theory, this technology aims to combine the advantages of lithium metal (theoretical specific capacity of $3860 \text{ mAh}\cdot\text{g}^{-1}$ and lower electrochemical potential of -3.04 V/RHE) with those of sulfur as a cathode material (theoretical specific capacity of $1675 \text{ mAh}\cdot\text{g}^{-1}$, inexpensive, and environmentally friendly). In practice, however, problems with redox shuttling caused by polysulfides, the volumetric expansion of sulfur-based cathodes, and the instability of lithium metal have hindered the development of this technology, particularly when compared to lithium-ion batteries, which are widely used today. However, with recent scientific advances, lithium-sulfur batteries have regained some appeal.[2]

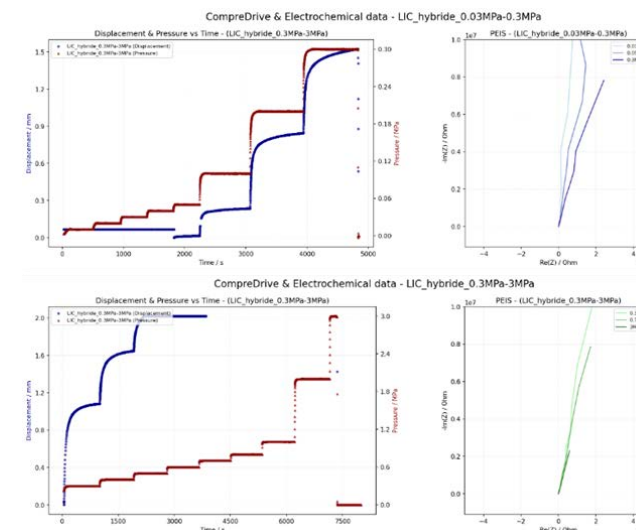
Results: This study uses electrochemical and impedance methods, varying temperature and pressure, to investigate the diffusion of polysulfides in solid electrolytes. In addition, surface chemistry (via XPS) and micro-structure (via SEM) provide insights into the evolution of the electrolytes. Characterization will focus on solid polymer membranes as well as inorganic halide-based electrolytes (Li_3InCl_6)[3]. The goal is to optimize these electrolytes for use in a full lithium-sulfur battery.

Acknowledgements: I acknowledges the support from the European Project ANGeLIC, the National Center for Scientific Research (CNRS) and the Grenoble Institute of Technology (Grenoble INP - UGA).

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Figure:



Keywords:

Pouch cell, Lithium, Polysulfides, CompreDrive

Coatings Based on Single-Ion Conducting Polymers and Multi-Walled Carbon Nanotubes for High-Voltage Cathode Materials

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Introduction: One of the main challenges presented by cathodic materials for lithium batteries is to ensure that capacity is maintained during cycling. The Ni-rich cathode $\text{LiNi}_{0.8}\text{Mn}_{0.1}\text{Co}_{0.1}\text{O}_2$ (NMC811) is considered a promising material due to its high energy density. However, this material presents a rapid decay in its capacity during cycling due to the direct contact of the NMC811 particles with the electrolyte. In this work, we investigated the development and the effects on the electrochemical properties of a coating based on a lithium single-ion conductor and MWCNTs, that prevent direct contact between the NMC811 particles and liquid electrolytes. This materials created a coating that acts as a channel for the transport of lithium ions in the interphases between particles and electrolytes without losing electronic conductivity. Furthermore, there are no reports on the use of single-ion conducting polymers as coatings for NMC materials, only reports on intrinsically conducting polymers to improve the electronic conductivity between cathodic components and capacity retention.

