



ECO2LIB Project Newsletter

Dear readers,

Welcome back to the sixth newsletter of the Horizon2020-project ECO2LIB. In this issue, we want to give you an overview of the project activities in the second reporting period of the project. In addition, for new readers, we also provide a short summary of the ECO2LIB project and some more information on the project consortium.

I hope you enjoy the newsletter and the activities we are doing!



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[ECO²LIB Project](#)

Summary of the ECO2LIB project

After the successful EU-project Sintbat, ECO2LIB aims to continue the effort by focusing on a new KPI, the cycle related costs per energy: €/kWh/cycle. This KPI very well reflects the real need of the customers in the energy storage market if a minimum volumetric energy density is added. The research and development activities will be supported by a clear recycling concept and an extended Life Cycle Assessment, to judge the environmental impact of the different options and to choose the best. To show both ECO-aspects (**ECO**logical and **ECON**omical) of our project the acronym ECO²LIB was created.

The consortium decided to continue the improvement of the well-established **Lithium-Ion system** with advanced materials, methods, and corresponding recycling-concept. So, it will be possible to directly exploit the results of ECO²LIB in an IPCEI project, which is under preparation.

Summary of the project progress

Month 36 marked the end of the second of three reporting periods. We are now entering the final phase of the project. So far, the following has been achieved:

Electrodes and Electrolytes: Generation 2 of the 3D current collector was completed. In comparison to standard flat foil, slight advantages of the 3D structure could be observed at higher current density. In a next step, the possibility of integrating the 3D current collector into existing manufacturing environments will be assessed.

The generation 2 anodes have been completed and a variety of tests was performed. The use of a higher amount of silicon in the electrode composition allows to reduce the electrode thickness significantly compared to the industrial reference. With such electrodes it was possible to reach the goal concerning cycle life (70% capacity retention after 300 cycles @100% DOD). In parallel, a next generation silicon-material was investigated and very promising results in terms of capacity retention could be observed. Both types of anodes could be processes on semi-industrial equipment without any problems. Afterwards, the manufacturing of Generation 2 CoinPower cells with improved capacity on mass production equipment was started.

Module specification: The design for the stationary storage module was finalised. In this context, a major step was the development of an optimised BMS that allows for significant cost and CO₂ reductions.

Characterisation: Electrochemical testing of the cells with a high silicon amount was conducted. These full cells showed significantly lower C-rate capabilities compared to individual electrodes tested previously in half-cell design. A potential explanation is that there could be a constructive buildup of the internal cell resistance when the silicon is (almost) fully delithiated and the NMC cathode is (almost) fully lithiated. This ultimately results in two resistive layers instead of one in the

half-cell design. Such a condition may occur when the cell is discharged at high C-rate. Further in-situ measurements are necessary to confirm this.

M36 General Assembly Meeting in Nördlingen, Germany

To conclude the first 3 of our 4.5 project years, the month 36 General Assembly meeting was held in February 2023 at VARTA Storage GmbH in Nördlingen, Germany. Apart from lively discussions and visits to several VARTA facilities, we also did a nice, guided tour through the historic city of Nördlingen, which is definitely worth a trip.



Publications

Publications in journals

Multi-scale quantification and modeling of aged nanostructured silicon-based composite anodes

Vorauer, T., Kumar, P., Berhaut, C.L. et al., *Commun Chem* 3, 141 (2020)

“Advanced anode material designs utilizing dual phase alloy systems like Si/FeSi₂ nano-composites show great potential to decrease the capacity degrading and improve the cycling capability for Lithium (Li)-ion batteries. Here, we present a multi-scale characterization approach to understand the (de-)lithiation and irreversible volumetric changes of the amorphous silicon (a-Si)/crystalline iron-silicide (c-FeSi₂) nanoscale phase and its evolution due to cycling, as well as their impact on the proximate pore network.” Read more: <https://doi.org/10.1038/s42004-020-00386-x>

Surface Oxidation of Nano-Silicon as a Method for Cycle Life Enhancement of Li-ion Active Materials

Ratynski, M., Hamankiewicz, B., Buchberger, D. A. et al., *Molecules* 2020, 25(18), 4093

“Among the many studied Li-ion active materials, silicon presents the highest specific capacity, however it suffers from a great volume change during lithiation. In this work, we present two methods for the chemical modification of silicon nanoparticles. Both methods change the materials' electrochemical characteristics. The combined XPS and SEM results show that the properties of the generated silicon oxide layer depend on the modification procedure employed.” Read more: <https://doi.org/10.3390/molecules25184093>

