

# Advanced Battery Materials and Interfaces: A European Perspective

Isidora Cekic-Laskovic\* and Martin Winter\*

Alkali metal/ion batteries of the future call for the discovery and design of high-performance materials, components and electrode|electrolyte interfaces as particularly complex domains which have seen major progress in the past few years regarding the novel battery materials, advanced characterization techniques and theoretical simulations/modelling capabilities. Battery interfaces and interphases (solid electrolyte interphase (SEI) on anode and the related cathode electrolyte interphase (CEI) on cathode) have always been both a blessing and a major limitation to the development of alkali-based batteries due to their complexity and dynamics.

This topical collection is devoted to research and development of battery materials and concomitant interfaces highlighting main advantages and limitations from experimental and theoretical point of view. In this spirit, contributions (six reviews, two perspectives and eight research articles) from fifteen research teams are well connected by this unifying theme. Cekic-Laskovic and Winter et al. summarize a comprehensive knowledge gained thus far on the impact of different liquid electrolyte components and resulting formulations on the interfaces and interphases encountered at Si-based electrodes [https://doi.org/10.1002/admi.202101898]. In the second contribution, Cekic-Laskovic and Winter et al. highlight the impact of the still poorly understood electrolyte decomposition chemistry and the in-depth research on the physicochemical and electrochemical properties of CEI formation and evolution at positive electrode [https://doi.org/10.1002/admi.202102078]. Villevielle provides an overview on characterization techniques to study electrode|electrolyte interfaces and formed interphases, as key parameters to control the battery fate during cycling and electrochemical ageing [admi.202101865]. Rojo et al. present a comprehensive research activities on structure, composition, transport properties and electrochemical performance of the electrode|electrolyte interface in non-aqueous Na-ion batteries [https://doi.org/10.1002/admi.202101773].

Palacin et al. provide an overview on interfaces and interphases in Ca and Mg batteries comprising different electrolyte solutions and proper characterisation alongside theoretical modelling understand the phenomena determining the mechanisms of the plating/stripping processes [https://doi.org/10.1002/admi.202101578]. Diddens et al. contribute with an overview on machine learning-enhanced multiscale models providing new pathways to inverse design of battery interphases with desired properties [https://doi.org/10.1002/admi.202101734]. Dominko et al. highlight the pitfalls and opportunities of electrochemical impedance spectroscopy as a valuable tool to study lithium|sulfur batteries and discuss promising future directions [https://doi.org/10.1002/admi.202101116]. Rolling at al. unveil the transport of ions, molecules and electrons across the SEI considering possible transport mechanisms and providing an overview of the results of transport studies on the SEI formed on carbon-based electrodes. [https://doi.org/10.1002/admi.202101891]. Wiczorek et al. contribute with a research article studying a Hückel type salt NaTDI-based electrolyte and its impact on the cycling behaviour against wet impregnated WI-NaNMC and Prussian White cathodes [https://doi.org/10.1002/admi.202102012]. Berg et al. report on complex scheme of competing electro-/chemical reactions behind the SEI formation as a result of ethylene carbonate and propylene carbonate reductions by complementary operando gas (OEMS) and mass deposition (EQCM-D) analysis [https://doi.org/10.1002/admi.202101258]. Brezesinski et al. develop a multi-element surface coating approach for next-generation Ni-rich oxide cathode materials enabling reduced transition-metal dissolution and outgassing at high SOC, thus resulting in enhanced long-term cycling performance of lithium ion batteries [https://doi.org/10.1002/admi.202101100]. Adelhelm et al. highlight the application of in situ (operando) electrochemical dilatometry as characterization descriptor enabling study of different charge storage mechanisms for lithium and sodium ions in hard carbon battery electrodes [https://doi.org/10.1002/admi.202100596]. Elm et al. present a straightforward, low-cost and scalable dry coating process for stabilization of the cathode|electrolyte interface in Ni-rich NMC electrode in thiophosphate-based all-solid-state batteries [https://doi.org/10.1002/admi.202101428]. Seidl et al. unravel the voltage-dependent oxidation mechanisms of poly(ethylene oxide) (PEO)-based solid-state battery electrolytes and point out that increase in energy density may be achieved either by using low-voltage/high-capacity electrode materials or protective coatings for high-voltage positive electrodes to prevent oxidation of PEO [https://doi.org/10.1002/admi.202100704]. Titirici et al. provide an elucidation of the SEI formation on micro-mesoporous hard-carbon with tailored porosity and highlight the impact of ether- and organic carbonate-based electrolytes

I. Cekic-Laskovic, M. Winter  
Helmholtz Institute Münster  
IEK-12  
Forschungszentrum Jülich GmbH  
Corrensstrasse 46, 48149 Münster, Germany  
E-mail: i.cekic-laskovic@fz-juelich.de; m.winter@fz-juelich.de  
M. Winter  
University of Münster  
MEET Battery Research Center  
Corrensstrasse 46, 48149 Münster, Germany

 The ORCID identification number(s) for the author(s) of this article can be found under <https://doi.org/10.1002/admi.202102538>.

DOI: 10.1002/admi.202102538

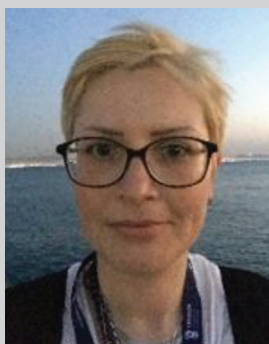
in Na-ion batteries by combined experimental and theoretical approach [https://doi.org/10.1002/admi.202101267]. And last but not least, Stein et al. provide insights into the hierarchical experimental laboratory automation and orchestration enabling modular autonomous feedback-loops in materials science [https://doi.org/10.1002/admi.202101987].

It is our anticipation that this fine collection will serve as a valuable resource for Advanced Materials Interfaces readers encouraging further research into the field of advanced battery

materials and interfaces with the focus set on understanding, control, and design of their functionalities/functions as the key for the development of ultra-performant, smart and sustainable alkali metal/ion batteries.

### Conflict of Interest

The authors declare no conflict of interest.



**Isidora Cekic-Laskovic** is a research group leader at the Helmholtz-Institute Münster (HI MS) “Ionics in Energy Storage” (IEK-12) an institute branch of Research Center Juelich. The main scope of her research is related to design, and development of advanced functional electrolytes with enhanced safety for lithium-based battery applications ranging from tailored synthesis of novel electrolyte components all the way to interfacial electrochemistry and processes. Complementary focus is set on the application of high throughput experimentation methodologies for accelerated battery electrolytes discovery and the generation of abundant pertinent interface/interphase data across the entire lifetime of the battery.



**Martin Winter** has been researching in the field of electrochemical energy storage and conversion for 30 years with a focus on the development of new materials, components and cell designs for batteries and supercapacitors. He currently holds a professorship for “Materials Science, Energy and Electrochemistry” at the Institute of Physical Chemistry at Muenster University, Germany. He is scientific director of the MEET Battery Research Center at Muenster University and founding director of the Helmholtz-Institute Muenster (HI MS, IEK-12) “Ionics in Energy Storage” an institute branch of Research Center Juelich.