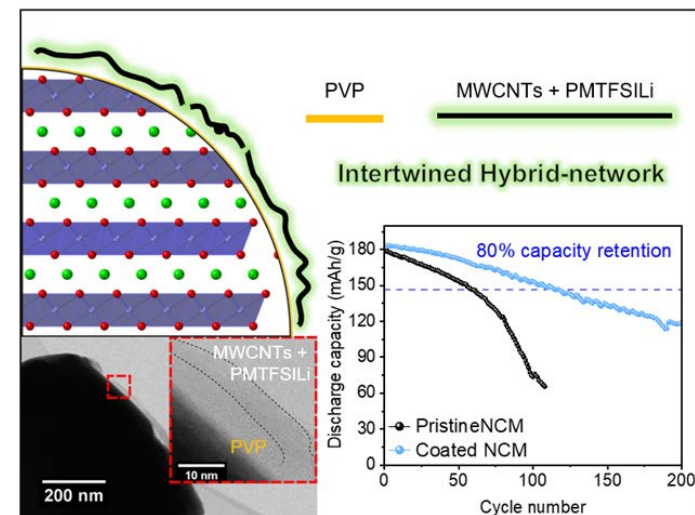
Results: XPS was carried out to investigate the presence and evolution of these coating compounds during cycling. In addition, SEM and TEM were performed to observe the surface morphology of the particles and determine the thickness of the coating. Finally, EIS was used to evaluate the effects of the coating compounds on the charging and discharging processes and their stability during cycling. This study shows that the development of modulated coatings can provide an innovative approach to obtaining Ni-rich cathode materials with a longer lifespan for lithium batteries.

Acknowledgements: This work has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N. 101069703 (PSIONIC project) and from the Slovenian Research and Innovation Agency (ARIS) through the research program P2-0423 is fully acknowledged.

References:

<https://doi.org/10.1016/j.jpowsour.2026.240041>

Figure:



Keywords:

NMC₈₁₁, Single-ion conducting polymer, MWCNTs, Coating

Industry Symposium

Modular Inert-Gas Mini-Environments for Lithium-Ion and All-Solid-State Battery Cell Production

Ferdinand Schmitt¹

Introduction: The processing of sensitive materials for lithium-ion batteries (LIBs) and all-solid-state batteries (ASSBs) requires carefully controlled atmospheres. Exposure to moisture, oxygen and, for certain materials, nitrogen can compromise material integrity and process reproducibility. Maintaining controlled conditions throughout material handling and cell manufacturing is therefore essential. Drawing on more than 50 years of experience in handling air-sensitive materials, MBRAUN provides modular inert-gas mini-environments for battery research and cell production.

Results: MBRAUN's glovebox solutions combine gas purification, continuous atmosphere monitoring and integrated process equipment. Depending on system configuration and process requirements, moisture, oxygen and nitrogen concentrations below one part per million (ppm) can be achieved.

Modular glovebox clusters accommodate interconnected manufacturing steps, includes ovens, mixing units, coating systems, cutting / notching tools, sheet stacking robot, hot-press, us-welding, sealing and electrolyte filling units. Enclosed transfers and automated material handling enable sensitive materials to move between connected process modules without exposure to ambient air.

Developed with a specialist partner network, these systems support configurations ranging from laboratory research to automated production. By enclosing critical process areas, the mini-environment approach reduces the volume requiring atmosphere control and offers a targeted alternative to facility-wide dry-room concepts. Its modular architecture supports the adaptation and expansion of process chains while maintaining controlled conditions for sensitive battery materials.

Keywords:

Battery Cell Production; Glovebox Technology; Inert Atmosphere; Mini-Environments; Lithium-Ion Batteries; All-Solid-State Batteries

Powering Battery Innovation Through Flexible Automation

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¹Comau S.p.A., Torino, Italy

Comau, a global leader in advanced automation solutions, is redefining how battery research and development transitions into industrial reality. To accelerate innovation without compromising the freedom needed in experimental environments, flexible automation emerges as a strategic enabler for R&D. By deploying reconfigurable, scalable, and versatile automated systems, Comau provides the operational flexibility required to manage diverse cell formats, dimensions, and different chemistries. This presentation explores how putting automation at the service of flexibility delivers higher standards of safety, process repeatability, and efficiency—empowering research entities and industrial players to rapidly validate next-generation battery technologies.

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