The role of coordination strength in solid polymer electrolytes: compositional dependence of transference numbers in the poly(ϵ -caprolactone)–poly(trimethylene carbonate) system

Eriksson, T., Mace, A., Mindemark, J., Brandell, D., *Phys. Chem. Chem. Phys.*, 2021,23

"Both polyesters and polycarbonates have been proposed as alternatives to polyethers as host materials for future polymer electrolytes for solid-state lithium-ion batteries. While being comparatively similar functional groups, the electron density on the coordinating carbonyl oxygen is different, thereby rendering different coordinating strength towards lithium ions. In this study, the transport properties of poly(ϵ -caprolactone) and poly(trimethylene carbonate) as well as random copolymers of systematically varied composition of the two have been investigated, in order to better elucidate the role of the coordination strength." Read more: <https://doi.org/10.1039/D1CP03929F>

Facile preparation of hierarchical 3D current collector for Li-ion anodes

Ratynski, M., Hamankiewicz, B., Czerwinski, A. *Electrochimica Acta*, 403 (2021)

„Beside great commercial success of Lithium-ion batteries, initiated by Sony in 1991, the cells manufacture details, active material selection, synthesis routes and further modifications are still under intense development. To increase the capacity of the whole cell, the researchers are focusing on new, high capacity, alloy type anode materials such as tin, germanium, aluminum and silicon. Apart from the great capacity, all of the alloy-type materials suffer from large volume changes during lithiation, e.g. silicon volume expansion can reach 300%." Read more: <https://doi.org/10.1016/j.electacta.2021.139698>

A cut finite-element method for fracture and contact problems in large-deformation solid mechanics

Poluektov, M., Figiel, Ł. *Computer Methods in Applied Mechanics and Engineering*, 388 (2022)

"Cut finite-element methods (CutFEMs) belong to the class of methods that allow boundaries/interfaces to cut through the elements, which avoids any meshing/remeshing problems. This is highly convenient from a practical point of view, especially when non-stationary interfaces are considered, e.g. phase boundaries in solids, as the interfaces can move independently of the mesh. There are many research directions related to CutFEM, one of which focuses on the equations of solid mechanics." Read more: <https://doi.org/10.1016/j.cma.2021.114234>

Carbonyl-Containing Solid Polymer Electrolyte Host Materials: Conduction and Coordination in Polyketone, Polyester, and Polycarbonate Systems

Eriksson, T., Gudla, H., Manabe, Y., et al. *Macromolecules* (2022)

"Research on solid polymer electrolytes (SPEs) is now moving beyond the realm of polyethers that have dominated the field for several decades. A promising alternative group of candidates for SPE host materials is carbonyl-containing polymers. In this work, SPE properties of three different types of carbonyl-coordinating polymers are compared: polycarbonates, polyesters, and polyketones. The investigated polymers were chosen to be as structurally similar as possible, with only the functional group being different, thereby giving direct insights into the role of the noncoordinating main-chain oxygens." Read more: <https://doi.org/10.1021/acs.macromol.2c01683>

Articles

Ageing of nanostructured silicon-based composite anodes: Morphology changes and inhomogeneous lithiation

Brunner, R. (2020)

"Alloy systems like Si/FeSi nano-composites have great potential as stable anode materials in Li-ion batteries, but their characterization at different scales and throughout their ageing remains challenging due their complex architecture." Read more: <https://go.nature.com/3lWmRuC>

Innovatives Materialdesign für hocheffiziente Energiespeicher [German]

Brunner, R. (2020)

"Ohne effiziente Energiespeicher und einhergehende Kosteneffizienz wird es keine Energiewende geben. Wie kann Energie möglichst effizient und über eine Vielzahl von Lade- und Entladezyklen gespeichert werden?" Read more: <https://www.just-magazin.com/innovatives-materialdesign-fuer-hocheffiziente-energiespeicher/>

Improving the Design of Anode Materials in Lithium Ion Batteries

Interview with R. Brunner on the ZEISS Blog

"Researchers use advanced imaging methods to understand the structure-property relationship

Dr. Roland Brunner is a Group Leader for Material and Damage Analytics in the Microelectronics Division at the Materials Center Leoben (MCL) in Austria. The group strongly focuses on 3D nano/micro-structure image-based characterization and analysis with respect to innovative materials used in microelectronics and energy, to trigger improved functional material design for industrial applications." Read more: <https://blogs.zeiss.com/microscopy/en/fesem-anode-materials/>

Elektrolyt utan giftigt fluor ger elbilsbatterier samma prestanda

Kristensson, J. (2020)

Article on the development of fluorine-free electrolytes at Uppsala University

<https://www.nyteknik.se/batterier-premium/elektrolyt-utan-giftigt-fluor-ger-elbilsbatterier-samma-prestanda/1177032>

Conferences, seminars, lectures

Date	Presentation title	Event	Speaker
26.05.2020	Operando synchrotron experiments and porous-electrode modeling: a combined approach. Case study: sequential lithiation mechanisms in Silicon-graphite blended anodes.	Battery 2030+ workshop	S. Lyonnard (CEA)
03.09.2020	Elimination of Fluorination: The Influence of Fluorine-Free Electrolytes on the Performance of Si-based Li-ion Batteries	ISE meeting	G. Hernández (Uppsala)
15.10.2020	Monitoring Li-ion batteries by advanced operando neutron techniques	ILL-ESS user meeting satellite workshop	S. Lyonnard (CEA)
11.2020	Elimination of Fluorination: The Influence of Fluorine-Free Electrolytes on the Performance of Si-based Li-ion Batteries	2020 Virtual MRS Spring/Fall Meeting & Exhibit	G. Hernández (Uppsala)
03.12.2020	Ecologically and Economically viable Production and Recycling of Lithium Ion Batteries	H2020 Low TRL Smart Grids and Storage Projects clustering event	B. Achzet (VARTA Storage)
25.01.2021	Akkutechnologien / Methoden der Materialcharakterisierung speziell im Bereich Energiespeicherung	Workshop Technical High School Leoben	R. Brunner (MCL)
03.2021	Improvement of the Cell Performance: Si/graphite coin cell interactive workshop to develop DOI for characterization workflow	Seminar Workshop with pupils from the Technical Highschool Leoben (HTL)	R. Brunner (MCL)
25.-29.07.2021	CutFEM approach for handling non-stationary interfaces in large-deformation solid mechanics: Application to fracture	16th US National Congress on Computational Mechanics	M. Poluektov, L. Figiel (UoW)
07.2021	Silicon-based Composite Anodes for Li-ion Batteries: Morphology Changes and Ageing	Zeiss Workshop	R. Brunner (MCL)
18-20.08.2021	Multiscale Investigation of an Si-Fe Alloy Anode Material for Storage Applications with Improved Aging Performance	American Association for Advanced Functional Materials	R. Brunner (MCL)
10.2021	Multiscale characterization of advanced Si-based composite anodes	KMM-VIN Workshop	R. Brunner (MCL)
09.12.2021	From Imaging to Knowledge: Towards More Advanced Li-Ion Batteries	Workshop Oslo on Batteries	R. Brunner (MCL)
17.12.2021	Ecologically and Economically viable Production and Recycling of Lithium Ion Batteries	H2020 Battery Projects Online Workshop	N. Bucher (VARTA Microbattery)
WS2021/22	Solar cells lecture	Lecture: Montanuniversität Leoben "Solar Cells" Communication with students Energy relevant topics and storage for PVs.	R. Brunner (MCL)
2021	Operando characterization of battery anodes using mXRD and combined SAXS/WAXS	iUCR, Invited Talk.	S. Lyonnard (CEA)
2021	Operando characterization of silicon-based battery anodes by neutron & synchrotron techniques	MRS, Boston. Invited Talk.	S. Lyonnard (CEA)
04.-06.04.2022	Modelling of chemo-mechanical processes in heterogeneous materials for energy storage	18th European Mechanics of Materials Conference (EMMC18)	M. Poluektov, A. Morozov, A. B. Freidin, L. Figiel (UoW)
11.04.2022	Creating Synergies Through R&D Projects	LiPLANET Expert Group	D. Ott (EurA)
04.05.2022	Multi-Method Characterization Workflow for Advanced Si-based Anodes	14th annual FIB SEM meeting	R. Brunner (MCL)
05.05.2022	Machine Learning Assisted Analysis of Chemical & Micro-Structure Properties in Advanced Si-based anodes	MPPE 2022	T. Vorauer (MCL)

05-09.06.2022	A cut finite-element method for fracture and contact problems in large-deformation solid mechanics	18th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS2022)	M. Poluektov, L. Figiel (UoW)
19.06.2022	Beyond Sweep Voltammetry to Assess Electrochemical Stability of Electrolytes	32nd Topical Meeting of the International Society of Electrochemistry (ISE)	G. Hernández (Uppsala)
28.06.2022	Uncovering the impact of coordination chemistry on cation transport in polymer electrolytes	EPF 2022	J. Mindemark (Uppsala)
28.06.2022	Gel Polymer electrolytes based on Methacrylate End-Capped Poly(trimethylene) carbonate oligomers for lithium batteries	EPF 2022	V. Vijayakumar (Uppsala)
05.07.2022	Safe and Sustainable Electrolytes for Lithium-Based Batteries	POF22 (Power Our Future)	G. Hernández (Uppsala)
31.08.-02.09.2022	Modeling silicon-graphite composite negative electrodes in lithium-ion batteries	8th International Conference on Advanced Computational Methods in Engineering (ACOMEN)	S. G. Sanadhya (UoW)
31.08.-02.09.2022	Multiscale modelling of chemo-mechanical processes in heterogeneous materials for energy storage	8th International Conference on Advanced Computational Methods in Engineering (ACOMEN)	M. Poluektov, L. Figiel (UoW)
19.09 - 21.09.2022	Advanced Imaging and Analysis of Si-Based Li-Ion Cells: Unravel the Microstructure – Material Property Relationship	Battery Days 2022	R. Brunner (MCL)
03.10.2022	Elucidating the Electrochemical Stability of Polymer Electrolytes	ISPE-17	G. Hernández (Uppsala)
WS2022/23	Solar cells lecture	Lecture: Montanuniversität Leoben “Solar Cells” Communication with students Energy relevant topics and storage for PVs.	R. Brunner (MCL)
06.10.2022	To hop or not to hop: How to accurately describe the diversity of ion transport modes in solid polymer electrolytes	ISPE-17	J. Mindemark (Uppsala)
Sept. 2022	Lithiation and aging mechanisms in nanostructured group-IV materials by operando techniques at Large Scale Facilities	ISE (online) meeting	S. Lyonnard (CEA)
01.03.2022	Accelerating battery characterization using neutron & synchrotron techniques: why and how ?	Battery2030+, Excellence Seminar on-line.	S. Lyonnard (CEA)
01.08.2022		ECM33, Versailles. Invited Talk.	S. Lyonnard (CEA)

The project consortium

VARTA Microbattery GmbH (Germany)

VARTA Microbattery (VMB) is an internationally leading and globally active manufacturer of retail and OEM batteries and has been operating for more than 125 years. [Read more](#)

CEA (France)

CEA is a French government-funded technological research organization. With more than 15,000 researchers and co-workers, its activities cover four main areas: Energy, Defence & security, Health & information technologies, and Fundamental research. Two institutes from CEA, both located on the CEA Grenoble centre, are involved in the ECO²LIB project. [Read more](#)

Warwick Manufacturing Group (UK)

WMG is a world leading research and education group, transforming organisations and driving innovation through a unique combination of collaborative research and development, and pioneering education programmes. [Read more](#)

VARTA Innovation GmbH (Austria)

VARTA Innovation GmbH (VI), with registered office in Graz, was founded in 2009 as a joint venture between VARTA Microbattery and Graz University of Technology. Within VARTA Innovation both, the industrial fabrication know-how from VARTA Microbattery and the basic research know-how from Graz University of Technology for various electrochemical energy storage systems are merged. [Read more](#)

EurA AG (Germany)

EurA AG has been established in Ellwangen (Baden-Württemberg, Germany) in 1999. The company currently employs more than 140 persons on 9 locations in Germany, Portugal, and Belgium. As an innovation service provider, EurA advises more than 1,500 mainly medium-sized companies in Germany, covering all industrial sectors. [Read more](#)

Uppsala University (Sweden)

Uppsala University, founded in 1477, is the oldest University in the Nordic countries, and generally ranked among the top 100 universities in the world. Today, it trains more than 43,000 students, and employs 6,000 people. There are about 2,500 active graduate students; 44% of these are women. Each year, the University awards some 270 doctoral degrees. [Read more](#)

Materials Center Leoben Forschung GmbH (Austria)

The Materials Center Leoben Forschung GmbH (MCL) is the leading Austrian institution in the field of applied materials science with around 150 employees. [Read more](#)

VARTA Storage GmbH (Germany)

VARTA Storage GmbH (VS) is a developer and manufacturer of stationary battery storage systems based in Nördlingen, Germany. The company has substantial know-how in the field of energy storage by using long-life lithium-ion batteries and conducts in this context innovative research and development activities. [Read more](#)

University of Warsaw (Poland)

University of Warsaw (UW) was founded in 1816. The University brings together scholars from a variety of disciplines. It is the place of a diversity of scientific research. Nearly 60,000 people study at the University of Warsaw every year. [Read more](#)

ACCUREC Recycling GmbH (Germany)

Accurec is a German SME company, founded in 1995 with its primary target to constitute the consumer battery recycling market in Germany. [Read more](#)



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 875514.

Published by:
EurA AG
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